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ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

1021 NORTH GRAND AVENUE EAST, P.O. BOX 19276, SPRINGFIELD, ILLINOIS 62794-9276 · (217) 782-3397

JB PRITZKER, GOVERNOR JOHN J. KIM, DIRECTOR

April 15, 2022

618/993-7200

Williamson Energy, LLC
P.O. Box 300
Johnston City, Illinois 62951

Re: Williamson Energy, LLC
Pond Creek Mine
NPDES Permit No. IL0077666
Bureau ID #W1998590001
Final Renewed Permit (Modified After Public Notice)

Gentlemen:

Attached is the final renewed NPDES Permit for your discharge. The Permit as issued covers discharge limitations, monitoring, and reporting requirements. Failure to meet any portion of the Permit could result in civil and/or criminal penalties. The Illinois Environmental Protection Agency is ready and willing to assist you in interpreting any of the conditions of the Permit as they relate specifically to your discharge.

The Final Permit as issued was modified after public notice based on comments received to incorporate the following:

1. Special Condition No. 14 added to require the permittee to install and operate a 1.0 million gallons per day (MGD) reverse osmosis (RO) unit by December 31, 2023:
    a. The RO permeate (treated water) will discharge through Outfalls 001-008.
    b. The RO reject will discharge to the Big Muddy River through Outfall 011.
2. Outfalls 009 and 009ES have been removed.
3. Special Condition No. 15 has been added to include the following relative to Outfall 011:
    a. Require sign on bank of Big Muddy River to notify public of existence and location of Outfall 011.
    b. Require chloride and conductivity monitoring of Outfall 011 effluent and in Big Muddy River (upstream and downstream) to confirm and ensure validity of calibration curves. Calibration curves are also required to be approved periodically by the Agency as outlined in the NPDES permit condition.
    c. Require Sulfate, Iron (dissolved) and Chloride monitoring of Outfall 011 effluent be performed three (3) times per week when the outfall is discharging.
    d. Require a mussel survey and macroinvertebrate survey approximately 1 year following initial discharge from Outfall 011.
    e. Verifies the mixing zone and zone of initial dilution (ZID) for the multi-port diffuser.
    f. Specify precipitation event and Big Muddy River flow condition restrictions for discharges from Outfall 011.
    g. Require that flow and chloride concentration data be available for review during inspections by IEPA and IDNR staff.
    h. Requires the pipeline to the Big Muddy River to include pressure control sensors (or similar type of equipment) to stop pumps in the event of loss of pressure.
    i. Require inspections of pipeline with reports made available to Agency personnel during site inspections.
    j. Reduced the maximum chloride concentration at Outfall 011 from 12,000 mg/L to 5,000 mg/L. This change affected the following:
        a. Reduced the dilution ratio needed from 34:1 to 13.3:1.
        b. Reduced the length of the mixing zone from 251 feet to 46 feet.
4. A yearly average concentration limit of 32.2 mg./l. for TSS (total suspended solids) is applied to discharges from Outfall 011 as indicated on the effluent page of the permit for this outfall.
5. Limits for additional parameters are included at specified Outfalls as follows:
    a. Mercury limit required for discharges from Outfall 001
    b. Copper and Nickel limits required for discharges from Outfall 002
    c. Iron (dissolved) limits required for discharges from Outfall 003
    d. Copper limits required for discharges from Outfall 004

e. Nickel limits required for discharges from Outfall 006
f. Iron (dissolved), Nickel and Zinc limits required for discharges from Outfall 007
g. Cadmium, Copper, Nickel and Zinc limits required for discharges from Outfall 008

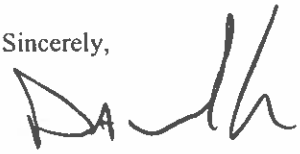
6. Special Condition No. 18 added to require discharges from Outfalls 006, 007, 008 and 011 include metals monitoring at a frequency of once per month for the first year that then twice annually spaced approximately every six (6) months apart for the remainder of the permit term.
7. Special Condition No. 16 has been added to require the following conditions relative to monitoring the Big Muddy River downstream of Outfall 011:
   a. Continuous monitoring of Outfall 011 at a point within 10 feet of edge of mixing zone.
   b. Monitoring of Outfall 011 for sulfate, iron (dissolved), copper, and nickel three times per week at a point within 10 feet of edge of mixing zone.
   c. The discharge from Outfall 011 must cease under the following conditions until the water quality standard can be met in the mixing zone:
      i. When the continuous chloride data (as measured by conductivity) is 40 percent above the chloride water quality standard more than 20 percent of the time.
      ii. When the sulfate samples are 40 percent above the sulfate water quality standard in more than 3 of the samples taken within the month.
      iii. When the iron (dissolved) samples are 40 percent above the iron (dissolved) water quality standard in more than 3 of the samples taken within the month.
      iv. When the copper samples are 20 percent above the copper water quality standard in more than 3 of the samples taken within the month.
      v. When the nickel samples are 20 percent above the nickel water quality standard in more than 3 of the samples taken within the month.
8. The NPDES permit authorizes a discharge only when the Big Muddy River is between 30 cfs and 2,350 cfs, except after a one-year, 24-hour precipitation event, Outfall 011 can discharge for six consecutive days. The one-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

Pursuant to the Final NPDES Electronic Rule, all permittees must report DMRs electronically unless a waiver has been granted by the Agency. The Agency utilizes NetDMR, a web based application, which allows the submittal of electronic Discharge Monitoring Reports instead of paper Discharge Monitoring Reports (DMRs). More information regarding NetDMR can be found on the Agency website, https://www2.illinois.gov/epa/topics/water-quality/surface-water/netdmr/Pages/quick-answer-guide.aspx. If your facility has received a waiver from the NetDMR program, a supply of preprinted paper DMR Forms will be sent to your facility. Additional information and instructions will accompany the preprinted DMRs. Please see the attachment regarding the electronic reporting rule.

The attached Permit is effective as of the date indicated on the first page of the Permit. Until the effective date of any re-issued Permit, the limitations and conditions of the previously-issued Permit remain in full effect. You have the right to appeal any condition of the Permit to the Illinois Pollution Control Board within a 35 day period following the issuance date.

Should you have questions concerning the Permit, please contact Iwona Ward at 618/993-7200.

Sincerely,



Darin E. LeCrone, P.E.
Manager Permit Section
Division of Water Pollution Control

DEL:IKW:cs/7817c/6-28-19

Enclosure: Final Permit

cc: IDNR/Office of Mines and Minerals/Land Reclamation/with Enclosure
IDNR/Division of Water Resources/with Enclosure
Marion Region/Mine Pollution Control Program/with Enclosure
BOW/DWPC/CAS
BOW/DWPC/Records

NPDES Permit No. IL0077666

Illinois Environmental Protection Agency

Division of Water Pollution Control

1021 North Grand Avenue, East

P.O. Box 19276

Springfield, Illinois 62794-9276

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

Reissued NPDES Permit

Expiration Date: April 30, 2027

Issue Date: April 15, 2022
Effective Date: May 1, 2022

Name and Address of Permittee:

Williamson Energy, LLC
P.O. Box 300
Johnston City, Illinois 62951

Facility Name and Address:

Williamson Energy, LLC
Pond Creek Mine
4 miles east of Johnston City, Illinois
(Williamson and Franklin Counties)

Discharge Number and Classification:		Receiving waters
001, 002, 003, 004, 005	Alkaline Mine Drainage	Unnamed tributary to Pond Creek
006, 007, 008	Acid Mine Drainage	Unnamed tributary to Pond Creek
011	Alkaline Mine Drainage	Big Muddy River

In compliance with the provisions of the Illinois Environmental Protection Act, Subtitle C and/or Subtitle D Rules and Regulations of the Illinois Pollution Control Board, and the Clean Water Act, the above-named permittee is hereby authorized to discharge at the above location to the above-named receiving stream in accordance with the standard conditions and attachments herein.

Permittee is not authorized to discharge after the above expiration date. In order to receive authorization to discharge beyond the expiration date, the permittee shall submit the proper application as required by the Illinois Environmental Protection Agency (IEPA) not later than 180 days prior to the expiration date.

Darin E. LeCrone, P.E.
Manager, Permit Section
Division of Water Pollution Control

DEL:IKW:cs/7516c/10-25-21

NPDES Permit No. IL0077666

Effluent Limitations and Monitoring

From the effective date of this Permit until the expiration date, the effluent of the following discharge shall be monitored and limited at all times as follows:

Outfalls*: 001 (Alkaline Mine Drainage)

Discharge Condition	Parameters												
	Total Suspended Solids (mg/L) ***		Iron (total) (mg/L) ***		pH** (S.U.) ***	Alkalinity/ Acidity ***	Sulfate (mg/L) ***	Chloride (mg/L) ***	Cadmium (Cd) (mg/L)	Mercury (ng/l) 12-month rolling average	Hardness ***	Flow (MGD)	Settleable Solids (ml/l)
	30 day average	daily maximum	30 day average	daily maximum									
I	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	12	Monitor Only	Measure When Sampling	-
II	-	-	-	-	6.0-9.0	-	1250	500	-	-	Monitor Only	Measure When Sampling	0.5
III	-	-	-	-	6.0-9.0	-	1250	500	-	-	Monitor Only	Measure When Sampling	-
IV	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	12	Monitor Only	Measure When Sampling	-

I Dry weather discharge (base flow or mine pumpage) from the outfall.

II In accordance with 35 Ill. Adm. Code 406.110(a), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period less than or equal to the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b). The 10-year, 24-hour precipitation event for this area is considered to be 5.21 inches.

III In accordance with 35 Ill. Adm. Code 406.110(d), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period greater than the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b).

IV Discharges continuing 24 hours after cessation of precipitation event that resulted in discharge. For outfalls which have no allowed mixing, monitoring requirements and permit limitations of Discharge Condition IV are identical to Discharge Condition I to which the outfall discharge has reverted.

Sampling during all Discharge Conditions shall be performed utilizing the grab sampling method.

*** There shall be a minimum of nine (9) samples collected during the quarter when the pond is discharging. Of these 9 samples, a minimum of one sample each month shall be taken during either Discharge Condition I or IV should such discharge condition occur. A "no flow" situation is not considered to be a sample of the discharge. In the event that Discharge Conditions II and/or III occur, grab sample of each discharge caused by the above precipitation events (Discharge Conditions II and/or III) shall be taken and analyzed for the parameters identified in the table above during at least 3 separate events each quarter. For quarters in which there are less than 3 such precipitation events resulting in discharges, a grab sample of the discharge shall be required whenever such precipitation event(s) occur(s). Should a sufficient number of discharge events occur during the quarter, the remaining three (3) quarterly samples may be taken during any of the Discharge Conditions described above.

The water quality standards for sulfate and chloride must be met in discharges from the above referenced outfall as well as in the receiving stream.

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* The Permittee is subject to the limitations, monitoring, and reporting requirements of Special Condition No. 13 for the discharges from Outfall 001 and unnamed tributary of Pond Creek receiving such discharges.

** No discharge is allowed from any above referenced permitted outfall during "low flow" or "no flow" conditions in the receiving stream unless such discharge meets the water quality standards of 35 Ill. Adm. Code 302.204 for pH.

NPDES Permit No. IL0077666

Effluent Limitations and Monitoring

From the effective date of this Permit until the expiration date, the effluent of the following discharge shall be monitored and limited at all times as follows:

Outfalls*: 002 (Alkaline Mine Drainage)

Discharge Condition	Parameters													
	Total Suspended Solids (mg/L) ***		Iron (total) (mg/L) ***		pH** (S.U.) ***	Alkalinity/ Acidity ***	Sulfate (mg/L) ***	Chloride (mg/L) ***	Cadmium (Cd) (mg/L)	Nickel (mg/L)	Copper (mg/L)	Hardness ***	Flow (MGD)	Settleable Solids (ml/l)
	30 day average	daily maximum	30 day average	daily maximum										
I	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	0.1104	0.0245	Monitor Only	Measure When Sampling	-
II	-	-	-	-	6.0-9.0	-	1250	500	-	-	-	Monitor Only	Measure When Sampling	0.5
III	-	-	-	-	6.0-9.0	-	1250	500	-	-	-	Monitor Only	Measure When Sampling	-
IV	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	0.1104	0.0245	Monitor Only	Measure When Sampling	-

I Dry weather discharge (base flow or mine pumpage) from the outfall.

II In accordance with 35 Ill. Adm. Code 406.110(a), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period less than or equal to the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b). The 10-year, 24-hour precipitation event for this area is considered to be 5.21 inches.

III In accordance with 35 Ill. Adm. Code 406.110(d), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period greater than the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b).

IV Discharges continuing 24 hours after cessation of precipitation event that resulted in discharge. For outfalls which have no allowed mixing, monitoring requirements and permit limitations of Discharge Condition IV are identical to Discharge Condition I to which the outfall discharge has reverted.

Sampling during all Discharge Conditions shall be performed utilizing the grab sampling method.

*** There shall be a minimum of nine (9) samples collected during the quarter when the pond is discharging. Of these 9 samples, a minimum of one sample each month shall be taken during either Discharge Condition I or IV should such discharge condition occur. A "no flow" situation is not considered to be a sample of the discharge. In the event that Discharge Conditions II and/or III occur, grab sample of each discharge caused by the above precipitation events (Discharge Conditions II and/or III) shall be taken and analyzed for the parameters identified in the table above during at least 3 separate events each quarter. For quarters in which there are less than 3 such precipitation events resulting in discharges, a grab sample of the discharge shall be required whenever such precipitation event(s) occur(s). Should a sufficient number of discharge events occur during the quarter, the remaining three (3) quarterly samples may be taken during any of the Discharge Conditions described above.

The water quality standards for sulfate and chloride must be met in discharges from the above referenced outfall as well as in the receiving stream.

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* The Permittee is subject to the limitations, monitoring, and reporting requirements of Special Condition No. 13 for the discharges from Outfall 002 and unnamed tributary of Pond Creek receiving such discharges.

** No discharge is allowed from any above referenced permitted outfall during "low flow" or "no flow" conditions in the receiving stream unless such discharge meets the water quality standards of 35 Ill. Adm. Code 302.204 for pH.

NPDES Permit No. IL0077666

Effluent Limitations and Monitoring

From the effective date of this Permit until the expiration date, the effluent of the following discharge shall be monitored and limited at all times as follows:

Outfalls*: 003 (Alkaline Mine Drainage)

Discharge Condition	Parameters												
	Total Suspended Solids (mg/L) ***		Iron (total) (mg/L) ***		pH** (S.U.) ***	Alkalinity/ Acidity ***	Sulfate (mg/L) ***	Chloride (mg/L) ***	Cadmium (Cd) (mg/L)	Iron (dissolved) (mg/L)	Hardness ***	Flow (MGD)	Settleable Solids (ml/l)
	30 day average	daily maximum	30 day average	daily maximum									
I	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	1.0	Monitor Only	Measure When Sampling	-
II	-	-	-	-	6.0-9.0	-	1250	500	-	-	Monitor Only	Measure When Sampling	0.5
III	-	-	-	-	6.0-9.0	-	1250	500	-	-	Monitor Only	Measure When Sampling	-
IV	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	1.0	Monitor Only	Measure When Sampling	-

I Dry weather discharge (base flow or mine pumpage) from the outfall.

II In accordance with 35 Ill. Adm. Code 406.110(a), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period less than or equal to the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b). The 10-year, 24-hour precipitation event for this area is considered to be 5.21 inches.

III In accordance with 35 Ill. Adm. Code 406.110(d), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period greater than the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b).

IV Discharges continuing 24 hours after cessation of precipitation event that resulted in discharge. For outfalls which have no allowed mixing, monitoring requirements and permit limitations of Discharge Condition IV are identical to Discharge Condition I to which the outfall discharge has reverted.

Sampling during all Discharge Conditions shall be performed utilizing the grab sampling method.

*** There shall be a minimum of nine (9) samples collected during the quarter when the pond is discharging. Of these 9 samples, a minimum of one sample each month shall be taken during either Discharge Condition I or IV should such discharge condition occur. A "no flow" situation is not considered to be a sample of the discharge. In the event that Discharge Conditions II and/or III occur, grab sample of each discharge caused by the above precipitation events (Discharge Conditions II and/or III) shall be taken and analyzed for the parameters identified in the table above during at least 3 separate events each quarter. For quarters in which there are less than 3 such precipitation events resulting in discharges, a grab sample of the discharge shall be required whenever such precipitation event(s) occur(s). Should a sufficient number of discharge events occur during the quarter, the remaining three (3) quarterly samples may be taken during any of the Discharge Conditions described above.

The water quality standards for sulfate and chloride must be met in discharges from the above referenced outfall as well as in the receiving stream.

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* The Permittee is subject to the limitations, monitoring, and reporting requirements of Special Condition No. 13 for the discharges from Outfall 003 and unnamed tributary of Pond Creek receiving such discharges.

** No discharge is allowed from any above referenced permitted outfall during "low flow" or "no flow" conditions in the receiving stream unless such discharge meets the water quality standards of 35 Ill. Adm. Code 302.204 for pH.

NPDES Permit No. IL0077666

Effluent Limitations and Monitoring

From the effective date of this Permit until the expiration date, the effluent of the following discharge shall be monitored and limited at all times as follows:

Outfalls*: 004 (Alkaline Mine Drainage)

Discharge Condition	Parameters												
	Total Suspended Solids (mg/L) ***		Iron (total) (mg/L) ***		pH** (S.U.) ***	Alkalinity/ Acidity ***	Sulfate (mg/L) ***	Chloride (mg/L) ***	Cadmium (Cd) (mg/L)	Copper (mg/L)	Hardness ***	Flow (MGD)	Settleable Solids (ml/l)
	30 day average	daily maximum	30 day average	daily maximum									
I	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	0.0245	Monitor Only	Measure When Sampling	-
II	-	-	-	-	6.0-9.0	-	1250	500	-	-	Monitor Only	Measure When Sampling	0.5
III	-	-	-	-	6.0-9.0	-	1250	500	-	-	Monitor Only	Measure When Sampling	-
IV	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	0.0245	Monitor Only	Measure When Sampling	-

I Dry weather discharge (base flow or mine pumpage) from the outfall.

II In accordance with 35 Ill. Adm. Code 406.110(a), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period less than or equal to the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b). The 10-year, 24-hour precipitation event for this area is considered to be 5.21 inches.

III In accordance with 35 Ill. Adm. Code 406.110(d), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period greater than the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b).

IV Discharges continuing 24 hours after cessation of precipitation event that resulted in discharge. For outfalls which have no allowed mixing, monitoring requirements and permit limitations of Discharge Condition IV are identical to Discharge Condition I to which the outfall discharge has reverted.

Sampling during all Discharge Conditions shall be performed utilizing the grab sampling method.

*** There shall be a minimum of nine (9) samples collected during the quarter when the pond is discharging. Of these 9 samples, a minimum of one sample each month shall be taken during either Discharge Condition I or IV should such discharge condition occur. A "no flow" situation is not considered to be a sample of the discharge. In the event that Discharge Conditions II and/or III occur, grab sample of each discharge caused by the above precipitation events (Discharge Conditions II and/or III) shall be taken and analyzed for the parameters identified in the table above during at least 3 separate events each quarter. For quarters in which there are less than 3 such precipitation events resulting in discharges, a grab sample of the discharge shall be required whenever such precipitation event(s) occur(s). Should a sufficient number of discharge events occur during the quarter, the remaining three (3) quarterly samples may be taken during any of the Discharge Conditions described above.

The water quality standards for sulfate and chloride must be met in discharges from the above referenced outfall as well as in the receiving stream.

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* The Permittee is subject to the limitations, monitoring, and reporting requirements of Special Condition No. 13 for the discharges from Outfall 004 and unnamed tributary of Pond Creek receiving such discharges.

** No discharge is allowed from any above referenced permitted outfall during "low flow" or "no flow" conditions in the receiving stream unless such discharge meets the water quality standards of 35 Ill. Adm. Code 302.204 for pH.

NPDES Permit No. IL0077666

Effluent Limitations and Monitoring

From the effective date of this Permit until the expiration date, the effluent of the following discharge shall be monitored and limited at all times as follows:

Outfalls*: 005 (Alkaline Mine Drainage)

Discharge Condition	Parameters											
	Total Suspended Solids (mg/L) ***		Iron (total) (mg/L) ***		pH** (S.U.) ***	Alkalinity/ Acidity ***	Sulfate (mg/L) ***	Chloride (mg/L) ***	Cadmium (Cd) (mg/L)	Hardness ***	Flow (MGD)	Settleable Solids (ml/l)
	30 day average	daily maximum	30 day average	daily maximum								
I	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	Monitor Only	Measure When Sampling	-
II	-	-	-	-	6.0-9.0	-	1250	500	-	Monitor Only	Measure When Sampling	0.5
III	-	-	-	-	6.0-9.0	-	1250	500	-	Monitor Only	Measure When Sampling	-
IV	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	Monitor Only	Measure When Sampling	-

I Dry weather discharge (base flow or mine pumpage) from the outfall.

II In accordance with 35 Ill. Adm. Code 406.110(a), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period less than or equal to the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b). The 10-year, 24-hour precipitation event for this area is considered to be 5.21 inches.

III In accordance with 35 Ill. Adm. Code 406.110(d), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period greater than the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b).

IV Discharges continuing 24 hours after cessation of precipitation event that resulted in discharge. For outfalls which have no allowed mixing, monitoring requirements and permit limitations of Discharge Condition IV are identical to Discharge Condition I to which the outfall discharge has reverted.

Sampling during all Discharge Conditions shall be performed utilizing the grab sampling method.

*** There shall be a minimum of nine (9) samples collected during the quarter when the pond is discharging. Of these 9 samples, a minimum of one sample each month shall be taken during either Discharge Condition I or IV should such discharge condition occur. A "no flow" situation is not considered to be a sample of the discharge. In the event that Discharge Conditions II and/or III occur, grab sample of each discharge caused by the above precipitation events (Discharge Conditions II and/or III) shall be taken and analyzed for the parameters identified in the table above during at least 3 separate events each quarter. For quarters in which there are less than 3 such precipitation events resulting in discharges, a grab sample of the discharge shall be required whenever such precipitation event(s) occur(s). Should a sufficient number of discharge events occur during the quarter, the remaining three (3) quarterly samples may be taken during any of the Discharge Conditions described above.

The water quality standards for sulfate and chloride must be met in discharges from the above referenced outfall as well as in the receiving stream.

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* The Permittee is subject to the limitations, monitoring, and reporting requirements of Special Condition No. 13 for the discharges from Outfall 005 and unnamed tributary of Pond Creek receiving such discharges.

** No discharge is allowed from any above referenced permitted outfall during "low flow" or "no flow" conditions in the receiving stream unless such discharge meets the water quality standards of 35 Ill. Adm. Code 302.204 for pH.

NPDES Permit No. IL0077666

Effluent Limitations and Monitoring

From the effective date of this Permit until the expiration date, the effluent of the following discharge shall be monitored and limited at all times as follows:

Outfalls*: 006 (Acid Mine Drainage)

Discharge Condition	Parameters													
	Total Suspended Solids (mg/L) ***		Iron (total) (mg/L) ***		pH** (S.U.) ***	Alkalinity/ Acidity ***	Sulfate (mg/L) ***	Chloride (mg/L) ***	Cadmium (Cd) (mg/l) ***	Nickel (mg/L)	Mn (total) (mg/L) ***	Hardness ***	Flow (MGD)	Settleable Solids (ml/l)
	30 day average	daily maximum	30 day average	daily maximum										
I	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	0.1104	1.0	Monitor Only	Measure When Sampling	-
II	-	-	-	-	6.0-9.0	-	1250	500	-	-	-	Monitor Only	Measure When Sampling	0.5
III	-	-	-	-	6.0-9.0	-	1250	500	-	-	-	Monitor Only	Measure When Sampling	-
IV	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	0.1104	1.0	Monitor Only	Measure When Sampling	-

I Dry weather discharge (base flow or mine pumpage) from the outfall.

II In accordance with 35 Ill. Adm. Code 406.110(b), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period greater than the 1-year, 24-hour precipitation event, but less than or equal to the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b). The 1-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

III In accordance with 35 Ill. Adm. Code 406.110(d), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period greater than the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b). The 10-year, 24-hour precipitation event for this area is considered to be 5.21 inches.

IV Discharges continuing 24 hours after cessation of precipitation event that resulted in discharge. For outfalls which have no allowed mixing, monitoring requirements and permit limitations of Discharge Condition IV are identical to Discharge Condition I to which the outfall discharge has reverted.

Sampling during all Discharge Conditions shall be performed utilizing the grab sampling method.

*** There shall be a minimum of nine (9) samples collected during the quarter when the pond is discharging. Of these 9 samples, a minimum of one sample each month shall be taken during either Discharge Condition I or IV should such discharge condition occur. A "no flow" situation is not considered to be a sample of the discharge. In the event that Discharge Conditions II and/or III occur, grab sample of each discharge caused by the above precipitation events (Discharge Conditions II and/or III) shall be taken and analyzed for the parameters identified in the table above during at least 3 separate events each quarter. For quarters in which there are less than 3 such precipitation events resulting in discharges, a grab sample of the discharge shall be required whenever such precipitation event(s) occur(s). Should a sufficient number of discharge events occur during the quarter, the remaining three (3) quarterly samples may be taken during any of the Discharge Conditions described above.

The water quality standards for sulfate and chloride must be met in discharges from the above referenced outfall as well as in the receiving stream.

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* The Permittee is subject to the limitations, monitoring, and reporting requirements of Special Condition No. 13 for the discharges from Outfall 006 and unnamed tributary of Pond Creek receiving such discharges. Also, discharges from Outfall 006 shall be subject to the limitations, monitoring, and reporting requirements of Special Condition No. 18.

** No discharge is allowed from any above referenced permitted outfall during "low flow" or "no flow" conditions in the receiving stream unless such discharge meets the water quality standards of 35 Ill. Adm. Code 302.204 for pH.

NPDES Permit No. IL0077666

Effluent Limitations and Monitoring

From the effective date of this Permit until the expiration date, the effluent of the following discharge shall be monitored and limited at all times as follows:

Outfalls*: 007 (Acid Mine Drainage)

Discharge Condition	Parameters															
	Total Suspended Solids (mg/L) ***		Iron (total) (mg/L) ***		pH** (S.U.) ***	Alkalinity/ Acidity ***	Sulfate (mg/L) ***	Chloride (mg/L) ***	Cadmium (Cd) (mg/L) ***	Mn (total) (mg/L) ***	Iron (dissolved) (mg/L)	Nickel (mg/L)	Zinc (mg/L)	Hardness ***	Flow (MGD)	Settleable Solids (ml/l)
	30 day average	daily maximum	30 day average	daily maximum												
I	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	1.0	1.0	0.1104	0.1635	Monitor only	Measure When Sampling	-
II	-	-	-	-	6.0-9.0	-	1250	500	-	-	-	-	-	Monitor only	Measure When Sampling	0.5
III	-	-	-	-	6.0-9.0	-	1250	500	-	-	-	-	-	Monitor only	Measure When Sampling	-
IV	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	1.0	1.0	0.1104	0.1635	Monitor only	Measure When Sampling	-

I Dry weather discharge (base flow or mine pumpage) from the outfall.

II In accordance with 35 Ill. Adm. Code 406.110(b), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period greater than the 1-year, 24-hour precipitation event, but less than or equal to the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b). The 1-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

III In accordance with 35 Ill. Adm. Code 406.110(d), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period greater than the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b). The 10-year, 24-hour precipitation event for this area is considered to be 5.21 inches.

IV Discharges continuing 24 hours after cessation of precipitation event that resulted in discharge. For outfalls which have no allowed mixing, monitoring requirements and permit limitations of Discharge Condition IV are identical to Discharge Condition I to which the outfall discharge has reverted.

Sampling during all Discharge Conditions shall be performed utilizing the grab sampling method.

*** There shall be a minimum of nine (9) samples collected during the quarter when the pond is discharging. Of these 9 samples, a minimum of one sample each month shall be taken during either Discharge Condition I or IV should such discharge condition occur. A "no flow" situation is not considered to be a sample of the discharge. In the event that Discharge Conditions II and/or III occur, grab sample of each discharge caused by the above precipitation events (Discharge Conditions II and/or III) shall be taken and analyzed for the parameters identified in the table above during at least 3 separate events each quarter. For quarters in which there are less than 3 such precipitation events resulting in discharges, a grab sample of the discharge shall be required whenever such precipitation event(s) occur(s). Should a sufficient number of discharge events occur during the quarter, the remaining three (3) quarterly samples may be taken during any of the Discharge Conditions described above.

The water quality standards for sulfate and chloride must be met in discharges from the above referenced outfall as well as in the receiving stream.

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* The Permittee is subject to the limitations, monitoring, and reporting requirements of Special Condition No. 13 for the discharges from Outfall 007 and unnamed tributary of Pond Creek receiving such discharges. Also, discharges from Outfall 007 shall be subject to the limitations, monitoring, and reporting requirements of Special Condition No. 18.

** No discharge is allowed from any above referenced permitted outfall during "low flow" or "no flow" conditions in the receiving stream unless such discharge meets the water quality standards of 35 Ill. Adm. Code 302.204 for pH.

NPDES Permit No. IL0077666

Effluent Limitations and Monitoring

From the effective date of this Permit until the expiration date, the effluent of the following discharge shall be monitored and limited at all times as follows:

Outfall*: 008 (Acid Mine Drainage)

Discharge Condition	Parameters															
	Total Suspended Solids (mg/L) ***		Iron (total) (mg/L) ***		pH** (S.U.) ***	Alkalinity/ Acidity ***	Sulfate (mg/L) ***	Chloride (mg/L) ***	Cadmium (Cd) (mg/L) ***	Mn (total) (mg/L) ***	Copper (mg/L)	Nickel (mg/L)	Zinc (mg/L)	Hardness ***	Flow (MGD)	Settleable Solids (ml/l)
	30 day average	daily maximum	30 day average	daily maximum												
I	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	1.0	0.0245	0.1104	0.1635	Monitor only	Measure When Sampling	-
II	-	-	-	-	6.0-9.0	-	1250	500	-	-	-	-	-	Monitor only	Measure When Sampling	0.5
III	-	-	-	-	6.0-9.0	-	1250	500	-	-	-	-	-	Monitor only	Measure When Sampling	-
IV	35	70	3.0	6.0	6.5-9.0	Alk.>Acid	1250	500	0.0144	1.0	0.0245	0.1104	0.1635	Monitor only	Measure When Sampling	-

I Dry weather discharge (base flow or mine pumpage) from the outfall.

II In accordance with 35 Ill. Adm. Code 406.110(b), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period greater than the 1-year, 24-hour precipitation event, but less than or equal to the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b). The 1-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

III In accordance with 35 Ill. Adm. Code 406.110(d), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period greater than the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.106(b). The 10-year, 24-hour precipitation event for this area is considered to be 5.21 inches.

IV Discharges continuing 24 hours after cessation of precipitation event that resulted in discharge. For outfalls which have no allowed mixing, monitoring requirements and permit limitations of Discharge Condition IV are identical to Discharge Condition I to which the outfall discharge has reverted.

Sampling during all Discharge Conditions shall be performed utilizing the grab sampling method.

*** There shall be a minimum of nine (9) samples collected during the quarter when the pond is discharging. Of these 9 samples, a minimum of one sample each month shall be taken during either Discharge Condition I or IV should such discharge condition occur. A "no flow" situation is not considered to be a sample of the discharge. In the event that Discharge Conditions II and/or III occur, grab sample of each discharge caused by the above precipitation events (Discharge Conditions II and/or III) shall be taken and analyzed for the parameters identified in the table above during at least 3 separate events each quarter. For quarters in which there are less than 3 such precipitation events resulting in discharges, a grab sample of the discharge shall be required whenever such precipitation event(s) occur(s). Should a sufficient number of discharge events occur during the quarter, the remaining three (3) quarterly samples may be taken during any of the Discharge Conditions described above.

The water quality standards for sulfate and chloride must be met in discharges from the above referenced outfall as well as in the receiving stream.

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* The Permittee is subject to the limitations, monitoring, and reporting requirements of Special Condition No. 13 for the discharges from Outfall 008 and unnamed tributary of Pond Creek receiving such discharges. Also, discharges from Outfall 008 shall be subject to the limitations, monitoring, and reporting requirements of Special Condition No. 18.

** No discharge is allowed from any above referenced permitted outfall during "low flow" or "no flow" conditions in the receiving stream unless such discharge meets the water quality standards of 35 Ill. Adm. Code 302.204 for pH.

NPDES Permit No. IL0077666

Effluent Limitations and Monitoring

From the effective date of this Permit until the expiration date, the effluent of the following discharge shall be monitored and limited at all times as follows:

Outfall*: 011* (Alkaline Mine Drainage)

Parameters															
Total Suspended Solids** (mg/l)			Iron** (total) (mg/l)		pH** (S.U.)	Alkalinity/ Acidity	Sulfate** (mg/l)	Chloride** (mg/l)	Mn** (total) (mg/l)		Hardness	Nickel (mg/L)	Copper (mg/L)	Flow (MGD)	Iron (Dissolved)
30 day average	Yearly average	daily maximum	30 day average	daily maximum					30 day average	daily maximum					
35	32.2	70	3.0	6.0	6.5-9.0	Alk.>Acid	See Special Condition No. 15	See Special Condition No. 15	2.0	4.0	Monitor only	See Special Condition No. 15	See Special Condition No. 15	Measure When Sampling	See Special Condition No. 15

All sampling shall be performed utilizing the grab sampling method.

** There shall be a minimum of three (3) samples per week collected from Outfall 011 when the pond is discharging. A "no flow" situation is not considered to be a sample of the discharge.

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* Operation and management of pumpage to Outfall 011 is subject to the requirements of Special Condition No. 15. Also, discharges from Outfall 011 shall be subject to the limitations, monitoring, and reporting requirements of Special Condition No. 18. Monitoring downstream of Outfall 011 is subject to the requirements of Special Condition 16.

NPDES Permit No. IL0077666

Effluent Limitations and Monitoring

Upon completion of Special Condition 10 and approval from the Agency, the effluent of the following discharge shall be monitored and limited at all times as follows:

Outfalls*: 001, 002, 003, 004, 005, 006, 007, 008 (Reclamation Area Drainage)

Discharge Condition	Parameters					
	pH** (S.U.) ***	Sulfate (mg/L) ***	Chloride (mg/L) ***	Hardness ***	Flow (MGD)	Settleable Solids (ml/l) ***
I	6.5-9.0	1250	500	Monitor only	Measure When Sampling	0.5
II	6.0-9.0	1250	500	Monitor only	Measure When Sampling	0.5
III	6.0-9.0	1250	500	Monitor only	Measure When Sampling	-
IV	6.5-9.0	1250	500	Monitor only	Measure When Sampling	0.5

I Dry weather discharge (base flow, if present) from the outfall.

II In accordance with 35 Ill. Adm. Code 406.109(b), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period less than or equal to the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations. The 10-year, 24-hour precipitation event for this area is considered to be 5.21 inches.

III In accordance with 35 Ill. Adm. Code 406.109(c), any discharge or increase in the volume of a discharge caused by precipitation within any 24-hour period greater than the 10-year, 24-hour precipitation event (or snowmelt of equivalent volume) shall comply with the indicated limitations instead of those in 35 Ill. Adm. Code 406.109(b).

IV Discharges continuing 24 hours after cessation of precipitation event that resulted in discharge. For reclamation area discharges, monitoring requirements and permit limitations of Discharge Condition IV are identical to Discharge Condition I to which the outfall discharge has reverted.

Sampling during all Discharge Conditions shall be performed utilizing the grab sampling method. A "no flow" situation is not considered to be a sample of the discharge.

*** One sample per month (1/month) shall be collected if and/or when a discharge occurs under either Discharge Condition I, II or IV and analyzed for the parameters identified in the table above. In addition, at least three (3) grab samples shall be taken each quarter from separate precipitation events under Discharge Condition III and analyzed for parameters indicated in the above table. For quarters in which there are less than 3 such precipitation events, a grab sample of the discharge shall be required whenever such precipitation event(s) occur(s).

The water quality standards for sulfate and chloride must be met in discharges from the above referenced outfall as well as in the receiving stream.

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* The Permittee is subject to the limitations, monitoring, and reporting requirements of Special Condition Nos. 13 and 14 for the discharges from Outfalls 001, 002, 003, 004, 005, 006, 007 and 008 and unnamed tributary to Pond Creek.

** No discharge is allowed from any above referenced permitted outfall during "low flow" or "no flow" conditions in the receiving stream unless such discharge meets the water quality standards of 35 Ill. Adm. Code 302.204 for pH.

NPDES Permit No. IL0077666

Effluent Limitations and Monitoring

Upon completion of Special Condition No. 11 and approval from the Agency, the effluent of the following discharge shall be monitored and limited at all times as follows:

Outfalls: 001, 002, 003, 004, 05, 006, 007, 008 (Stormwater Discharge)

Parameters	
pH* (S.U.) **	Settleable Solids (ml/l) **
6.0-9.0	0.5

Stormwater discharge monitoring is subject to the following reporting requirements:

Analysis of samples must be submitted with second quarter Discharge Monitoring Reports.

If discharges can be shown to be similar, a plan may be submitted by November 1 of each year preceding sampling to propose grouping of similar discharges and/or updated previously submitted groupings. If updating of a previously submitted plan is not necessary, a written notification to the Agency, indicating such is required. Upon approval from the Agency, one representative sample for each group may be submitted.

Annual stormwater monitoring is required for all discharges until Final SMCRA Bond is released and approval to cease such monitoring is obtained from the Agency.

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* No discharge is allowed from any above referenced permitted outfalls during "low flow" or "no flow" conditions in the receiving stream unless such discharge meets the water quality standards of 35 Ill. Adm. Code 302.204 for pH.

** One (1) sample per year shall be collected and analyzed for the indicated parameter; however, such sampling and analysis is required only if and/or when a discharge occurs from the individual Outfall(s) identified above.

NPDES Permit No. IL0077666

Construction Authorization No. 3117-15

Authorization is hereby granted to the above designee to construct and operate the mine and mine refuse area described as follows:

Surface facilities in support of an underground mine containing a total of 986.10 acres, also identified as IDNR/OMM Permit Nos. 375 417 and 456, and as described in IEPA Log Nos. 3117-15 and 3117-15-A, located in Sections 2, 3, 4, 7, 8, 9, 10, 12, 14, 15, 16, 17, 18 and 29, Township 8 South, Range 4 East, and Sections 11, 12, 13, 35, 36, Township 8 South, Range 3 East, Williamson County, 3rd P.M., Illinois, and Sections 1, 2 and 12, Township 8 South, Range 2 East, and Sections 7, 8, 9, 11, 14, 15, 16, and 17, Township 8 South, Range 3 East, and Sections 27, 28, 29, 30, 31, 32, 34 and 35, Township 7 South, Range 2 East, Franklin County , 3rd P.M., Illinois.

The surface facilities at this site contain drainage control structures (ditches) and nine (9) sediment basins, incline slope, coal preparation plant, coal stockpiles, refuse disposal areas, coal conveyors, railroad loop, ventilation shafts, parking areas, access roads, and office and maintenance buildings. The following additional areas are being added to the original facilities approved for this operation.

An additional area of 4.05 acres, identified as IBR No. 4 to OMM Permit No. 375, located in Section 12, Township 8 South, Range 3 East, in Williamson County, Illinois. As proposed and depicted in IEPA Log Nos. 2416-06 and 2416-06-A, installation of three (3) boreholes and associated pipeline to ensure mine ventilation is approved. Runoff from the area approved herein should be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 9.71 acres, identified as IBR No. 5 to OMM Permit No. 375, located in Section 13, Township 8 South, Range 3 East, in Williamson County, Illinois. As proposed and depicted in IEPA Log Nos. 2380-06 and 2380-06-A, installation of the support facilities to ensure mine ventilation is approved. Runoff from the area approved herein should be controlled by two temporary catch basins, silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 3.20 acres, identified as IBR No. 10 to OMM Permit No. 375, located in Section 8, Township 8 South, Range 4 East, in Williamson County, Illinois. As proposed and depicted in IEPA Log Nos. 1396-07 and 1396-07-A, installation of two (2) boreholes and a vertical pump to ensure mine ventilation is approved. Runoff from the area approved herein should be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 12.50 acres, identified as IBR No. 11 to OMM Permit No. 375, located in Sections 4, 7 and 8, Township 8 South, Range 4 East, in Williamson County, Illinois. As proposed and depicted in IEPA Log Nos. 1525-07 and 1525-07-A, this area is incorporated for the installation of the water line from the Locust Grove Shaft area to Pond 006. Runoff from the area approved herein should be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 0.36 acres, identified as IBR to OMM Permit No. 375, located in Sections 11 and 12, Township 8 South, Range 3 East, in Williamson County, Illinois. As proposed and depicted in IEPA Log Nos. 0190-08 and 0190-08-A, re-alignment of access road is approved. Runoff from the area approved herein should be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 3.57 acres, identified as IBR No. 14 to OMM Permit No. 375, located in Section 9, Township 8 South, Range 4 East, in Williamson County, Illinois. As proposed and depicted in IEPA Log No. 0369-08, two (2) boreholes will be drilled and a vertical pump will be installed to ensure mine ventilation. Runoff from the area approved herein will be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 8.1 acres, identified as IBR No. 25 to OMM Permit No. 375, located in Sections 9 and 10, Township 8 South, Range 4 East, in Williamson County, Illinois. As proposed and depicted in IEPA Log No. 8091-10, two (2) concrete transport boreholes and access road will be constructed and a turbine pump, buried waterline and power line will be installed. Runoff from the area approved herein will be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 2.13 acres, identified as IBR No. 55 to OMM Permit No. 375, located in Section 9 and 16, Township 8 South, Range 4 East, in Williamson County, Illinois. As proposed and depicted in IEPA Log No. 5530-13 a buried pump discharge pipeline and electrical power line will be installed. Runoff from the area approved herein will be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 4.18 acres, identified as IBR No. 52 to OMM Permit No. 375, located in Section 15, Township 8 South, Range 4 East, Williamson County, Illinois. As proposed and depicted in IEPA Log No. 5168-13, this area is being incorporated for the construction of an underground mine support facility including a borehole and installation of an electric vertical turbine pump. The area will also include a buried pipeline and electric power line. Runoff from the area approved herein will be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 3.3 acres, identified as IBR No. 57 to OMM Permit No. 375, located in Section 18, Township 8 South, Range 4 East, in Williamson County, Illinois. As proposed and depicted in IEPA Log No. 4088-14, two (2) boreholes will be constructed and a pump and waterline will be installed to pump underground mine pumpage to an existing waterline along Jordan Fort Road. Topsoil stockpiles will also be located with the IBR area. Runoff from the area approved herein will be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 3.3 acres, identified as IBR No. 58 to OMM Permit No. 375, located in Sections 8 and 17, Township 8 South, Range 4 East, in Williamson County, Illinois. As proposed and depicted in IEPA Log No. 5477-13, two (2) boreholes will be constructed and a pump and waterline will be installed to pump underground mine water and to ensure underground ventilation. Runoff from the area approved herein will be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 9.89 acres, identified as IBR No. 60 to OMM Permit No. 375, located in Section 13, Township 8 South, Range 3 East, Williamson County, Illinois. As proposed and depicted in IEPA Log No. 4237-14, this area is for the development of topsoil and subsoil storage areas and construction of associated drainage ditches. Two (2) drainage ditches, identified as Collection Ditch Nos. D-5E-1 and D-5D-1, directs runoff from this area to existing Ditch D-5c and Pond 005.

An additional area of 1.0 acres, identified as IBR No. 78 to OMM Permit No. 375, located in Section 13, Township 8 South, Range 3 East, and Sections 7 and 18, Township 8 South, Range 4 East, in Williamson County, Illinois. As proposed and depicted in IEPA Log No. 9082-19, this area is incorporated into this permit for a buried four-inch waterline to be installed. Runoff from the area approved herein will be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 19.9 acres, identified as IBR No. 79 to OMM Permit No. 375, located in Sections 35 and 36, Township 7 South, Range 3 East, in Franklin County, Illinois. As proposed and depicted in IEPA Log No. 9083-19, this area is incorporated into this permit for installation of a supply shaft to transport supplies underground as required for the continued effective operation of approved mine plan, belt air shaft and fan to supply required ventilation along with six (6) steel cased boreholes with a diameter less ten 10 5/8 inches for power and other supplies, power substation, dry storage barn and equipment yard. Runoff from the area approved herein will be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

An additional area of 17.01 acres, identified as IBR No. 83 to OMM Permit No. 375, located in Sections 2, 3, 9 and 10, Township 8 South, Range 4 East, in Williamson County, Illinois. As proposed and depicted in IEPA Log No. 9109-19, this area is incorporated into this permit for a access roadway, one 16.5 foot bleeder shaft, utility boreholes, concrete pad for transformer, a compressor station and a portable crib plant. Runoff from the area approved herein will be controlled by silt fence, mulching, seeding, vegetation, rock check dams, erosion control blankets, etc.

As described in IEPA Log No. 7395-11 and previously approved under Subtitle D Permit No. 2012-MA-7395-1, a permit area consisting of 9.82 acres located in Section 10, Township 8 South, Range 4 East, Williamson County, is incorporated into this permit for the construction of compressor bore hole, installation of a buried power line and an access road. All runoff from this area shall be monitored in accordance with stormwater monitoring requirements of Special Condition No. 12 of this NPDES Permit. This additional area is included in the total permit acreage cited above.

As described in IEPA Log No. 6141-12 and previously approved under Subtitle D Permit No. 2012-MA-6141-1, a permit area consisting of 0.64 acres located in Section 13, Township 8 South, Range 3 East, Williamson County, is incorporated into this permit for the construction of borehole for the batch material supply of crushed stone and concrete to the underground mine. All runoff from this area shall be monitored in accordance with stormwater monitoring requirements of Special Condition No. 12 of this NPDES Permit. This additional area is included in the total permit acreage cited above.

As described in IEPA Log No. 6562-12 and previously approved under Subtitle D Permit No. 2013-MA-6562, a permit area consisting of 3.81 acres located in Section 16, Township 8 South, Range 4 East, Williamson County, is incorporated into this permit for the construction of a steel-liner drill hole and temporary installation of a pumpable cement product mixing plant used for underground mine. All runoff from this area shall be monitored in accordance with stormwater monitoring requirements of Special Condition No. 12 of this NPDES Permit. This additional area is included in the total permit acreage cited above.

As described in IEPA Log No. 6039-12 and previously approved under Subtitle D Permit No. 2015-MA-6039, a permit area consisting of 4.65 acres located in Section 14, Township 8 South, Range 4 East, Williamson County, is incorporated into this permit for installation of ventilation shaft site. All runoff from this area shall be monitored in accordance with stormwater monitoring requirements of Special Condition No. 12 of this NPDES Permit. This additional area is included in the total permit acreage cited above.

As described in IEPA Log No. 2273-16 and previously approved under Subtitle D Permit No. 2016-MA-2273, a permit area consisting of 6.5 acres located in Section 29, Township 8 South, Range 4 East, Williamson County, is incorporated into this permit for the construction of a concrete lined South District Supply Shaft to provide supplies to underground workings, three (3) boreholes, a pole barn and an access road. All runoff from this area shall be monitored in accordance with stormwater monitoring requirements of Special Condition No. 12 of this NPDES Permit. This additional area is included in the total permit acreage cited above.

As previously approved under Subtitle D Permit No. 2014-MW-4275, a fine coal refuse (slurry) disposal area incorporating the use of geotextile tubes was developed at Pond Creek Mine site. As described and depicted in IEPA Log Nos. 4275-14, 4275-14-A, 4275-14-B, 1475-14-C development of this area included construction of a low permeability liner consisting of four (4) foot compacted clay with a hydraulic conductivity of 1 x 10^{-7} cm/sec, or less. Surface runoff and dewatering of the geotextile tubes is collected in a "no-discharge" perimeter containment basin and pumped to existing refuse disposal area or coal preparation plant. Hereby incorporated into this permit is a modification of the drainage control plan to allow stormwater runoff from the area to discharge through sediment ditches and spillway into existing Ditch D-5C and through Pond No. 005, as described and depicted in IEPA Log No. 3117-15. Reclamation of the geotextile tube refuse disposal area shell consists of construction of a low permeability cap consisting of four (4) foot compacted clay with hydraulic conductivity of 1x10^{-7}cm/sec, or less. Rooting medium and topsoil required for establishment of vegetative cover shall be in addition to the four (4) foot compacted clay low permeability cap. Four (4) monitoring wells identified as Well Nos. GW-29, GW-30, GW-31 and GW-32 shall be installed at each corner of the geotextile tube placement area. Groundwater monitoring shall be performed in accordance with Condition No. 13.

As described in IEPA Log Nos.1186-17, 1186-17-Band 1385-17, and previously approved under Subtitle D Permit No. 2017-MA-1186-1, a permit area consisting of 17.7 acres located in Section 12, Township 8 South, Range 3 East, Williamson County, is incorporated into this permit for construction of a Water Management Facility consisting of three (3) water holding cells. Construction and development of the water Management facility includes topsoil removal, grading, foundation preparation and installation of a low permeability liner consisting of four (4) foot compacted clay liner with a hydraulic conductivity of 1 x 10^{-7} cm/sec within the water holding cells. Compacted clay liner shall also be subject to and in accordance with the specifications and testing requirements of Condition No. 12. All runoff from this area shall be monitored in accordance with stormwater monitoring requirements of Special Condition No. 12 of this NPDES Permit. This additional area is included in the total permit acreage cited above. Four (4) monitoring wells identified as Well Nos. GW-33, GW-34, GW-35 and GW-36 shall be installed as depicted in IEPA Log Nos. 1186-17, 1186-17-B and 1385-17 Groundwater monitoring shall be performed in accordance with Condition No.13.

The following mining operations plan changes are incorporated into this permit:

Log No. 2413-06	The Mining Operations Plan has been revised to include the construction of an access tunnel under the railroad loop and administration building.
Log No. 2414-06	The Mine Operations Map has been revised to depict the revised various structures within the support facility.
Log No. 0371-08	Installation of a concrete sump at the existing road tunnel and a pipeline which will discharge to Sediment Pond No. 003, identified as IPR No. 13 to OMM Permit No. 375.

Surface drainage control is provided by nine (9) sedimentation ponds with discharges designated as 001, 002, 003, 004, 005 and 011 classified as alkaline mine drainage, and Outfalls 006, 007, 008 classified as acid mine discharge. The sanitary wastewater water treatment system will be approved by the Illinois Department of Public Health.

The location and receiving stream of the Outfalls at this facility is as follows:

Outfall No.	Latitude			Longitude			Receiving Water
	DEG	MIN	SEC	DEG	MIN	SEC	
001	37°	50'	59.2"	88°	49'	37.5"	Unnamed tributary to Pond Creek
002	37°	50'	26.0"	88°	49'	51.5"	Unnamed tributary to Pond Creek
003	37°	50'	26.0"	88°	49'	58.0"	Unnamed tributary to Pond Creek
004	37°	50'	25.0"	88°	49'	56.6"	Unnamed tributary to Pond Creek
005	37°	50'	9.1"	88°	50'	00.0"	Unnamed tributary to Pond Creek
006	37°	50'	28.4"	88°	50'	40.6"	Unnamed tributary to Pond Creek
007	37°	50'	29.5"	88°	49'	34.0"	Unnamed tributary to Pond Creek
008	37°	50'	31.4"	88°	49'	33.9"	Unnamed tributary to Pond Creek
011	37°	52'	37"	89°	01'	49"	Big Muddy River

Original Sedimentation Ponds with discharges designated as Outfall Nos. 007 and 008 have been re-designed as described and depicted in IEPA Log No. 8554-10.

Refuse disposal
Refuse Disposal Area as previously approved in IEPA Log No. 3054-05, was constructed in phases as depicted and described in IEPA Log No. 2377-06 (RDA No. 1), Refuse Disposal Area No. 2 was constructed at Pond Creek Mine facilities as proposed and described in IEPA Log Nos. 1465-07, 1465-07-B, 1465-07-D, 1465-07-E, 1465-07-G, 1520-07, 0346-08, 9005-09, 9198-09, 9198-09-A, 8114-10, 8114-10-A, 7185-11, 7225-11, 6431-12, 6431-12-A and 5378-13.

As previously approved under Subtitle D Permit No. 2015-MA-3432, construction and development of Refuse Disposal Area No. 3 includes topsoil removal, grading, foundation preparation for refuse area, also construction of the water holding cell and installation of four (4) foot compacted clay liner was performed in accordance with the procedures discussed and outlined in IEPA Log No. 3432-15. As described in IEPA Log No. 3432-15, all stormwater runoff from the deposited coarse refuse within the RDA No. 3 is collected and maintained within the RDA No. 3 and/or is pumped into the slurry impounding structure of the existing RDA, which is an integral part of the Pond Creek Mine No. 1 coal preparation plant closed circuit wastewater handling system.

As described and depicted in IEPA Log Nos. 3001-15 and 3001-15-C Refuse Disposal Area No. 3 (RDA 3) is approved for construction. RDA 3 is located immediately east of the RDA 1 and RDA 2 areas, contains 229.78 acres, and is included in the above cited total Permit acreage. The area for RDA 3 is located in Section 12, Township 8 South, Range 3 East and Section 7, Township 8 South, Range 4 East, Williamson County, Illinois. To not increase chloride and sulfates due to construction of RDA 3, the mine is reclaiming the outslopes of the RDA 1 and RDA 2 that previously discharged through Outfalls 007 and 008. There will be no increase in loading due to the construction of RDA 3. Runoff from this area will be tributary to previously constructed water holding cell. Construction of four (4) foot compacted clay liners for the Refuse Disposal Area No. 3, shall be subject to and in accordance with the specifications and testing requirements of Condition No. 12. With prior approval as to thickness and installation procedures, an HDPE synthetic liner may be utilized in lieu of the compacted clay liners proposed.

Mixing Zone (Big Muddy River)
Excess water will be transported from the Pond Creek Mine to Outfall No. 011 on the Big Muddy River through a high-density polyethylene (HDPE) pipeline. Water will be pumped from the Water Holding Cell by pumps through approximately 12.5 miles of pipe to the diffuser located at the mixing zone location. The pipeline ROW will be approximately 50 feet in width with a total permitted area of approximately 70.7 acres. The amount of water that could be discharged through the Pipeline depends upon the chloride concentration in the discharge stream, the background chloride content and the flow in the Big Muddy River. The upper limit to the discharge will be based on the pumping capacity of the facility. Maximum pumping rate of 5,000 gallons per minute or 11.1 cfs. from the facility. The volume of water discharged to Big Muddy River will be dependent upon the flow in the Big Muddy River and the chloride concentration of the water in the Water Holding Cell and the chloride concentration coming downstream in the River.

During operations of the pipeline, continuous flow monitors will be installed to provide protection against leakage. Flow will be monitored near the pump discharge while the pipeline is within the sediment control structure of Pond Creek Mine. Flow will also be monitored at the mixing zone location. This instrumentation will be connected to an alarm monitoring system and flow data will be transmitted to a central location for tracking and assessing system operations. The flow monitoring system operation and maintenance is subject to the requirements of Special Condition No. 15.

Groundwater monitoring for the facility will consist of Monitoring Well Nos. MW-10, MW-11, MW-12, MW-13, MW-8R, MW-28, GW-1, GW-2, GW-4, GW-5, GW-9, GW-33, GW-34, GW-35 and GW-36. Groundwater monitoring requirements are outlined in Condition No. 13.

This Construction Authorization replaces Construction Authorization No. 3054-05.

The abandonment plan shall be executed and completed in accordance with 35 Ill. Adm. Code 405.109.

All water remaining upon abandonment must meet the requirements of 35 Ill. Adm. Code 406.202. For the constituents not covered by 35 Ill. Adm. Code Parts 302 or 303, all water remaining upon abandonment must meet the requirements of 35 Ill. Adm. Code 406.106.

NPDES Permit No. IL0077666

Construction Authorization No. 3117-15

This Authorization is issued subject to the following Condition(s). If such Condition(s) require(s) additional or revised facilities, satisfactory engineering plan documents must be submitted to this Agency for review and approval to secure issuance of a Supplemental Authorization to Construct.

1. If any statement or representation is found to be incorrect, this permit may be revoked and the permittee thereupon waives all rights thereunder.

2. The issuance of this permit (a) shall not be considered as in any manner affecting the title of the premises upon which the mine or mine refuse area is to be located; (b) does not release the permittee from any liability for damage to person or property caused by or resulting from the installation, maintenance or operation of the proposed facilities; (c) does not take into consideration the structural stability of any units or parts of the project; and (d) does not release the permittee from compliance with other applicable statutes of the State of Illinois, or with applicable local laws, regulations or ordinances.

3. Final plans, specifications, application and supporting documents as submitted by the permittee and approved by the Agency shall constitute part of this permit in the records of the Agency.

4. There shall be no deviations from the approved plans and specifications unless revised plans, specifications and application shall first have been submitted to the Agency and a supplemental permit issued.

5. The permit holder shall notify the Agency (217/782-3637) immediately of an emergency at the mine or mine refuse area which causes or threatens to cause a sudden discharge of contaminants into the waters of Illinois and shall immediately undertake necessary corrective measures as required by 35 Ill. Adm. Code 405.111. (217/782-3637 for calls between the hours of 5:00 p.m. to 8:30 a.m. and on weekends.)

6. The termination of an NPDES discharge monitoring point or cessation of monitoring of an NPDES discharge is not authorized by this Agency until the permittee submits adequate justification to show what alternate treatment is provided or that untreated drainage will meet applicable effluent and water quality standards.

7. Initial construction activities in areas to be disturbed shall be for collection and treatment facilities only. Prior to the start of other activities, surface drainage controls shall be constructed and operated to avoid violations of the Act or Subtitle D. At such time as runoff water is collected in the sedimentation pond, a sample shall be collected and analyzed, for the parameters designated as 1M through 15M under Part 5-C of Form 2C and the effluent parameters designated herein with the results sent to this Agency. Should additional treatment be necessary to meet the standards of 35 Ill. Adm. Code 406.106 or applicable water quality standards, a Supplemental Permit must be obtained. Discharge from ponds is not allowed unless applicable effluent and water quality standards are met in the basin discharge(s).

8. This Agency must be informed in writing and an application submitted if drainage, which was previously classified as alkaline (pH greater than 6.0), becomes acid (pH less than 6.0) or ferruginous (base flow with an iron concentration greater than 10 mg/L). The type of drainage discharging to the basin should be reclassified in a manner consistent with the applicable provisions of 35 Ill. Adm. Code Part 406. The application should discuss the treatment method and demonstrate how the discharge will meet the applicable standards.

9. A permittee has the obligation to add a settling aid if necessary to meet the suspended solids or settleable solids effluent standards. The selection of a settling aid and the application practice shall be in accordance with a. or b. below

    a. Alum ($Al_2(SO_4)_3$), hydrated lime ($Ca(OH)_2$), soda ash (Na_2CO_3), alkaline pit pumpage, acetylene production by-product (tested for impurities), and ground limestone are acceptable settling aids and are hereby permitted for alkaline mine drainage sedimentation ponds.

    b. Any other settling aids such as commercial flocculents and coagulants are permitted only on prior approval from the Agency. To obtain approval a permittee must demonstrate in writing to the Agency that such use will not cause a violation of the toxic substances standard of 35 Ill. Adm. Code 302.210 or of the appropriate effluent and water quality standards of 35 Ill. Adm. Code parts 302, 304, and 406.

10. A general plan for the nature and disposition of all liquids used to drill boreholes shall be filed with this Agency prior to any such operation. This plan should be filed at such time that the operator becomes aware of the need to drill unless the plan of operation was contained in a previously approved application.

11. Any of the following shall be a violation of the provisions required under 35 Ill. Adm. Code 406.202:

    a. It is demonstrated that an adverse effect on the environment in and around the receiving stream has occurred or is likely to occur.

b. It is demonstrated that the discharge has adversely affected or is likely to adversely affect any public water supply.

c. The Agency determines that the permittee is not utilizing Good Mining Practices in accordance with 35 Ill. Adm. Code 406.204 which are fully described in detail in Sections 406.205, 406.206, 406.207 and 406.208 in order to minimize the discharge of total dissolved solids, chloride, sulfate, iron and manganese. To the extent practical, such Good Mining Practices shall be implemented to:

   i. Stop or minimize water from coming into contact with disturbed areas through the use of diversions and/or runoff controls (Section 406.205).

   ii. Retention and control within the site of waters exposed to disturbed materials utilizing erosion controls, sedimentation controls, water reuse or recirculation, minimization of exposure to disturbed materials, etc. (Section 406.206).

   iii. Control and treatment of waters discharged from the site by regulation of flow of discharges and/or routing of discharges to more suitable discharge locations (Section 406.207).

   iv. Utilized unconventional practices to prevent the production or discharge of waters containing elevated contaminant concentrations such as diversion of groundwater prior to entry into a surface or underground mine, dewatering practices to remove clean water prior to contacting disturbed materials and/or any additional practices demonstrated to be effective in reducing contaminant levels in discharges (Section 406.208).

12. The four (4) foot compacted clay liner to be constructed course refuse disposal area, fine coal refuse area (RDA No. 3) shall be subject to the specifications and procedures presented in IEPA Log No. 3001-15-C.

Construction Specifications

a. All soils to be used for the compacted clay liner shall be free of grass, vines, vegetation and rock or stones greater than four (4) inches in diameter.

b. Samples collected from the borrow area shall be evaluated in accordance with ASTM D422, D4318 and D2487 to ensure classification criteria are met.

c. Each successive soil lift shall be placed to a 6 to 8 inch loose thickness; however, in no instance shall the loose lift thickness exceed the length of the pads or feet on the compactor or roller.

d. Each soil lift shall be compacted to the minimum Standard Proctor (ASTM D698) density identified in item no. 12(q) below, at a moisture content of 0% to 5% above the optimum moisture content of the soil.

e. Inter-lift surfaces shall be adequately scarified to ensure inter-lifting bonding.

f. Liner construction shall be performed to consistent achievement of density, moisture content, and hydraulic conductivity for each successive lift.

g. The placement of frozen material or the placement material on frozen ground is prohibited.

h. Contemporaneous placement or protective covering shall be provided to prevent drying, desiccation and/or freezing where necessary.

i. Liner construction shall be completed in a manner which reduces void spaces within the soil and liner.

j. All construction stakes shall be removed during construction, and all test holes (Shelby tube samples) are to be backfilled with bentonite.

k. The compacted clay liner shall be constructed in a manner to achieve a uniform barrier with a hydraulic conductivity of 1×10^{-7} cm/sec.

l. In the event that acceptable compaction results are not achieved, the soil lift shall be reprocessed or removed and replaced. If moisture content is less than optimum, or greater than 5% above optimum, the falling material shall be wetted or dried to a moisture content within specification and re-compacted. If the dry density is below specification, the failing material shall be re-compacted until a passing test is achieved.

m. In the event of a failing conductivity test, the soil may be removed or re-compacted and retested until a passing result is obtained; or the soil immediately above and below the test specimen from the same Shelby tube may be tested. If both tests pass, the original test shall be nullified. If either test fails, that portion of the liner shall be rejected and shall be reconstructed and retested until passing results are obtained. The limits of necessary reconstruction shall be determined by additional sampling and testing within the failed region, thereby isolating the failing area of work.

Testing Specifications

n. Prior to initiating soil liner construction, borrow soils shall be identified, qualified, and verified. At minimum, a representative sample of each soil type identified within the borrow area is to be collected and analyzed for gradation, compaction, and hydraulic conductivity characteristics.

o. Samples collected from borrow area shall be evaluated in accordance with ASTM D422, D4318 and D2487 to ensure classification criteria are met.

p. Samples collected from the borrow area shall be tested in accordance with ASTM D 698 to determine maximum dry density and optimum moisture content of the soil.

q. Samples collect from the borrow area shall be compacted to 90% and 95% standard Proctor density at or near optimum moisture content. The hydraulic conductivity of the re-compacted samples shall be determined in accordance with ASTM D5084 procedures. The results of this testing shall be used to establish the minimum dry density for soil liner compaction necessary to achieve a hydraulic conductivity of 1×10^{-7} cm/sec or less.

r. Moisture and density testing by nuclear methods (ASTM D2922 and D3017) shall be conducted at a rate of at least one test per 1,000 cubic yards placed. Testing locations shall be random and shall not be known to the earthwork contractor prior to lift placement.

s. To ensure the accuracy and reproducibility of the nuclear testing, all nuclear density gauges shall be certified to calibration. Soil compaction tests shall be double-checked with independent test methods. A drive cylinder test and laboratory moisture content determination shall be conducted and compared to gauge readings. These independent checks shall be made at the outset of construction and on a bi-weekly basis (e.g., every ten working days) thereafter.

t. Samples for hydraulic conductivity verification shall be retrieved from the compacted soil liner and tested in accordance with ASTM D5084 procedures. Samples shall be retrieved using three-inch Shelby tubes. Samples shall be completed at frequency of one sample/test per 20,000 cubic yards placed. The vertical location of the recovered samples shall be varied so that representative portions or lifts of the contractor prior to soil liner construction.

u. Survey checks shall be conducted at a minimum spacing of 100 ft. centers, and at 100 ft. intervals along each line where a break in slope occurs, to verify liner thickness. To verify liner thickness, the survey checks shall be taken before and after liner construction.

13. Groundwater monitoring requirements for Well Nos. MW-10, MW-11, MW-12, MW-13, MW-8R, MW-28, GW-1, GW-2, GW-4, GW-5, GW-9, GW-33, GW-34, GW-35 and GW-36 are as follows:

a. Ambient background monitoring shall be performed for all referenced wells. Such ambient monitoring shall consist of six (6) samples collected during the first year (approximately bi-monthly) following well installation but no later than during the first year of operation or disturbance to determine ambient background concentrations. Background monitoring shall include the following list of constituents:

Aluminum	Fluoride	Sulfate
Antimony	Iron (dissolved)	Thallium
Arsenic	Iron (total)	Total Dissolved Solids
Barium	Lead	Vanadium
Beryllium	Manganese (dissolved)	Zinc
Boron	Manganese (total)	pH (field)
Cadmium	Mercury	Acidity
Chloride	Molybdenum	Alkalinity
Chromium	Nickel	Hardness
Cobalt	Phenols	Static Water Elevation
Copper	Selenium	
Cyanide	Silver	

b. Following the ambient monitoring as required under Condition No. 13(a) above, routine monitoring shall continue on a quarterly basis as follows:

i. Monitoring Well Nos. MW-10, MW-11, MW-12, MW-13, MW-8R, MW-28, GW-2, GW-5, GW-9, GW-33, GW-34, GW-35 and GW-36 shall continue to be monitored quarterly for the contaminants identified in Condition No. 13(a) above.

ii. Monitoring Well Nos. GW-1 and GW-4 shall be monitored quarterly as required by IDNR/OMM for the following list of constituents:

Chloride	Total Dissolved Solids
Iron (dissolved)	Hardness
Iron (total)	Acidity
Manganese (dissolved)	Alkalinity
Manganese (total)	pH
Sulfate	Static Water Elevation

c. Following completion of active mining and reclamation, post-mining monitoring of all above referenced wells shall consist of six (6) samples collected during a 12-month period (approximately bi-monthly) to determine post-mining concentrations. Post-mining monitoring shall include the list of constituents identified in Condition No. 13(a) above.

d. Groundwater monitoring reports shall be submitted to the Agency in accordance with Special Condition Nos. 3 and 5 of this NPDES permit.

e. A statistically valid representation of background and/or post mining water quality required under Condition No. 13(b) above shall be submitted utilizing the following method. This method shall be used to determine the upper 95 percent confidence limit for each parameter listed above.

Should the Permittee determine that an alternate statistical method would be more appropriate based on the data being evaluated, the Permittee may request utilization of such alternate methodology. Upon approval from the Agency, the alternate methodology may be utilized to determine a statistically valid representation of background and/or post mining water quality.

The following method should be used to predict the confidence limit when single groundwater samples are taken from each monitoring (test) well.

i. Determine the arithmetic mean $\left(\overline{X}_b\right)$ of each indicator parameter for the sampling period. If more than one well is used, an equal number of samples must be taken from each well.

$$\overline{X}_b = \frac{X_1 + X_2 + \ldots X_n}{n}$$

Where:

$\overline{X}_b$ = Average value for a given chemical parameter

X_n = Values for each sample

n = the number of samples taken

ii. Calculate the background and/or post mining variance (S_b^2) and standard deviation (S_b) for each parameter using the values (X_n) from each sample of the well(s) as follows:

$$S_b^2 = \frac{(X_1 - \overline{X}_b)^2 + (X_2 - \overline{X}_b)^2 + \ldots + (X_n - \overline{X}_b)^2}{n-1}$$

$$S_b = \sqrt{S_b^2}$$

iii. Calculate the upper confidence limit using the following formula:

$$CL = \overline{X}_b \pm t\sqrt{1 + 1/n}\ \ (S_b)$$

Where:

CL = upper confidence limit prediction
(upper and lower limits should be calculated for pH)
t = onetailed t value at the required significance
level and at n1 degrees of freedom from Table 1
(a twotailed t value should be used for pH)

iv. If the values of any routine parameter for any monitoring well exceed the upper confidence limit for that parameter, the permittee shall conclude that a statistically significant change has occurred at that well.

v. When some of the background and/or post mining values are less than the Method Detection Limit (MDL), a value of one-half (1/2) the MDL shall be substituted for each value that is reported as less than the MDL. All other computations shall be calculated as given above.

If all the background and/or post mining values are less than the MDL for a given parameter, the Practical Quantitation Limit (PQL), as given in 35 Ill. Adm. Code Part 724 Appendix I shall be used to evaluate data from monitoring wells. If the analytical results from any monitoring well exceed two (2) times the PQL for any single parameter, or if they exceed the PQLs for two or more parameters, the permittee shall conclude that a statistically significant change has occurred.

Table 1
Standard tTables Level of Significance

Degrees of freedom	tvalues (onetail)		tvalues (twotail)*	
	99%	95%	99%	95%
4	3.747	2.132	4.604	2.776
5	3.365	2.015	4.032	2.571
6	3.143	1.943	3.707	2.447
7	2.998	1.895	3.499	2.365
8	2.896	1.860	3.355	2.306
9	2.821	1.833	3.250	2.262
10	2.764	1.812	3.169	2.228
11	2.718	1.796	3.106	2.201
12	2.681	1.782	3.055	2.179
13	2.650	1.771	3.012	2.160
14	2.624	1.761	2.977	2.145
15	2.602	1.753	2.947	2.131
16	2.583	1.746	2.921	2.120
17	2.567	1.740	2.898	2.110
18	2.552	1.734	2.878	2.101
19	2.539	1.729	2.861	2.093
20	2.528	1.725	2.845	2.086
21	2.518	1.721	2.831	2.080
22	2.508	1.717	2.819	2.074
23	2.500	1.714	2.807	2.069
24	2.492	1.711	2.797	2.064
25	2.485	1.708	2.787	2.060
30	2.457	1.697	2.750	2.042
40	2.423	1.684	2.704	2.021

Adopted from Table III of "Statistical Tables for Biological Agricultural and Medical Research" (1947, R.A. Fisher and F. Yates).

* For pH only when required.

NPDES Permit No. IL0077666

Special Conditions

Special Condition No. 1: No effluent from any mine related facility area under this permit shall, alone or in combination with other sources, cause a violation of any applicable water quality standard as set out in the Illinois Pollution Control Board Rules and Regulations, Subtitle C: Water Pollution.

Special Condition No. 2: Samples taken in compliance with the effluent monitoring requirements shall be taken at a point representative of the discharge, but prior to entry into the receiving stream.

Special Condition No. 3: All periodic monitoring and reporting forms, including Discharge Monitoring Report (DMR) forms, shall be submitted to the Agency according to the schedule outlined in Special Condition No. 4 or 5 below with one (1) copy forwarded to each of the following addresses:

Illinois Environmental Protection Agency
Division of Water Pollution Control
1021 North Grand Ave., East
P.O. Box 19276
Springfield, IL 62794-9276

Attn: Compliance Assurance Section

Illinois Environmental Protection Agency
Mine Pollution Control Program
2309 West Main Street, Suite 116
Marion, Illinois 62959

The Permittee will be required to submit electronic DMRs (NetDMR) instead of mailing paper DMRs to the IEPA, unless a waiver is approved by the Agency. More information, including registration information for the NetDMR program, can be obtained on the IEPA website, https://www2.illinois.gov/epa/topics/water-quality/surface-water/netdmr/Pages/quick-answer-guide.aspx.

Special Condition No. 4: Completed Discharge Monitoring Report (DMR) forms and as well as upstream and downstream monitoring results, shall be retained by the Permittee for a period of three (3) months and shall be submitted electronically (or mailed if waiver is approved by the Agency) and received by the IEPA at the addresses indicated in Special Condition No. 3 above in accordance with the following schedule, unless otherwise specified by the permitting authority.

Period	Received by IEPA
January, February, March	April 15
April, May, June	July 15
July, August, September	October 15
October, November, December	January 15

The Permittee shall record discharge monitoring results on Discharge Monitoring Report (DMR) forms using one such form for each Outfall and Discharge Condition each month. In the event that an Outfall does not discharge during a monthly reporting period or under a given Discharge Condition, the DMR form shall be submitted with "No Discharge" indicated.

Any and all monitoring results, other than NPDES outfall discharge results reported through NetDMR, shall be submitted to the Agency at the addresses indicated in Special Condition No. 3 above.

Special Condition No. 5: Completed periodic monitoring and reporting, other than DMR's and stream monitoring (i.e., groundwater monitoring, coal combustion waste analysis reports, etc.), shall be retained by the Permittee for a period of three (3) months and shall be mailed and received by the IEPA at the addresses indicated in Special Condition No. 3 above in accordance with the following schedule, unless otherwise specified by the permitting authority.

Period	Received by IEPA
January, February, March	May 1
April, May, June	August 1
July, August, September	November 1
October, November, December	February 1

Special Condition No. 6: The Agency may revise or modify the permit consistent with applicable laws, regulations or judicial orders.

Special Condition No. 7: If an applicable effluent standard or limitation is promulgated under Sections 301(b)(2)(C) and (D), 304(b)(2), and 307(a)(2) of the Clean Water Act and that effluent standard or limitation is more stringent than any effluent limitation in the permit or controls a pollutant not limited in the NPDES Permit, the Agency shall revise or modify the permit in accordance with the more stringent standard or prohibition and shall so notify the permittee.

Special Condition No. 8: The permittee shall notify the Agency in writing by certified mail within thirty days of abandonment, cessation, or suspension of active mining for thirty days or more unless caused by a labor dispute. During cessation or suspension of active mining, whether caused by a labor dispute or not, the permittee shall provide whatever interim impoundment, drainage diversion, and wastewater treatment is necessary to avoid violations of the Act or Subtitle D Regulations.

Special Conditions

Special Condition No. 9: Plans must be submitted to and approved by this Agency prior to construction of any future sedimentation ponds. At such time as runoff water is collected in the sedimentation pond, a sample shall be collected and analyzed for the parameters designated as 1M-15M under Part 5-C of Form 2C and the effluent parameters designated herein with the results sent to this Agency. Should additional treatment be necessary to meet these standards, a Supplemental Permit must also be obtained. Discharge from a pond is not allowed unless applicable effluent and water quality standards are met.

Special Condition No. 10: The special reclamation area effluent standards of 35 Ill. Adm. Code 406.109 apply only on approval from the Agency. To obtain approval, a request form and supporting documentation shall be submitted to request the discharge be classified as a reclamation area discharge. The Agency will notify the permittee upon approval of the change.

Special Condition No. 11: The special stormwater effluent standards apply only on approval from the Agency. To obtain approval, a request with supporting documentation shall be submitted to request the discharge to be classified as a stormwater discharge. The documentation supporting the request shall include analysis results indicating the discharge will consistently comply with reclamation area discharge effluent standards. The Agency will notify the permittee upon approval of the change.

Special Condition No. 12: Annual stormwater monitoring is required for all discharges not tributary to a sediment basin until Final SMCRA Bond is released and approval to cease such monitoring is obtained from the Agency.

a. Each discharge must be monitored for pH and settleable solids annually.

b. Analysis of samples must be submitted with second quarter Discharge Monitoring Reports. A map with discharge locations must be included in this submittal.

c. If discharges can be shown to be similar, a plan may be submitted by November 1 of each year preceding sampling to propose grouping of similar discharges and/or update previously submitted groupings. If updating of a previously submitted plan is not necessary, a written notification to the Agency indicating such is required. Upon approval from the Agency, one representative sample for each group may be submitted.

Special Condition No. 13: Sediment Pond Operation and Maintenance (Outfalls 001, 002, 003, 004, 005, 006, 007 and 008):

a. For discharges resulting from precipitation events, in addition to the alternate effluent (Discharge Condition Nos. II and III) monitoring requirements, as indicated on the applicable effluent pages of this Permit, discharges from Outfalls 001, 002, 003, 004, 005, 006, 007, 008 shall be monitored and reported for Discharge Rate, Sulfate, Chloride and Hardness.

b. The following sampling and monitoring requirements are applicable to flow in the unnamed tributary to Pond Creek which receive discharges from Outfalls 001, 002, 003, 004, 005, 006, 007, 008.

   i. All sampling and monitoring required under 13(b)(ii) and (iii) below shall be performed during a discharge and monitoring event from the associated outfall.

   ii. Unnamed tributary to Pond Creek shall be monitored and reported quarterly for Discharge Rate, Chloride, Sulfate and Hardness downstream of the associated outfall. This downstream monitoring shall be performed a sufficient distance downstream of the associated outfall to ensure that complete mixing has occurred. At such time that sufficient information has been collected regarding receiving stream flow characteristics and in-stream contaminant concentrations the permittee may request a re-evaluation of the monitoring frequency required herein for possible reduction or elimination. For the purpose of re-evaluating the downstream monitoring frequency of the receiving stream, "sufficient information" is defined as a minimum of ten (10) quarterly sampling events.

   In the event that downstream monitoring of the receiving waters is eliminated during the term of this permit based on an evaluation of the quarterly data, a minimum of three (3) additional samples analyzed for the parameters identified above must be submitted with the permit renewal application a minimum of 180 days prior to expiration of this permit.

   iii. Unnamed tributary to Pond Creek shall be monitored and reported annually for Discharge Rate, Chloride, Sulfate and Hardness upstream of the associated outfall.

Special Condition No. 14: The Permittee shall install and operate a 1.0 MGD (million gallon per day) reverse osmosis (RO) unit with operation to begin no later than December 31, 2023.

a. The RO permeate (treated water) will discharge though Outfalls 001 thru 008. Discharge may be through any single or combination of multiple outfalls at any given time.

b. The RO reject will discharge to the Big Muddy River through Outfall 011.

Special Conditions

Special Condition No. 15: Sediment Pond Operation and Maintenance (Outfall 011):

a. Pursuant to 35 Ill. Adm. Code Part 302.102, discharges from the referenced outfalls that otherwise would not meet the water quality standards of 35 Ill. Adm. Code Part 302 may be permitted if sufficient flow exists in the receiving stream to ensure that applicable water quality standards are met. That is, discharges not meeting the water quality standards of 35 Ill. Adm. Code Part 302 may only be discharged at such times that sufficient flow exists in the receiving stream to ensure that water quality standards in the receiving stream beyond the area of allowed mixing will not be exceeded. The permittee shall determine the effluent limitation for chloride and/or the maximum effluent flow rate allowable to maintain water quality in the receiving stream. The following equations shall be used to make such determinations:

$$C_{DS} = [C_E Q_E + 0.25 C_{US} Q_{US}]/ (0.25 Q_{US} + Q_E)$$

Where:

C_E = Effluent concentration (mg/L)

Q_E = Effluent flow rate (cfs) for Outfall 011

Q_{US} = Upstream flow rate (cfs)

C_{US} = Upstream concentration (mg/L)

C_{DS} = Downstream concentration

The "calculated" downstream concentration (C_{DS}) shall be less than 500 mg/L for chloride and reported on the discharge monitoring reports (DMRs).

Chloride is limited in the NPDES permit at the limits described below. The maximum flow from Outfall 011 is 5,000 gpm and the maximum chloride concentration is 5,000 mg/L.

Sulfate, chloride and Iron (dissolved) shall be monitored from the effluent three (3) times per week when discharging.

The maximum dispersion required for all water quality parameters is 13.3:1. Model predictions have been made for a maximum effluent total flow rate of 11.1 cfs. At the maximum chloride concentration of 5,000 mg/L, this maximum discharge requires a river flow of 1,734 cfs to meet a dispersion of 13.3:1 in less than 25 % of the river volume. The maximum distance to meet the water quality standard for all scenarios is 46 feet downstream with a plume width of 25 feet.

The zone of initial dilution for Ports 1 and 2 has a length of 4.5 feet by a width of 1.12 feet each. The zone of initial dilution for Port 3 has a length of 5.68 feet by a width of 1.38 feet. The zone of initial dilution for Port 4 has a length of 7.64 feet by a width of 1.97 feet. The zone of initial dilution for Port 5 has a length of 9.18 feet by a width of 2.23 feet. The mixing zone has a length of 46 feet by a width of 25 feet.

The permit allows discharge from Outfall 011 when the Big Muddy River is between 30 to 2350 cfs, except after a 1-year, 24-hour precipitation event, Outfall 011 can discharge for 6 consecutive days. The 1-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

The upstream flow (Q_{US}) should be based on the full flow measurement upstream of the proposed Outfall 011 that shall be approved by the Agency.

Flow & chloride concentrations should be available for the inspector during inspections.

The upstream and downstream conductivity monitoring locations need to be approved by the Agency.

The permittee shall install a conductivity monitor upstream of the discharge to determine a chloride concentration (C_{US}) correlated to the conductivity value. In addition, the permittee shall install a continuous conductivity monitor located within ten (10) feet of the edge of the mixing zone downstream of Outfall 011 to ensure that the chloride concentration (correlated to the conductivity value) stays within the chloride water quality standard. The daily maximum downstream chloride concentration controlled to conductivity shall be reported on the DMR's.

Monthly chloride samples and conductivity measurements, in the Big Muddy River (upstream and downstream) and in the effluent is required to ensure that the calibration curves remain accurate. The calibration curves should be approved by the Agency before discharge, after six months of operation, and yearly thereafter.

Outfall 011 should include signage on the bank of the Big Muddy River to inform people on the Big Muddy River that the outfall is present.

A mussel survey and a macroinvertebrate survey is required 1 year after commencement of the discharge from Outfall 011, during the next sampling period.

The pipeline should be constructed with the new material, pressure control sensors (or other type of equipment) to stop the pumps when there is a loss of pressure in the pipeline should be installed. Inspection reports of the pipeline should be available to the Agency's inspector when requested.

b. The following sampling and monitoring requirements are applicable to flow in Big Muddy River, which receives the discharges from Outfall 011.

   i. All sampling and monitoring required under 15(b)(ii) and (iii) below shall be performed during a discharge and monitoring event from the associated outfall.

   ii. The Big Muddy River shall be monitored and reported quarterly for Discharge Rate, Sulfate, Chloride and Hardness downstream of the associated outfall. This downstream monitoring shall be performed a sufficient distance downstream of the associated outfall to ensure that complete mixing has occurred. At such time that sufficient information has been collected regarding stream flow characteristics and in-stream contaminant concentrations, the permittee may request a re-evaluation of the monitoring frequency required herein for possible reduction or elimination. For the purpose of re-evaluating the downstream monitoring frequency of the receiving stream, "sufficient information" is defined as a minimum of ten (10) quarterly sampling events.

   In the event that downstream monitoring of the receiving waters is eliminated during the term of this permit based on an evaluation of the quarterly data, a minimum of three (3) additional samples analyzed for the parameters identified above must be submitted with the permit renewal application a minimum of 180 days prior to expiration of this permit.

   iii. The Big Muddy River shall be monitored and reported annually for Discharge Rate, Sulfate, Chloride and Hardness upstream of the associated outfall.

Special Condition No. 16: Outfall 011 downstream monitoring.

a. A continuous conductivity monitor (correlated to chloride) shall be installed within 10 feet downstream of the edge of the mixing zone.

b. The facility shall collect three samples per week from the receiving stream of Sulfate, Nickel, Copper, and Iron (dissolved) within 10 feet downstream of the edge of the mixing zone.

c. If the measured concentration of Chloride, at the downstream monitoring location, exceeds 700 mg/l (this equals 40% over the water quality standard) more than 20 percent of the time in any month, the discharge from Outfall 011 shall cease until the water quality standard can be met within the mixing zone.

d. If the water quality standard, based on a hardness of 91 mg/L as $CaCO_3$, for Sulfate and Iron (dissolved) exceeds the numbers below at the downstream monitoring location, in more than 3 of the samples taken within the month, the discharge from Outfall 011 shall cease until the water quality standards can be met within the mixing zone.

   i. Sulfate = 700 mg/l (this is 40% over the WQS)

   ii. Iron (dissolved) = 1.4 mg/l (this is 40% over the WQS)

e. If the water quality standard, based on a hardness of 91 mg/L as $CaCO_3$, for Copper (dissolved) and Nickel (dissolved) exceeds the numbers below at the downstream monitoring location, by 20 percent* in more than 3 of the samples taken within the month, the discharge from Outfall 011 shall cease until the water quality standards can be met within the mixing zone.

   i. Copper (dissolved) = 0.0126 mg/l (this is 20% over the WQS)

   ii. Nickel (dissolved) = 0.0055 mg/l (this is 20% over the WQS)

Special Condition No. 17: Data collected in accordance with Special Condition Nos. 13 and 15 above will be utilized to evaluate the appropriateness of the effluent limits established in this Permit. Should the Agency's evaluation of this data indicate revised effluent limits are warranted; this permit may be reopened and modified to incorporate more appropriate effluent limitations. This data will also be used for determination of effluent limitations at the time of permit renewal.

Special Conditions

Special Condition No. 18: Discharges from Outfalls 006, 007, 008 and 011 shall be monitored once per month for the first year and then twice annually spaced at approximately every 6-month apart for the remaining 5-year term of this NPDES Permit. Sampling of the discharges shall be performed utilizing the grab sampling method and analyzed for total (unfiltered) concentrations. The results of the sampling required under this Special Condition shall be submitted twice annually to the Agency in January and July of each calendar year to the addresses indicated in the Special Condition No. 3 above. The parameters to be sampled and the detection limits (minimum reported limits) are as follows:

Parameter	Detection Limit
Arsenic	0.05 mg/L
Barium	0.50 mg/L
Cadmium	0.001 mg/L
Chromium (hexavalent)	0.01 mg/L
Chromium	0.05 mg/L
Copper	0.005 mg/L
Lead	0.05 mg/L
Manganese	0.50 mg/L
Mercury*	1.00 ng/l**
Nickel	0.005 mg/L
Phenols	0.005 mg/L
Selenium	2.000 µg/l***
Silver	0.003 mg/L
Zinc	0.025 mg/L

* Utilize USEPA Method 1631E and the digestion procedure described in Section 11.1.1.2 of 1631E.
** 1.00 ng/l (nanogram/liter) = 1 part per trillion.
*** µg/l = micrograms/liter

Attachment H

Standard Conditions

Definitions

Act means the Illinois Environmental Protection Act, 415 ILCS 5 as Amended.

Agency means the Illinois Environmental Protection Agency.

Board means the Illinois Pollution Control Board.

Clean Water Act (formerly referred to as the Federal Water Pollution Control Act) means Pub. L 92-500, as amended. 33 U.S.C. 1251 et seq.

NPDES (National Pollutant Discharge Elimination System) means the national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements, under Sections 307, 402, 318 and 405 of the Clean Water Act.

USEPA means the United States Environmental Protection Agency.

Daily Discharge means the discharge of a pollutant measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling. For pollutants with limitations expressed in units of mass, the "daily discharge" is calculated as the total mass of the pollutant discharged over the day. For pollutants with limitations expressed in other units of measurements, the "daily discharge" is calculated as the average measurement of the pollutant over the day.

Maximum Daily Discharge Limitation (daily maximum) means the highest allowable daily discharge.

Average Monthly Discharge Limitation (30 day average) means the highest allowable average of daily discharges over a calendar month, calculated as the sum of all daily discharges measured during a calendar month divided by the number of daily discharges measured during that month.

Average Weekly Discharge Limitation (7 day average) means the highest allowable average of daily discharges over a calendar week, calculated as the sum of all daily discharges measured during a calendar week divided by the number of daily discharges measured during that week.

Best Management Practices (BMPs) means schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the State. BMPs also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Aliquot means a sample of specified volume used to make up a total composite sample.

Grab Sample means an individual sample of at least 100 milliliters collected at a randomly-selected time over a period not exceeding 15 minutes.

24-Hour Composite Sample means a combination of at least 8 sample aliquots of at least 100 milliliters, collected at periodic intervals during the operating hours of a facility over a 24-hour period.

8-Hour Composite Sample means a combination of at least 3 sample aliquots of at least 100 milliliters, collected at periodic intervals during the operating hours of a facility over an 8-hour period.

Flow Proportional Composite Sample means a combination of sample aliquots of at least 100 milliliters collected at periodic intervals such that either the time interval between each aliquot or the volume of each aliquot is proportional to either the stream flow at the time of sampling or the total stream flow since the collection of the previous aliquot.

(1) **Duty to comply**. The permittee must comply with all conditions of this permit. Any permit noncompliance constitutes a violation of the Act and is grounds for enforcement action, permit termination, revocation and reissuance, modification, or for denial of a permit renewal application. The permittee shall comply with effluent standards or prohibitions established under Section 307(a) of the Clean Water Act for toxic pollutants within the time provided in the regulations that establish these standards or prohibitions, even if the permit has not yet been modified to incorporate the requirements.

(2) **Duty to reapply**. If the permittee wishes to continue an activity regulated by this permit after the expiration date of this permit, the permittee must apply for and obtain a new permit. If the permittee submits a proper application as required by the Agency no later than 180 days prior to the expiration date, this permit shall continue in full force and effect until the final Agency decision on the application has been made.

(3) **Need to halt or reduce activity not a defense**. It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

(4) **Duty to mitigate**. The permittee shall take all reasonable steps to minimize or prevent any discharge in violation of this permit which has a reasonable likelihood of adversely affecting human health or the environment.

(5) **Proper operation and maintenance**. The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with conditions of this permit. Proper operation and maintenance includes effective performance, adequate funding, adequate operator staffing and training, and adequate laboratory and process controls, including appropriate quality assurance procedures. This provision requires the operation of back-up, or auxiliary facilities, or similar systems only when necessary to achieve compliance with the conditions of the permit.

(6) **Permit actions**. This permit may be modified, revoked and reissued, or terminated for cause by the Agency pursuant to 40 CFR 122.62 and 40 CFR 122.63. The filing of a request by the permittee for a permit modification, revocation and reissuance, or termination, or a notification of planned changes or anticipated noncompliance, does not stay any permit condition.

(7) **Property rights**. This permit does not convey any property rights of any sort, or any exclusive privilege.

(8) **Duty to provide information**. The permittee shall furnish to the Agency within a reasonable time, any information which the Agency may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit, or to determine compliance with the permit. The permittee shall also furnish to the Agency upon request, copies of records required to be kept by this permit.

(9) **Inspection and entry**. The permittee shall allow an authorized representative of the Agency or USEPA (including an authorized contractor acting as a representative of the Agency or USEPA), upon the presentation of credentials and other documents as may be required by law, to:

(a) Enter upon the permittee's premises where a regulated facility or activity is located or conducted, or where records

must be kept under the conditions of this permit;

(b) Have access to and copy, at reasonable times, any records that must be kept under the conditions of this permit;

(c) Inspect at reasonable times any facilities, equipment (including monitoring and control equipment), practices, or operations regulated or required under this permit; and

(d) Sample or monitor at reasonable times, for the purpose of assuring permit compliance, or as otherwise authorized by the Act, any substances or parameters at any location.

(10) **Monitoring and records**.

(a) Samples and measurements taken for the purpose of monitoring shall be representative of the monitored activity.

(b) The permittee shall retain records of all monitoring information, including all calibration and maintenance records, and all original strip chart recordings for continuous monitoring instrumentation, copies of all reports required by this permit, and records of all data used to complete the application for this permit, for a period of at least 3 years from the date of this permit, measurement, report or application. Records related to the permittee's sewage sludge use and disposal activities shall be retained for a period of at least five years (or longer as required by 40 CFR Part 503). This period may be extended by request of the Agency or USEPA at any time.

(c) Records of monitoring information shall include:

(1) The date, exact place, and time of sampling or measurements;

(2) The individual(s) who performed the sampling or measurements;

(3) The date(s) analyses were performed;

(4) The individual(s) who performed the analyses;

(5) The analytical techniques or methods used; and

(6) The results of such analyses.

(d) Monitoring must be conducted according to test procedures approved under 40 CFR Part 136, unless other test procedures have been specified in this permit. Where no test procedure under 40 CFR Part 136 has been approved, the permittee must submit to the Agency a test method for approval. The permittee shall calibrate and perform maintenance procedures on all monitoring and analytical instrumentation at intervals to ensure accuracy of measurements.

(11) **Signatory requirement**. All applications, reports or information submitted to the Agency shall be signed and certified.

(a) **Application**. All permit applications shall be signed as follows:

(1) For a corporation: by a principal executive officer of at least the level of vice president or a person or position having overall responsibility for environmental matters for the corporation:

(2) For a partnership or sole proprietorship: by a general partner or the proprietor, respectively; or

(3) For a municipality, State, Federal, or other public agency: by either a principal executive officer or ranking elected official.

(b) **Reports**. All reports required by permits, or other information requested by the Agency shall be signed by a person described in paragraph (a) or by a duly authorized representative of that person. A person is a duly authorized representative only if:

(1) The authorization is made in writing by a person described in paragraph (a); and

(2) The authorization specifies either an individual or a position responsible for the overall operation of the facility, from which the discharge originates, such as a plant manager, superintendent or person of equivalent responsibility; and

(3) The written authorization is submitted to the Agency.

(c) **Changes of Authorization**. If an authorization under (b) is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, a new authorization satisfying the requirements of (b) must be submitted to the Agency prior to or together with any reports, information, or applications to be signed by an authorized representative.

(d) **Certification**. Any person signing a document under paragraph (a) or (b) of this section shall make the following certification:

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

(12) **Reporting requirements**.

(a) **Planned changes**. The permittee shall give notice to the Agency as soon as possible of any planned physical alterations or additions to the permitted facility.
Notice is required when:

(1) The alteration or addition to a permitted facility may meet one of the criteria for determining whether a facility is a new source pursuant to 40 CFR 122.29 (b); or

(2) The alteration or addition could significantly change the nature or increase the quantity of pollutants discharged. This notification applies to pollutants which are subject neither to effluent limitations in the permit, nor to notification requirements pursuant to 40 CFR 122.42 (a)(1).

(3) The alteration or addition results in a significant change in the permittee's sludge use or disposal practices, and such alteration, addition, or change may justify the application of permit conditions that are different from or absent in the existing permit, including notification of additional use or disposal sites not reported during the permit application process or not reported pursuant to an approved land application plan.

(b) **Anticipated noncompliance**. The permittee shall give advance notice to the Agency of any planned changes in the permitted facility or activity which may result in noncompliance with permit requirements.

(c) **Transfers**. This permit is not transferable to any person except after notice to the Agency.

(d) **Compliance schedules**. Reports of compliance or noncompliance with, or any progress reports on, interim and final requirements contained in any compliance schedule of this permit shall be submitted no later than 14 days following each schedule date.

(e) **Monitoring reports**. Monitoring results shall be reported at the intervals specified elsewhere in this permit.

(1) Monitoring results must be reported on a Discharge Monitoring Report (DMR).

(2) If the permittee monitors any pollutant more frequently than required by the permit, using test procedures approved under 40 CFR 136 or as specified in the permit, the results of this monitoring shall be included in the calculation and reporting of the data submitted in the DMR.

(3) Calculations for all limitations which require averaging of measurements shall utilize an arithmetic mean unless otherwise specified by the Agency in the permit.

(f) **Twenty-four hour reporting**. The permittee shall report any noncompliance which may endanger health or the environment. Any information shall be provided orally within 24-hours from the time the permittee becomes aware of the circumstances. A written submission shall also be provided within 5 days of the time the permittee becomes aware of the circumstances. The written submission shall contain a description of the noncompliance and its cause; the period of noncompliance, including exact dates and time; and if the noncompliance has not been corrected, the anticipated time it is expected to continue; and steps taken or planned to reduce, eliminate, and prevent reoccurrence of the noncompliance. The following shall be included as information which must be reported within 24-hours:

(1) Any unanticipated bypass which exceeds any effluent limitation in the permit.

(2) Any upset which exceeds any effluent limitation in the permit.

(3) Violation of a maximum daily discharge limitation for any of the pollutants listed by the Agency in the permit or any pollutant which may endanger health or the environment.

The Agency may waive the written report on a case-by-case basis if the oral report has been received within 24-hours.

(g) **Other noncompliance**. The permittee shall report all instances of noncompliance not reported under paragraphs (12) (d), (e), or (f), at the time monitoring reports are submitted. The reports shall contain the information listed in paragraph (12) (f).

(h) **Other information**. Where the permittee becomes aware that it failed to submit any relevant facts in a permit application, or submitted incorrect information in a permit application, or in any report to the Agency, it shall promptly submit such facts or information.

(13) **Bypass**.

(a) Definitions.

(1) Bypass means the intentional diversion of waste streams from any portion of a treatment facility.

(2) Severe property damage means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production.

(b) Bypass not exceeding limitations. The permittee may allow any bypass to occur which does not cause effluent limitations to be exceeded, but only if it also is for essential maintenance to assure efficient operation. These bypasses are not subject to the provisions of paragraphs (13)(c) and (13)(d).

(c) Notice.

(1) Anticipated bypass. If the permittee knows in advance of the need for a bypass, it shall submit prior notice, if possible at least ten days before the date of the bypass.

(2) Unanticipated bypass. The permittee shall submit notice of an unanticipated bypass as required in paragraph (12)(f) (24-hour notice).

(d) Prohibition of bypass.

(1) Bypass is prohibited, and the Agency may take enforcement action against a permittee for bypass, unless:

(i) Bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;

(ii) There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance; and

(iii) The permittee submitted notices as required under paragraph (13)(c).

(2) The Agency may approve an anticipated bypass, after considering its adverse effects, if the Agency determines that it will meet the three conditions listed above in paragraph (13)(d)(1).

(14) **Upset**.

(a) Definition. Upset means an exceptional incident in which there is unintentional and temporary noncompliance with technology based permit effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

(b) Effect of an upset. An upset constitutes an affirmative defense to an action brought for noncompliance with such technology based permit effluent limitations if the requirements of paragraph (14)(c) are met. No determination made during administrative review of claims that noncompliance was caused by upset, and before an action for noncompliance, is final administrative action subject to judicial review.

(c) Conditions necessary for a demonstration of upset. A permittee who wishes to establish the affirmative defense of upset shall demonstrate, through properly signed, contemporaneous operating logs, or other relevant evidence that:

(1) An upset occurred and that the permittee can identify the cause(s) of the upset;

(2) The permitted facility was at the time being properly operated; and

(3) The permittee submitted notice of the upset as required in paragraph (12)(f)(2) (24-hour notice).

(4) The permittee complied with any remedial measures required under paragraph (4).

(d) Burden of proof. In any enforcement proceeding the permittee seeking to establish the occurrence of an upset has the burden of proof.

(15) **Transfer of permits.** Permits may be transferred by modification or automatic transfer as described below:
  (a) Transfers by modification. Except as provided in paragraph (b), a permit may be transferred by the permittee to a new owner or operator only if the permit has been modified or revoked and reissued pursuant to 40 CFR 122.62 (b) (2), or a minor modification made pursuant to 40 CFR 122.63 (d), to identify the new permittee and incorporate such other requirements as may be necessary under the Clean Water Act.
  (b) Automatic transfers. As an alternative to transfers under paragraph (a), any NPDES permit may be automatically transferred to a new permittee if:
    (1) The current permittee notifies the Agency at least 30 days in advance of the proposed transfer date;
    (2) The notice includes a written agreement between the existing and new permittees containing a specified date for transfer of permit responsibility, coverage and liability between the existing and new permittees; and
    (3) The Agency does not notify the existing permittee and the proposed new permittee of its intent to modify or revoke and reissue the permit. If this notice is not received, the transfer is effective on the date specified in the agreement.

(16) All manufacturing, commercial, mining, and silvicultural dischargers must notify the Agency as soon as they know or have reason to believe:
  (a) That any activity has occurred or will occur which would result in the discharge of any toxic pollutant identified under Section 307 of the Clean Water Act which is not limited in the permit, if that discharge will exceed the highest of the following notification levels:
    (1) One hundred micrograms per liter (100 ug/l);
    (2) Two hundred micrograms per liter (200 ug/l) for acrolein and acrylonitrile; five hundred micrograms per liter (500 ug/l) for 2,4-dinitrophenol and for 2-methyl-4,6 dinitrophenol; and one milligram per liter (1 mg/l) for antimony.
    (3) Five (5) times the maximum concentration value reported for that pollutant in the NPDES permit application; or
    (4) The level established by the Agency in this permit.
  (b) That they have begun or expect to begin to use or manufacture as an intermediate or final product or byproduct any toxic pollutant which was not reported in the NPDES permit application.

(17) All Publicly Owned Treatment Works (POTWs) must provide adequate notice to the Agency of the following:
  (a) Any new introduction of pollutants into that POTW from an indirect discharge which would be subject to Sections 301 or 306 of the Clean Water Act if it were directly discharging those pollutants; and
  (b) Any substantial change in the volume or character of pollutants being introduced into that POTW by a source introducing pollutants into the POTW at the time of issuance of the permit.
  (c) For purposes of this paragraph, adequate notice shall include information on (i) the quality and quantity of effluent introduced into the POTW, and (ii) any anticipated impact of the change on the quantity or quality of effluent to be discharged from the POTW.

(18) If the permit is issued to a publicly owned or publicly regulated treatment works, the permittee shall require any industrial user of such treatment works to comply with federal requirements concerning:
  (a) User charges pursuant to Section 204 (b) of the Clean Water Act, and applicable regulations appearing in 40 CFR 35;
  (b) Toxic pollutant effluent standards and pretreatment standards pursuant to Section 307 of the Clean Water Act; and
  (c) Inspection, monitoring and entry pursuant to Section 308 of the Clean Water Act.

(19) If an applicable standard or limitation is promulgated under Section 301(b)(2)(C) and (D), 304(b)(2), or 307(a)(2) and that effluent standard or limitation is more stringent than any effluent limitation in the permit, or controls a pollutant not limited in the permit, the permit shall be promptly modified or revoked, and reissued to conform to that effluent standard or limitation.

(20) Any authorization to construct issued to the permittee pursuant to 35 Ill. Adm. Code 309.154 is hereby incorporated by reference as a condition of this permit.

(21) The permittee shall not make any false statement, representation or certification in any application, record, report, plan or other document submitted to the Agency or the USEPA, or required to be maintained under this permit.

(22) The Clean Water Act provides that any person who violates a permit condition implementing Sections 301, 302, 306, 307, 308, 318, or 405 of the Clean Water Act is subject to a civil penalty not to exceed $25,000 per day of such violation. Any person who willfully or negligently violates permit conditions implementing Sections 301, 302, 306, 307, 308, 318 or 405 of the Clean Water Act is subject to a fine of not less than $2,500 nor more than $25,000 per day of violation, or by imprisonment for not more than one year, or both.
Additional penalties for violating these sections of the Clean Water Act are identified in 40 CFR 122.41 (a)(2) and (3).

(23) The Clean Water Act provides that any person who falsifies, tampers with, or knowingly renders inaccurate any monitoring device or method required to be maintained under this permit shall, upon conviction, be punished by a fine of not more than $10,000, or by imprisonment for not more than 2 years, or both. If a conviction of a person is for a violation committed after a first conviction of such person under this paragraph, punishment is a fine of not more than $20,000 per day of violation, or by imprisonment of not more than 4 years, or both.

(24) The Clean Water Act provides that any person who knowingly makes any false statement, representation, or certification in any record or other document submitted or required to be maintained under this permit, including monitoring reports or reports of compliance or non-compliance shall, upon conviction, be punished by a fine of not more than $10,000 per violation, or by imprisonment for not more than 6 months per violation, or by both.

(25) Collected screening, slurries, sludges, and other solids shall be disposed of in such a manner as to prevent entry of those wastes (or runoff from the wastes) into waters of the State. The proper authorization for such disposal shall be obtained from the Agency and is incorporated as part hereof by reference.

(26) In case of conflict between these standard conditions and any other condition(s) included in this permit, the other condition(s) shall govern.

(27) The permittee shall comply with, in addition to the requirements of the permit, all applicable provisions of 35 Ill. Adm. Code, Subtitle C, Subtitle D, Subtitle E, and all applicable orders of the Board or any court with jurisdiction.

(28) The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit is held invalid, the remaining provisions of this permit shall continue in full force and effect.

(Rev. 7-9-2010 bah)

DOCUMENT

2

Williamson Energy, LLC
Pond Creek Mine No. 1

National Pollutant Discharge Elimination System (NPDES) Permit
Responsiveness Summary

Regarding

December 18, 2019 Public Hearing

Illinois Environmental Protection Agency
Office of Community Relations
April 15, 2022

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Final April 15, 2022

Illinois Environmental Protection Agency

Williamson Energy, LLC
Pond Creek Mine No. 1
NPDES Permit
Permit Number IL0077666

Illinois EPA Permit Decision

On April 15, 2022, the Illinois Environmental Protection Agency (Illinois EPA, IEPA, or Agency) approved a NPDES permit for Williamson Energy, LLC Pond Creek Mine No. 1.

The draft NPDES permit was public noticed on July 12, 2019 and placed on the Illinois EPA public notice webpage. On October 30, 2019, the hearing notice was posted and on January 13, 2020, the hearing transcript was posted. These documents are available at (enter IL0077666 into the search above the "Posting Date"):
https://www2.illinois.gov/epa/public-notices/Pages/npdes-individual-notices.aspx

The following changes have been made to the draft permit that was placed on public notice on July 12, 2019:

1. **Special Condition No. 14 was added to require the permittee to install and operate a 1.0 million gallons per day (MGD) reverse osmosis (RO) unit by December 31, 2023:**
    a. **The RO permeate (treated water) will discharge through Outfalls 001-008.**
    b. **The RO reject will discharge to the Big Muddy River through Outfall 011.**
2. **Proposed Outfalls 009 and 009ES have been removed due to the impaired status of Pond Creek.**
3. **Special Condition No. 15 has been added to require the following conditions relative to Outfall 011:**
    a. **Posting of signs on the bank of Big the Muddy River to notify the public of the existence and location of Outfall 011.**
    b. **Chloride and conductivity monitoring of Outfall 011 effluent and in the Big Muddy River (upstream and downstream) to confirm and ensure validity of calibration curves. Calibration curves are also required to be approved periodically by the Agency as outlined in the NPDES permit condition No. 15.**
    c. **A requirement that sulfate, iron (dissolved) and chloride monitoring of Outfall 011 effluent be performed three (3) times per week when the outfall is discharging.**
    d. **Requires a mussel survey and a macroinvertebrate survey approximately one year following initial discharge from Outfall 011.**
    e. **Verifies the mixing zone and zone of initial dilution (ZID) for the multi-port diffuser.**
    f. **Specifies precipitation event and Big Muddy River flow condition restrictions for discharges from Outfall 011.**

g. Requires flow and chloride concentration data to be available for review during inspections by Illinois EPA and Illinois Department of Natural Resources (IDNR) staff.
h. Requires the pipeline system to include pressure control sensors (or similar type of equipment) to stop pumps in the event of loss of pressure.
i. Requires pipeline inspections be made available to Agency personnel during site inspections.
j. Reduced the maximum chloride concentration at Outfall 011 from 12,000 mg/L to 5,000 mg/L. This change affected the following:
    a. Reduced the dilution ratio needed from 34:1 to 13.3:1.
    b. reduced the length of the mixing zone from 251 feet to 46 feet.

4. A yearly average concentration limit of 32.2 mg/L for TSS (total suspended solids) is applied to discharges from Outfall 011 to the Big Muddy River as indicated on the effluent page of the permit for this outfall.
5. Limits for additional parameters are included in the permit for specified Outfalls as follows:
    a. Mercury limits required for discharges from Outfall 001
    b. Copper and nickel limits required for discharges from Outfall 002
    c. Iron (dissolved) limits required for discharges from Outfall 003
    d. Copper limits required for discharges from Outfall 004
    e. Nickel limits required for discharges from Outfall 006
    f. Iron (dissolved), nickel and zinc limits required for discharges from Outfall 007
    g. Cadmium, copper, nickel and zinc limits required for discharges from Outfall 008
6. Special Condition No. 18 was added to require discharges from Outfalls 006, 007, and 008, into Pond Creek, and Outfall 011, into the Big Muddy River, include metals monitoring at a frequency of once per month for the first year and then twice annually spaced approximately every six months apart for the remainder of the permit term.
7. Special Condition No. 16 has been added to require the following conditions relative to monitoring the Big Muddy River downstream of Outfall 011:
    a. Continuous monitoring of Outfall 011 at a point within 10 feet of edge of mixing zone.
    b. Monitoring of Outfall 011 for sulfate, iron (dissolved), copper, and nickel three times per week at a point within 10 feet of edge of mixing zone.
    c. The discharge from Outfall 011 must cease under the following conditions until the water quality standard can be met in the mixing zone:
        i. When the continuous chloride data (as measured by conductivity) is 40 percent above the chloride water quality standard more than 20 percent of the time.
        ii. When the sulfate samples are 40 percent above the sulfate water quality standard in more than 3 of the samples taken within the month.

iii. **When the iron (dissolved) samples are 40 percent above the iron (dissolved) water quality standard in more than 3 of the samples taken within the month.**
iv. **When the copper samples are 20 percent above the copper water quality standard in more than 3 of the samples taken within the month.**
v. **When the nickel samples are 20 percent above the nickel water quality standard in more than 3 of the samples taken within the month.**

8. **The NPDES permit authorizes a discharge only when the Big Muddy River is between 30 cfs and 2,350 cfs, except after a one-year, 24-hour precipitation event, Outfall 011 can discharge for six consecutive days. The one-year, 24-hour precipitation event for this area is considered to be 2.97 inches.**

Pre-Hearing Public Outreach

The hearing notice was mailed or e-mailed to:

- Williamson & Franklin County officials;
- Municipal officials in Johnston City;
- Local, state and federal elected officials;
- Those on the NPDES public notice list; and
- Those who have requested to be notified of Bureau of Water hearings.

December 18, 2019 Public Hearing

Hearing Officer Christine Zeivel opened the hearing on December 18, 2019, 6:00 p.m. at Rent One Park Diamond Club, 1000 Miners Drive, Marion, Illinois. Comments and questions were received from the public. Hearing Officer Christine Zeivel closed the hearing at 9:34 pm on December 18, 2019.

Illinois EPA personnel were available before and during the hearing to meet with elected officials, news media, and concerned citizens. Approximately 185 people representing the permittee and environmental groups participated in or attended the public hearing. A court reporter prepared a transcript of the public hearing, which was posted January 13, 2020 on the Illinois EPA website. The hearing record remained open through January 17, 2020. The Illinois EPA hearing panel included the following Agency staff:

Christine Zeivel, Hearing Officer, Office of Community Relations
Iwona Ward, Permit Section, Bureau of Water
Darin LeCrone Permit Section, Bureau of Water
Scott Twait, Standards Section, Bureau of Water
Stefanie Diers, Division of Legal Counsel

Background of Williamson Energy, LLC Pond Creek Mine

The Illinois EPA Bureau of Water prepared a draft NPDES permit for Williamson Energy, LLC, whose corporate address is P.O. Box 300 Johnston City, Illinois 62951. The Pond Creek Mine is located four miles east of Johnston City, Illinois in Williamson and Franklin Counties.

Illinois EPA held this hearing for the purpose of receiving comments on the draft permit prior to taking final action on the permit application. Issues relevant to this proceeding included the antidegradation analysis and the applicant's compliance with the permitting requirements of the federal Clean Water Act and Subtitle C of Title 35 of the Illinois Administrative Code.

The applicant proposes additional surface facilities area to an existing underground coal mine (SIC 1222). Mine operations result in the discharge of alkaline and acid mine drainage. The following proposed modifications were incorporated into the public noticed Permit renewal: 1) one (1) new outfall designated as Outfall No. 011; 2) various mining operation and drainage control plan revisions; 3) 229.78 acres incorporated for new Refuse Disposal Area (RDA) No. 3; 4) 70.7 acres incorporated for the pipeline to the Big Muddy River; 5) 145.32 acres for various incidental boundary revisions (IBRs) for additional permit area; 6) bi-annual metals monitoring of discharges from Outfall Nos. 006, 007, 008, and 011; and 7) previously issued State Construction and Operating Permits (Subtitle D Permits).

Responses to Comments, Questions and Concerns

Comments, questions, and concerns are in regular text, and Illinois EPA responses are in bold text.

NPDES Permit

1. Why are they not required to monitor as close as possible to the edge of the designated mixing zone, which is the point of compliance?

   The NPDES permit requires the discharger to calculate the concentration at the edge of the mixing zone. Additionally, in order to verify the calculations at the edge of the mixing zone, the permit requires the discharger to install a conductivity meter downstream of the mixing zone. To address this concern, the permit has been modified to require the downstream continuous monitor to be located within 10 feet of the edge of the mixing zone.

   Special condition 15 (b)(ii) of the NPDES permit requires quarterly monitoring for discharge rate, sulfate, chloride and hardness at a location downstream where complete mixing of the receiving stream has occurred. However, this monitoring is not for compliance purposes, but to get sufficient data to calculate the sulfate WQS for the next permit cycle.

2. Why is Pond Creek Mine not included in the draft permit? It's a polluted tributary.

   See response to question #47.

3. What recourse do citizens have when they see a violation occurring and assume that risk of making a complaint, yet the polluters are allowed to bully us, the citizens, in silence? Are off-hour discharges a reoccurring problem with this mine? Why would there be no discharge monitoring report (DMR) since March of 2019?

   If a citizen has any information about a violation occurring, they may call the Illinois EPA office at 618-993-7200 and report a complaint anonymously.

   Based on the information that the Agency has, it is not believed that off-hour discharging is an issue. The Illinois EPA consistently receives notifications from the mine of discharge events where effluent may exceed permitted limits as required by the facility's NPDES permit. The Agency is currently proceeding through the enforcement process for effluent excursions.

   The NPDES permit does not restrict discharges to certain times of day since many discharges are in response to rainfall events which may occur at any time. Mine pumpage is generally from small water collection pits located within the underground operation that fill with groundwater and/or operational water and

must be pumped to the surface. For safety of workers and mine operations, this pumpage may be necessary at any time of day as groundwater enters the underground operation on a continual basis, 24-hours a day.

DMR data may be obtained under the Freedom of Information Act (FOIA) by visiting the Agency website at https://www2.illinois.gov/epa/foia/Pages/default.aspx to file an electronic request for information. Additionally, the DMR data can be found by going to the Enforcement and Compliance History Online (ECHO) system website, please see the response to question #11. For the response as to no discharge being reported since March of 2019, please see the response to question #22.

4. Does the Illinois EPA evaluate the company monitoring numbers they are sending or is the Agency seeing it live as it is being imputed? How is it being reported to you?

Monitoring results are reported on DMRs which are submitted quarterly to the Agency. The Agency runs monthly compliance reports using the Integrated Compliance Information System (ICIS)/ECHO to detect Significant Non-Compliance (SNC) of NPDES permits. ICIS/ECHO automatically detects violations such as DMR non-receipt, effluent limit violations, or delinquent schedules or reports. If a violation is identified as SNC, the Illinois EPA initiates the appropriate enforcement action, pursuant to Section 31 of the Illinois Environmental Protection Act (Act), to resolve the SNC violations.

5. The Sugar Camp Mine has had a permit approved to build a similar pipeline to the Big Muddy River. Do you know if that pipeline will be constructed?

Although outside the scope of this responsiveness summary, the following is provided for informational purposes only. The initial Sugar Camp application for the pipeline to the Big Muddy River received in December 2019 was deemed incomplete by IDNR Office of Mines and Minerals (OMM). The Applicant was notified of this determination and provided with a summary of additional information required for the permit to be deemed complete and the IDNR/OMM review to proceed. It is the Agency's understanding that at this time the OMM application has been deemed complete and the review is underway. Thus, a permit for the construction of the pipeline at Sugar Camp Mine has not yet been issued.

6. Why isn't Williamson Energy required to put up a bond for repairing damage that may be caused by their operations, that is damage to the Big Muddy River wildlife and the people who depend on the Big Muddy for recreation?

All bonding requirements are regulated by IDNR OMM in accordance with 62 Ill. Adm. Code Part 1800.

7. In 2004, the Big Muddy River Total Maximum Daily Load Report (TMDL) states that the Big Muddy River is compromised and impaired in part for mining operations. The 2019 report again stated the same thing. Abandoned coal mines should be identified in addition to other mining activities which contribute to manganese and sulfate concentrations, which is exactly what the violations are for this company. Is the Illinois EPA going against its own implementation plans by considering granting a permit for a pipeline which will infuse the river with more elevated levels of chlorides, sulfates, manganese and other pollutants? Does this not go against the Clean Water Act?

   The Big Muddy River TMDL Report (October 2004) evaluated sulfate and manganese impairments in the Big Muddy River (waterbody segment IL_N-12) and developed TMDLs based on the water quality standards (WQS) of 500 mg/L for sulfates and 1.0 mg/L for manganese. These WQS have been modified by the Illinois Pollution Control Board (IPCB or Board) since then.

   The IPCB promulgated the manganese WQS, based on hardness, in R2011-18 on November 15, 2012, and corrected for "dissolved" manganese in R2011-18(B) on May 16, 2013. The United States Environmental Protection Agency (USEPA) approved the manganese WQS on May 28, 2013.

   The IPCB also promulgated the sulfate WQS, based on hardness and chloride, in R2007-009 on September 4, 2008. USEPA approved the sulfate WQS and removal of the total dissolved solids (TDS) WQS on March 19, 2009.

   The Illinois Environmental Protection Act (Act) and the Board regulations require that the Agency consider the current promulgated WQS in issuing NPDES permits.

   Consistent with R2011-18(B), based on the critical hardness of 145 mg/L at Ambient Water Quality Monitoring Network (AWQMN) station N-12, the Agency calculated an acute and chronic WQS for manganese at 5.62 mg/L and 2.39 mg/L, respectively.

   In drafting the permit, the Agency reviewed the water quality data for waterbody Segment N-11 and found that, from January 2000 to January 2020, there have been no exceedances of the updated WQS for manganese. The highest manganese result of 2.56 mg/L was taken on September 13, 2010. The second highest manganese result of 1.5 mg/L was taken on July 26, 2007. The NPDES permit has a manganese limit at the effluent standard of 2.0 mg/L as a 30-day average and 4.0 mg/L as a daily maximum, therefore, the effluent will meet the current manganese WQS.

   Similarly, consistent with R2007-009, based on the critical hardness of 145 mg/L and an average chloride of 38.33 at AWQMN station N-12, the Agency calculated a WQS at 1,312 mg/L for sulfate.

In drafting the permit, the Agency reviewed the water quality data for waterbody Segment N-11 and found that, from January 2000 to January 2020, there have been no exceedances of the updated WQS for sulfate. The highest sulfate result of 809 mg/L was taken on September 30, 2003. The second highest sulfate result of 591 mg/L was taken on October 21, 2008.

The Upper Big Muddy TMDL Report (May 2019) evaluated fecal coliform, sedimentation/siltation, and sulfates for Waterbody Segment IL_N-11. The TMDL set a waste load allocation on those facilities that discharge effluents with fecal coliform. The discharge from Outfall 011 is below the water quality sampling station Waterbody Segment IL_N-11. Further, as the discharge from Outfall 011 is not a source of fecal coliform, no limit for fecal coliform was added in the permit.

The May 2019 TMDL prepared a load reduction strategy to address the sedimentation/siltation impairment, as there are no numeric WQS for these constituents. The Load Reduction Strategy (LRS) identified a target of 32.2 mg/L for TSS as an average concentration. The NPDES permit has been modified to incorporate a limit of 32.2 mg/L for Outfall 011, applied as a yearly average.

Further, data analysis as part of the Stage 3 TMDL/LRS preparation has indicated that sulfate impairment may not currently exist. Sulfate is not listed as an impairment in the 2018 Integrated Report.

Based on the discussion above, the sulfate, chloride and TSS limits in the permit does not conflict with the 2004 and 2019 TMDLs.

As part of the Upper Big Muddy TMDL Report (May 2019), an Implementation Plan titled - Watershed Implementation Plan To Achieve the TMDLs and Load Reduction Strategy in the Upper Big Muddy River Watershed has been developed and may be found in the last pages of the report. The information is available at: https://www2.illinois.gov/epa/topics/water-quality/watershed-management/tmdls/Pages/reports.aspx

8. In this decision-making has there been platforms made for the consideration of the indigenous people's values of this area?

The Illinois EPA is committed to protecting the health of the citizens of Illinois and its environment as well as promoting environmental equity. To this affect, the Illinois EPA had NPDES permit ILR10BK23 related to the 12-mile waterline project for Williamson Energy, reviewed by the State Historic Preservation Office (SHPO). SHPO reviewed the permit with the premise in protecting cultural issues, historic, architectural, and archaeological sites. The Illinois EPA supports the objectives of achieving environmental equity for all of the citizens of Illinois.

9. A lot of the information the Illinois EPA has looked at when making this decision is being compiled by the mining corporation itself. My question is, does the Illinois EPA find this data on its own or with other third parties in regard to the watershed analysis or water monitoring or is most of the data around this decision coming from the mine and what they've collected so far and continue to collect?

   The NPDES permitting program is a federal program delegated to the State. The program is based on the review of a permit application which includes sampling data and other information, provided by the applicant, to fully characterize the wastewater and the proposed discharges. The NPDES program also includes collection of samples by the permittee, and the self-reporting of results by the submission of DMRs to the Illinois EPA. However, in addition to data provided by the applicant/permittee, the Illinois EPA also utilizes data from its AWQMN stations on the Big Muddy River, both upstream and downstream of Outfall 011. The ambient stations are sampled for water quality approximately every six weeks. The ambient data was also utilized in the evaluation, analysis, and determination of applicable NPDES permit limits.

10. Does the Illinois EPA have any plans to conduct its own analysis? Things like the effluent that comes out and then does the Illinois EPA just do regular analyses and tests further on is its own. Will that be something that the Illinois EPA include as a point in future documents?

    The Agency typically collects samples at NPDES permitted facilities during routine mine inspections. These samples are analyzed by either the Agency laboratory or an outside third-party laboratory. IDNR also inspects the sites and periodically collects samples.

11. Does the Illinois EPA do any monitoring at all, or does the coal mine do all of the monitoring? The data that is collected by the coal mine, does the public have access to this information as well, specifically if something were to go wrong with the equipment?

    Please refer to the response to Item No. 10 above regarding Illinois EPA and IDNR monitoring of mine discharges.

    The public has access to all DMR data under the FOIA. Additionally, the data can be found by going to the ECHO website: https://echo.epa.gov/trends/loading-tool/get-data/monitoring-data-download and clicking on the date range to change and then entering "IL0077666" into the NPDES ID box. After pressing "Submit", the website will open an Excel worksheet with the data.

12. Does the Illinois EPA consider the history of the permit compliance before approving new NDPES permits? If not, why?

As a general rule, the Illinois EPA does not consider the enforcement-related history of an applicant as part of the permit review process. This is because the structure of the Act, as revealed in its provisions, divides permitting and enforcement functions into separate programs, although there are limited exceptions that will be discussed later. The Act provides for a state-wide program that is aided by private remedies, namely, the enforcement provisions found at Titles VIII and XII, to hold polluters responsible for the harm that they cause.

Civil enforcement can be brought through a filing of a complaint in a circuit court or with the Board against any person that violates the Act, Board regulations or a permit. Legal actions can be initiated by state prosecutorial officials or by any person through a citizen's suit. Such cases can involve extensive discovery proceedings, pre-trial procedures, and eventually either a settlement or a trial (or evidentiary hearing) to determine liability and requested relief (civil penalties, injunction, cease and desist, etc.) sought in the complaint. A complainant bears the burden of proof in a civil enforcement action.

On the other hand, permitting programs are codified at Title X of the Act and in the Board's implementing regulations, including 35 Ill. Adm. Code Part 309 governing (states NPDES) permits. These requirements assure that the permit review is conducted as a record proceeding, which is part of an intricate administrative continuum between the Illinois EPA and the Board. Under Section 39(a) and Part 309, the Illinois EPA reviews an application for an NPDES permit according to a formal standard of issuance and permit content requirements, as discussed above, and other rules of procedures.

If an applicant appeals an agency decision to deny or issue the permit, the Board acts as an overseer to determine whether the permit decision, based exclusively on the record prepared by the Illinois EPA, is supported by the relevant standard of administrative review. The burden of proof in a permit appeal is on the applicant and because the review is based only on the record assembled by the Illinois EPA, discovery proceedings are usually limited. Other procedures not addressed by the Act or implementing regulations may also be relevant to the Illinois EPA's permitting role. This includes procedural due process implications outlined by appellate court rulings beginning nearly forty years ago.

A seminal case is Martell v. Mauzy, which laid the groundwork for later recognition that the programs are separate. The federal district court decision held that the Illinois EPA's denial of an operating permit based on "putative" (or alleged) violations required a pre-denial hearing by the Illinois EPA, as opposed to the usual post-decision appeal procedures before the Board, because it

deprived the applicant of recognized liberty interests protected by procedural due process. Other cases followed, establishing the basic principles that have frequently been cited by the Illinois EPA at informational permit hearings and in responsiveness documents for many years. The Illinois Third District Appellate Court affirmed the Pollution Control Board's decision that a special waste stream permit was improperly denied on the grounds of alleged violations cited from a parallel pre-enforcement action. In citing to the Board's opinion that the Act's procedures for permitting and enforcement are "separate and distinct," the appellate court affirmed the Board and upheld the latter's inference that the permit denial process was "improperly" used in lieu of enforcement.

Also, see response to question #16.

13. How will the unfiltered water discharged into the Big Muddy be filtered? By whom and how is the discharge monitored? Monitoring needs to occur at all times to assess chemical discharge.

The wastewater will not be filtered, however, the wastewater will be treated by a settling basin before being discharged to the Big Muddy River. The settling basis is an earthen structure using sedimentation to remove settleable matter and turbidity from wastewater.

The Water Holding Cell will receive decant water from the RDA, underground mine pumpage, and ultimately, reject from the RO system and will discharge to the Big Muddy River via Outfall 011.

The RDA as well as the Water Holding Cell will act as a settling basin to settle out suspended solids. Monitoring of the discharge will be performed by the Permittee in accordance with the NPDES permit. In addition, as indicated in response to question #10, the Agency as well as IDNR/OMM may monitor this discharge during site inspections.

The renewed and modified NPDES permit requires monthly effluent monitoring for the first year following the effective date of the permit after which semi-annual sampling of Outfall 011 for the parameters listed in Special Condition No. 18 of the NPDES permit. These parameters are: arsenic, barium, cadmium, chromium (hexavalent), chromium, copper, lead, manganese, mercury, nickel, phenols, selenium, silver, and zinc.

In addition, for Outfall 011, in order to determine the chloride concentration at the edge of the mixing zone, the facility will use upstream flow and continuous chloride concentration data and the effluent flow and continuous chloride concentration data to determine the concentration of chloride at the edge of the mixing zone, as per Special Condition No. 15 of the NPDES permit. This value will be reported on the DMR and must not exceed 500 mg/L. The upstream and

effluent chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration.

Additionally, the permit also requires the facility to install a continuous monitor within 10 feet downstream of the edge of the mixing zone. The downstream chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration. This value will be reported on the DMR and must not exceed 500 mg/L.

Special Condition No. 16 also requires increased monitoring for sulfate, nickel, copper, and iron (dissolved) to three times per week for Outfall 011 within 10 feet downstream of the edge of the mixing zone.

14. Can the Illinois EPA be held accountable by law for allowing a pipeline to discharge as in mine drainage with elevated concentrations of numerous pollutants into a river that is currently listed as impaired and is also a candidate for Wild and Scenic River Designation?

Under the Illinois Environmental Protection Act, the Illinois EPA is responsible for the implementation of the NPDES permit program to ensure compliance with applicable standards and requirements. As discussed below, the NPDES permit has terms and conditions to ensure that the discharge from this mine facility will be protective of the existing uses of the Big Muddy River and Pond Creek.

For Outfall 011, the Agency performed the reasonable potential analysis to determine that the following contaminants do not have a reasonable potential to exceed the WQS in the effluent: arsenic, chromium (total), cyanide (available), iron (dissolved), lead, manganese, mercury, phenols, silver, zinc, and selenium. The Agency also determined that there is no reasonable potential to exceed the WQS outside of the mixing zone for cadmium, copper, nickel, sulfate, and chloride. Further, the Agency determined that there is no reasonable potential to exceed the acute WQS outside of the ZID for cadmium, copper, and nickel.

The unnamed tributaries of Pond Creek and Pond Creek itself are not listed as biologically significant streams in the 2008 IDNR Publication Integrating Multiple Taxa in a Biological Stream Rating System, nor are the unnamed tributaries of Pond Creek given an integrity rating in that document. However, Pond Creek itself is rated a "C" stream approximately 7.0 miles downstream of the outfalls.

The Big Muddy River is not listed as a biologically significant stream in the 2008 IDNR Publication Integrating Multiple Taxa in a Biological Stream Rating System, nor is it given an integrity rating in that document.

Please see the response to question #7 as to the Big Muddy River being listed as impaired.

35 Ill. Adm. Code 302.101 divides the uses of Illinois waters into four groups: General Use; Public and Food Processing Water Supply Use; Chicago Area Water System and the Lower Des Plaines River Uses; and Lake Michigan Basin Use. General Use is used throughout the State and is applicable to the Big Muddy River and Pond Creek. The Board's rules at 35 Ill. Adm. Code 302.202 indicate that the General Use must protect the State's water for the following uses: aquatic life, wildlife, agricultural use, secondary contact use, and most industrial uses.

WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill. Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

The federal regulations at 40 CFR 131.13 authorize states to use mixing zones and zones of initial dilution to implement WQS. Illinois has adopted mixing zones and zones of initial dilution WQS located at 35 Ill. Adm. Code 302.102.

In the zone immediately surrounding an outfall, both the acute and the chronic criteria may be exceeded, but the acute criterion must be met at the edge of this zone, which is often referred to as the acute mixing zone or the ZID. The acute mixing zone is sized to prevent lethality to passing organisms in order to protect the designated use of the waterbody as a whole. In case of the mixing zone, which is often called the chronic mixing zone, the chronic criterion may be exceeded, but the acute criterion must be met. The chronic criterion must be met at the edge of the chronic mixing zone. The chronic mixing zone is sized to protect the designated use of the waterbody as a whole.

Based on the above, the Agency has made a determination that all existing uses will be protected.

15. How many more violations have occurred since 2017? How many violations in total does Williamson energy have? Have the impacts of these violations on aquatic life been assessed?

27 total effluent violations have occurred since 2017. Williamson Energy has a total of 78 effluent violations from July 1, 2005 through September 30, 2021.

Any potential impacts or affects to the aquatic life in the receiving stream would be noted and/or determined during the Agency's routine stream sampling. The Big Muddy River basin is sampled by the Illinois EPA and the IDNR as part of the Intensive Basin Survey (IBS) program, a cooperative sampling effort that routinely collects a variety of samples including fish and macroinvertebrate assemblages. IBS sampling is conducted every five years and has also historically included mussel surveys as resources allow. While the next IBS sampling year for the Big Muddy River basin is 2023, this river system is sampled approximately every six weeks, via the AWQMN or ambient sampling, for water chemistry.

Also, additional biological sampling can be conducted as needed. Big Muddy River sampling locations included in these programs include stations upstream and downstream of the proposed Outfall 011, which is downstream of Route 149. Illinois EPA sampling (IBS and AWQMN) is conducted by the Illinois EPA's Surface Water Section. For the IBS sampling, river levels impact the ability to conduct biological sampling. For example, only fish sampling was possible in 2018 on the mainstem portion of the Big Muddy River, no macroinvertebrate sampling was possible on the mainstem that year (bug samples were taken at Pond Creek on Liberty School Road, Station NG-05). The closest upstream sampling point on the Big Muddy River is on Route 149 west of Plumfield (Station code is N-11). The nearest downstream sampling point on the Big Muddy River is on Route 127 in Murphysboro (Station code is N-12).

The results from this Agency sampling program are used to determine stream impairment. There are five segments downstream (IL_N-11, IL_N-17, IL_N-16, IL_N-12, and IL_N-99) and each has been assessed as follows:

- **The Big Muddy River, Waterbody Segment, IL_N-11, is listed on the 2018 Illinois Integrated Water Quality Report and Section 303(d) List as impaired for aquatic life use with potential causes given as dissolved oxygen, iron, sedimentation/siltation, and total suspended solids, primary contact use with potential cause given as fecal coliform, and fish consumption use with potential cause given as mercury and polychlorinated biphenyls (PCBs). Aesthetic quality use is fully supported.**
- **The Big Muddy River, Waterbody Segment, IL_N-17, is listed on the 2018 Illinois Integrated Water Quality Report and Section 303(d) List as impaired for aquatic life use with potential causes given as sedimentation/siltation and total suspended solids and fish consumption use with potential cause given as mercury.**

- **The Big Muddy River, Waterbody Segment, IL_N-16, is listed on the 2018 Illinois Integrated Water Quality Report and Section 303(d) List as impaired for aquatic life use with potential causes given as dissolved oxygen and sedimentation/siltation and fish consumption use with potential cause given as mercury.**
- **The Big Muddy River, Waterbody Segment, IL_N-12, is listed on the 2018 Illinois Integrated Water Quality Report and Section 303(d) List as impaired for aquatic life use with potential causes given as dissolved oxygen and total suspended solids and fish consumption use with potential cause given as mercury. Aquatic life and primary contact uses are fully supported.**
- **The Big Muddy River, Waterbody Segment, IL_N-99, is listed on the 2018 Illinois Integrated Water Quality Report and Section 303(d) List as impaired for aquatic life use with potential causes given as dissolved oxygen, phosphorus, and total suspended solids and fish consumption use with potential cause given as mercury. Aquatic life use is fully supported.**

To address the impaired status of Pond Creek, the permittee will be required to install and operate a 1.0 MGD RO unit by December 31, 2023. The permittee is authorized to discharge the RO permeate (treated water) to one of the eight sedimentation basins that discharge to Pond Creek via Outfalls 001 – 008 and the RO reject water to the Big Muddy River via Outfall 011.

16. Are there any Illinois EPA regular regulations or stipulations under the Clean Water Act regarding granting new permits or additions to existing permit when the company requesting them have an extensive history of violations?

Notably, two exceptions originate from statutory amendments by the Illinois General Assembly to the Act in 2003 in P.A. 93-575 (93rd General Assembly). The amendments introducing these exceptions to Section 39(a) of the Act did not eclipse the existing framework of the Act or its implementing regulations, as much of that construct was left untouched. The legislature also did not overrule existing caselaw and, as such, the changes simply memorialized existing caselaw and other provisions of the Act that existed at the time.

The first exception created by the amendments to Section 39(a) allows for Agency discretion in considering "prior adjudications of noncompliance" with the Act for environmental releases by an applicant. The Illinois EPA only uses this authority rarely, in large part, because judicial (or quasi-judicial) rulings based 'on the merits' of an environmental enforcement case are uncommon. The bar set by these criteria is high, as it is perhaps meant to protect against a potential deprivation of the same interests claimed by the applicant in Martell v.

Mauzy. Based on institutional knowledge, the Illinois EPA has used analogous, but more specific authority found in Section 39(i) in a handful of prior occasions.

The other exception introduced in the 2003 amendments allows for agency discretion in imposing reasonable conditions relating to a "past compliance history" with the Act as is necessary to correct, detect, or prevent "noncompliance." See, 415 ILCS 5/39(a). The Illinois EPA does not routinely employ this authority, as it is also prudently viewed to hold a high bar by requiring demonstrated, not merely alleged, noncompliance. However, the Illinois EPA will sometimes incorporate relevant requirements from a final adjudication into an NPDES permit, often doing so at the request of a respondent who has been directed to undertake a permitting change as a result of a settlement.

The Agency has included a Special Condition to address this comment. Special Condition No. 16 in the final permit requires that the discharge from Outfall 011 cease under certain conditions, such as: 1) when the continuous chloride data (as measured by conductivity) is 40 percent above the chloride WQS more than 20 percent of the time; 2) when the sulfate samples are 40 percent above the sulfate WQS in more than three of the samples taken within the month; 3) when the iron (dissolved) samples are 40 percent above the iron (dissolved) WQS in more than three of the samples taken within the month; 4) when the copper samples are 20 percent above the copper WQS in more than three of the samples taken within the month; or 5) when the nickel samples are 20 percent above the nickel WQS in more than three of the samples taken within the month.

17. My concern is the contaminant discharges may not be adequately controlled based on the described sampling plans described in the special conditions section.

The monitoring of the applicant's effluent was placed in the NPDES permit to adequately characterize the effluent and to ensure that WQS will be met in the receiving stream. Since the NPDES permit was public noticed, the following changes have been made to the NPDES permit:

Special Condition No. 15 of the draft permit has been modified to reduce the maximum chloride concentration for Outfall 011 from 12,000 mg/L to 5,000 mg/L.

The NPDES permit defines the mixing zone and ZIDs for each of the ports. The ZID for Ports 1 and 2 has a length of 4.5 feet by a width of 1.12 feet each. The ZID for Port 3 has a length of 5.68 feet by a width of 1.38 feet. The ZID for Port 4 has a length of 7.64 feet by a width of 1.97 feet. The ZID for Port 5 has a length of 9.18 feet by a width of 2.23 feet. The mixing zone has a length of 46 feet by a width of 25 feet.

Special Condition No. 16 in the final permit requires that the discharge from Outfall 011 cease under certain conditions, such as: 1) when the continuous

chloride data (as measured by conductivity) is 40 percent above the chloride WQS more than 20 percent of the time; 2) when the sulfate samples are 40 percent above the sulfate WQS in more than three of the samples taken within the month; 3) when the iron (dissolved) samples are 40 percent above the iron (dissolved) WQS in more than three of the samples taken within the month; 4) when the copper samples are 20 percent above the copper WQS in more than three of the samples taken within the month; or 5) when the nickel samples are 20 percent above the nickel WQS in more than three of the samples taken within the month.

Special Condition No. 16 also requires increased monitoring for sulfate, nickel, copper, and iron (dissolved) to three times per week for Outfall 011 within 10 feet downstream of the edge of the mixing zone.

To address the impaired status of Pond Creek, the permittee will be required to install and operate a 1.0 MGD RO unit by December 31, 2023. The permittee is authorized to discharge the RO permeate (treated water) to one of the eight sedimentation basins that discharge to Pond Creek via Outfalls 001 – 008 and the RO reject water to the Big Muddy River via Outfall 011.

The renewed/modified NPDES permit requires monthly effluent monitoring for the first year following the effective date of the permit after which semi-annual sampling for Outfalls 006, 007, 008, and 011 for the parameters listed in Special Condition No.18 of the NPDES permit. These parameters are: arsenic, barium, cadmium, chromium (hexavalent), chromium, copper, lead, manganese, mercury, nickel, phenols, selenium, silver, and zinc.

At the direction of Illinois EPA, the applicant has conducted additional sampling in response to comments previously received for Outfalls 001-008. Based upon the additional data, the NPDES permit has been modified to include additional NPDES permit limits for mercury at Outfall 001, copper and nickel at Outfall 002, iron (dissolved) at Outfall 003, copper at Outfall 004, nickel at Outfall 006, iron (dissolved), nickel, and zinc at Outfall 007, and cadmium, copper, nickel, and zinc at Outfall 008.

The permit includes additional effluent sampling, for Outfall 011, for sulfate, iron, and chloride will be sampled three times per week.

Additionally, the NPDES permit authorizes a discharge only when the Big Muddy River is between 30 cfs and 2,350 cfs, except after a one-year, 24-hour precipitation event, Outfall 011 can discharge for six consecutive days. The one-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

The permit has a condition that the mussel and invertebrate survey on the Big Muddy River will be repeated one year after commencement of the discharge.

Additionally, the NPDES permit has been modified to incorporate a limit of 32.2 mg/L for Outfall 011 applied as a yearly average.

The permit includes monitoring or limits for all parameters that could be present in the mine discharge.

18. Several documents have said the pipeline is only for 10 years and then it will be removed. Is this the projected end of date of the coal seam and mine closure?

Illinois EPA does not have any documents from the applicant indicating a 10-year service life of this pipeline.

a.) Who is going to pay for the removal of the pipeline?

IDNR OMM Land Reclamation Division requires a bond for all approved reclamation plans. The surface disturbance operations for this corridor is approved as OMM Permit No. 456.

b.) How many inspections has the Illinois EPA completed since the mine became operational?

The Agency has 17 inspection reports on file for the Pond Creek mine.

c.) How many field inspectors does the Marion Office currently have?

The Agency has four field inspectors from the wastewater program.

d.) What measures of enforcement has been taken on this issue with the Company? (this question is getting at citizens being bullied; samples should be taken on the weekend; off hour discharge complaints. He also cites to a report that says despite daily influent of 2.7 million gallons of underground water seeping into the mine, there have been no discharge monitoring reports since March 2019 and the report goes on to say that the mass water balance of influent water and discharged water does not appear consistent.)

Illinois EPA has referred Williamson Energy, LLC to the Illinois Attorney General's Office based on a February 6, 2020 violation notice for violations observed during a compliance inspection including the discharge of contaminants into receiving streams from outfalls at Pond Creek in violation of effluent and WQS. On May 25, 2021, Illinois EPA issued a violation notice to Williamson Energy, LLC following numerous bypass notices and subsequent inspections in which Illinois EPA inspectors observed the discharges of contaminants into receiving streams from outfalls at Pond Creek in violation of effluent and WQS. As there is an active enforcement case that is ongoing, the Agency cannot further elaborate on the details of the enforcement case.

Regarding the water balance, please see the response to question #18(e).

e.) The report cites under Monitoring Violations "Analysis not conducted of discharges, inadequate monitoring frequency of sampling, invalid/unrepresented samples as required by the permit. How is that a mine requesting a new permit to dump 2.9-3.5 million gallons per day of mining waste has no record of discharges for months at a time, no record of discharge release, and no water sampling data on public record? Where is the mine waste going every day?

Williamson Energy is pumping approximately 2.7 million gallons of mine water daily to the surface collection system. The estimated 2.7 million gallons of water pumped from the mine daily is only a general estimate. Water pumped from underground is conveyed via pipelines to Refuse Disposal Area No. 3 (IDNR Permit No. 417). Water from the mine is also used at the preparation plant and underground operations.

The facility has increased the crest elevation of the Refuse Disposal Area, creating additional water holding capacity. The water level on January 3, 2018 was at elevation 486.0 feet and on October 28, 2021, the water level was at elevation 543.2 feet. This is an increase of 57.2 feet of elevation, which equates to approximately 1,800,000,000 total gallons of additional storage. Due to the excessive water flowing into the underground operations, which could become a safety issue for the mine workers, the facility has been storing the water on-site. The facility has acknowledged having excess water at their operation and has been working on the proposed discharge to the Big Muddy River as a long-term solution.

19. Why would Illinois EPA issue a permit to a company going into a bankruptcy? What is the financial status of Williamson Energy? Would they be able to ameliorate or mitigate any harmful events? Does the corporation and the Illinois EPA expect public funds and the environment to absorb the costs?

IDNR's mine permit considers the financial assurance of the mining company in granting its permit. The Act or Board regulations do not provide the Agency with such authority.

Under the Act, the Illinois EPA is required to issue a permit to an applicant upon proof that the proposed facility or equipment will not cause a violation of the Act or promulgated regulations. See, 415 ILCS 5/39(a). This standard is a mandatory one, expressed in the language of the provision as a "duty" that is imposed upon the Illinois EPA. While Agency deliberation of certain aspects of the permit may be grounded in the exercise of discretion, the broader legal

standard governing permit issuance or denial limits the discretion of the Illinois EPA.

In this case, the applicant provided data to show that its discharge will comply with all applicable WQS. The NPDES permit, as drafted, contains limits and conditions to ensure that the discharge meets the applicable WQS, which are protective of the existing uses of the Big Muddy River. The Illinois EPA finds that the legal standard noted above has been met. Nothing in the record, including the public comments on the draft permit, adduces otherwise.

The Agency doesn't expect public funds and environment to absorb the costs. All bonding requirements are regulated by the IDNR OMM in accordance with 62 Ill. Adm. Code Part 1800.

20. During spring Big Muddy pushes water back into our fields and wastewater is mostly salt which creates dead spots. Who will be responsible for decline in crop yield?

The Agency has evaluated the proposed discharge to the Big Muddy River, and has determined that the discharge will not cause an exceedance of WQS outside of the mixing zone, and will not be of sufficient volume to have an adverse effect on flooding which may already be occurring on a seasonal basis.

The NPDES permit defines the mixing zone. The mixing zone has a length of 46 feet by a width of 25 feet.

Additionally, the NPDES permit authorizes a discharge only when the Big Muddy River is between 30 cfs and 2,350 cfs, except after a one-year, 24-hour precipitation event, Outfall 011 can discharge for six consecutive days. The one-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

21. Does IDNR OMM inspect or cover the same regulations the Illinois EPA does?

Although some overlap can be found in the IDNR OMM and Illinois EPA, Mine Pollution Control Program (MPCP) regulations, the Agency regulates activities that could generate refuse, result in a discharge, or potentially cause water pollution, including the regulation of discharges to surface waters from mining operations. IDNR OMM regulates exploration, extraction, site reclamation and related mining activities. The Illinois EPA regulations may be found in 35 Ill. Adm. Code, Subtitle D: Mine Related Water Pollution, Parts 401 through 407. These regulations cite, incorporate, and utilize various other state and federal regulations for the permitting and management of coal mine related facilities.

The IDNR OMM regulations are contained in 62 Ill. Adm. Code 1700 through 1850.

22. Why is data incomplete? How does one know if the polluter has exceeded the allowable limits if the EPA are not requiring complete reporting of data?

The data is not "incomplete." During the months with no data, the facility had no discharge during those months. When "No Discharge" is reported on the DMR, it means that no discharge occurred during that month.

23. Can you explain the excessive limits and lack of regulation of minerals that are cumulative and in large amounts to toxic life?

At the direction of Illinois EPA, the applicant has conducted additional sampling in response to comments previously received for Outfalls 001-008. Based upon the additional data, the NPDES permit has been modified to include additional NPDES permit limits for mercury at Outfall 001, copper and nickel at Outfall 002, iron (dissolved) at Outfall 003, copper at Outfall 004, nickel at Outfall 006, iron (dissolved), nickel, and zinc at Outfall 007, and cadmium, copper, nickel, and zinc at Outfall 008.

For Outfall 011, the Agency performed the reasonable potential analysis to determine that the following contaminants do not have a reasonable potential to exceed the WQS in the effluent: arsenic, chromium (total), cyanide (available), iron (dissolved), lead, manganese, mercury, phenols, silver, zinc, and selenium. The Agency also determined that there is no reasonable potential to exceed the WQS outside of the mixing zone for cadmium, copper, nickel, sulfate, and chloride. Further, the Agency determined that there is no reasonable potential to exceed the acute WQS outside of the ZID for cadmium, copper, and nickel.

Special Condition No. 15 of the draft permit has been modified to reduce the maximum chloride concentration for Outfall 011 from 12,000 mg/L to 5,000 mg/L.

Since the discharger is required to comply with all applicable WQS prior to discharge or after mixing in the mixing zone and ZID, the designated uses will be fully protected.

24. Please explain how, in a matter of days the Company's status on the ECHO site changed from yellow to blue.

Yellow on ECHO indicates either a Reportable Non-Compliance (RNC status) or a Non-Reportable Non-Compliance. (NON-RNC). These types of violations are considered minor/Category 2 violations and are either paperwork violations or a minor effluent exceedances of the permit limit. Category 2 violations are resolved automatically by ICIS logic, which is based on the resolution criteria contained in USEPA's NPDES Enforcement Management System EMS – (1989):

https://www.epa.gov/enforcement/enforcement-management-system-national-pollutant-discharge-elimination-system-clean.

ECHO is refreshed weekly. The RNC report runs over the weekend and applies the violation and resolution logic and updates the RNC. This is an automated process. Below is the ECHO link describing the date sources and date extracted date/ and next scheduled extract: https://echo.epa.gov/resources/echo-data/about-the-data#sources.

The resolution is usually through submission of the report or when the effluent violations have been resolved.

25. If the Governor cares about the environment, then why has the Illinois EPA referred so few cases to the Attorney General's office, even with all the consistent violations of the mine?

The Agency has and does refer cases to the Illinois Attorney General's Office. Violation Notices, and correction of non-compliance issues related to Violation Notices, are administered by the Illinois EPA pursuant to Section 31 of the Illinois Environmental Protection Act. See 415 ILCS 5/31. With respect to Pond Creek Mine, VN W-2019-50223, was issued on February 6, 2020, for violations found at a site inspection that showed several WQS violations. The resulting violations were for deposited contaminants, discharge of contaminants, offensive conditions, offensive discharge, effluent standards violations, failure to comply with NPDES Permit, and failure to comply with good mining practices. The Illinois EPA has referred these violations to the Illinois Attorney General's Office.

In addition, Violation Notice W-2021-50080 was issued on 5/25/2021 due to numerous unauthorized discharges/bypasses from the Williamson Energy Pond Creek Mine #1's Outfall 006 into the receiving stream resulting in WQS violations. The Illinois EPA either received notification or observed these unauthorized discharges/bypasses from Williamson Energy. The resulting violations were for unpermitted/unauthorized point source discharge, NPDES bypass violations, deposited contaminants, discharge of contaminants, offensive conditions, offensive discharge, effluent standards violations, water quality violations, and failure to comply with good mining practices. Illinois EPA is in the process of referring these violations to the Illinois Attorney General's Office. The significant/chronic DMR effluent violations seen at mainly outfall 006, for Chloride and Sulfate, will be added via a supplemental referral to the Illinois Attorney General Office's existing enforcement action against Williamson Energy.

Also, there was a prior enforcement case before the Board, which is now closed. See People v. Williamson Energy, PCB 2019-85.

Groundwater Issues

26. I have not seen anything at all anywhere that's a solution to this saline water seeping into the mine from an underground aquifer. Why hasn't it been suggested that this saline water could be placed in the depths of the earth with these injection wells?

The mine infiltration water could be discharged directly to an Underground Injection Control (UIC) well (often referred to as a deep well) if conditions were appropriate for such activity. The injection wells must be installed at extreme depths to ensure they do not affect potential aquifers used for public consumption and into a geologic formation that is capable of receiving excess water.

The receiving underground formation at this mine site has a limited amount of volume it can receive instantaneously and long term. As the underground formation is filled with excess water, its acceptance can be diminished. Consequently, multiple wells cannot be installed in close proximity to one another or they will negatively influence one another and restrict flow. In order to completely utilize this technology at Pond Creek mine, it is estimated that nine deep injection wells spaced an adequate distance apart would be needed. Additionally, miles of pipeline conveying water to each individual well. An ultra-filtration system would also be needed to remove any suspended solids from the water prior to injection.

At a near-by affiliated mine that operates two deep injection wells, ongoing operation of water disposal has been hampered by excess pressures, scaling of injection tubing, and plugging off the receiving geologic formation. Due to these operational challenges, the wells have been inactive for several years. When injecting during optimal conditions, the wells only accepted a fraction of the amount of water Pond Creek mine would need to dispose of. Because of reasons stated above, Deep Well Injection is an unreliable and impractical alternative given these conditions to dispose of the amount of water infiltrating the Pond Creek mine.

27. What are the long-term impacts of continual water usage and water withdrawal on nearby communities?

The community water supply in the area of the mine is a surface water supply, thus not impacted by water usage. The community water supply itself will continue to be able to supply the nearby communities and the mine. The few private wells in the area are generally less than 200 feet in depth. The formation with the saline water is approximately 450 to 600 feet in depth. Any impact of water withdrawal from this depth on the more shallow private wells would be expected to be minimal.

28. What is Foresight's daily Rend Lake water usage in initial stages of coal production? What does it pay Adena Resources and the State of Illinois for this use? Explain the water contracts and Foresight's use of Tennessee Valley Authority's coal.

Currently, Sugar Camp, LLC uses Rend Lake water to supplement make-up water for coal processing when necessary. According to the permittee, they have authorization for Pond Creek mine to utilize this source of water as coal processing make-up water; however, Pond Creek mine does not currently use this approved availability of Rend Lake water. Williamson Energy does not mine, control, or have access to Tennessee Valley Authority coal. The State of Illinois does not get paid for water usage; however, it does get reimbursed for operation and maintenance costs of Rend Lake that the state pays to the Army Corps of Engineers. The IDNR Office of Water Resources allocates a set volume of Rend Lake storage that can be utilized for water withdraw (usage). This is done by an agreement between the state and the interested entity for a set maximum water use.

29. What are the impacts of ongoing groundwater pumping at the mine and the effect of social and economic development in the area?

The purpose of ongoing groundwater pumping at the mine is to control the amount of water in the mine so that the mine workers can safely operate the mine. Impacts to ground water use in the area are expected to be minimal. Refer to response to question #27 for further explanation on use of groundwater in the area.

30. In response to the question of why deep injection wells for salty water was not being considered, has Foresight provided numbers to the Illinois EPA to justify assertion? If it comes from saline aquifers why not return it to them instead of dumping surface waters containing life?

At Foresight's Sugar Camp operation, two underground injection wells were installed – Well 1 in September 2013 and Well 2 in October 2014. The wells operated until January 2017, at which point the wells ceased operating because of operational issues and were not able to utilize the wells. The history of these two wells showed they only accepted, on average 3,750,000 gallons per month, which represents less than 4% of Pond Creek water disposal needs. Also see response to question #26.

Antidegradation Assessment/Water Quality Standards

31. Williamson Energy was found to have 45 effluent violations between the years 2015 and 2017. Eleven of those violations were sulfate and ten were chloride in Pond Creek. How can you say that we will not have problems with water quality when they have repeated problems with water quality? How can the water be safe if they're repeatedly violated?

Please see the response to question #25, regarding the Agency's enforcement against Williamson Energy for effluent violations.

The NPDES permit contains limits and conditions to ensure that the discharge meets WQS, which are protective of the existing uses of Pond Creek.

To address the impaired status of Pond Creek, the permittee will be required to install and operate a 1.0 MGD RO unit by December 31, 2023. The permittee is authorized to discharge the RO permeate (treated water) to one of the eight sedimentation basins that discharge to Pond Creek via Outfalls 001 – 008 and the RO reject water to the Big Muddy River via Outfall 011.

Additionally, the NPDES permit authorizes a discharge to the Big Muddy River and contains limits and conditions to ensure that the discharge meets WQS which are protective of the existing uses of the Big Muddy River.

Special Condition No. 16 in the final permit requires that the discharge from Outfall 011 cease under certain conditions, such as: 1) when the continuous chloride data (as measured by conductivity) is 40 percent above the chloride WQS more than 20 percent of the time; 2) when the sulfate samples are 40 percent above the sulfate WQS in more than three of the samples taken within the month; 3) when the iron (dissolved) samples are 40 percent above the iron (dissolved) WQS in more than three of the samples taken within the month; 4) when the copper samples are 20 percent above the copper WQS water quality standard in more than three of the samples taken within the month; or 5) when the nickel samples are 20 percent above the nickel WQS in more than three of the samples taken within the month.

Based on the above, the permit ensures that uses will be maintained in Pond Creek and the Big Muddy River.

32. Has it been determined by the Illinois EPA or IDNR if there are endangered species or mussel beds, because there's no mention of endangered species anywhere except for they won't be affected or any species, because the water quality will be met, which is not true, because they violate all the time.

Yes, a detailed summary for IDNR and IEPA actions are as follows:

On November 2, 2016, the IDNR EcoCAT web-based tool was used, which indicated that there were no records of aquatic threatened or endangered species present in the vicinity of the discharge. While the IDNR EcoCAT web-based tool did not terminate the consultation because of the nearby presence of Chuck-Will's-Willow (*Caprimulgus carolinensis*), IDNR evaluated the information and terminated the consultation on September 26, 2019, which was reevaluated and terminated again on October 22, 2021. In their termination letters, IDNR reiterated that there were no records of threatened or endangered species present. However, the termination letters indicated that there were 11

species designated in the Illinois Wildlife Action Plan as "Species in Greatest Need of Conservation" (SGNC). The SGNC that occur in the Big Muddy River include the Alligator Gar (*Atractosteus spatula*), Blacktail Shiner (*Cyprinella venusta*), Brown Bullhead (*Ameiurus Nebulosus*), Flier (*Centrarchus macropterus*), Mooneye (*Hiodon tergisus*), Paddlefish (*Polyodon spathula*), Pugnose Minnow (*Opsopoeodus emiliae*), Ribbon Shiner (*Lythrurus fumeus*), River Darter (*Percina shumardi*), Spottail Darter (*Etheostoma squamiceps*), and Stripetail Darter (*Etheostoma kennicotti*). IDNR also noted that the Pistolgrip (*Tritogonia verrucose*) has also been found in the Big Muddy River. In conclusion, IDNR indicated that "strict adherence to all effluent limits and all effluent monitoring requirements in accordance with NPDES Permit IL0077666 is requested."

The mussel survey was conducted April 22-26 and June 5, 2020. The stream discharge rate at the Plumfield, Illinois gauge was between 742 and 855 cfs during this study. The permit has a condition that the mussel survey will be repeated one year after commencement of the discharge.

The survey area encompassed the width of the river from 50 m upstream to 150 m downstream of the proposed outfall location. The mixing zone has a length of 46 feet (13.3 m) by a width of 25 feet (7.62 m). The Survey Area was divided into 40 approximately 10x10 m cells. Four 5-minute qualitative samples were collected within each cell. Qualitative sampling entailed a diver searching the substrate, collecting all unionids encountered within the time period. Substrate composition (Wentworth scale) and water depth (meters) were recorded at the beginning of each sample. Unionids were classified as live, fresh dead, and weathered dead. Live individuals were identified to species, aged, and measured (length in millimeters). At least one individual of each live species was photographed, and (if available) a dead shell of each species was retained as a voucher specimen. All live individuals of non-listed species were relocated to a Recipient Area upstream of the project area with a similar substrate and depth profile as the Survey Area.

A total of 46 live individuals of 11 species were collected from the Survey Area. *Megalonaias nervosa* was the most commonly collected species (n=13), followed by *Leptodea fragilis* (n=11) and *Potamilus alatus* (n=5); remaining species were represented by 4 or fewer live individuals each, including the following; *Fusconaia flava* (n=1), *Tritogonia verrucosa* (n=2), *Quadrula quadrula* (n=1), *Lampsilis teres* (n=4), *Truncilla truncata* (n=1), *Lampsilis cardium* (n=1), *Pyganodon grandis* (n=3), and *Lasmigona complanata* (n=4). Abundance was low, with 16 of 37 searched cells yielding no live individuals.

Unionids were scattered throughout the Survey Area; however, abundance appeared to be greater towards the downstream end of the site, as 23 of the 46 live individuals were collected there. Therefore, the greatest concentration of mussels found were approximately 80 meters downstream of the mixing zone. No mussel beds were found in the mixing zone. In the area of the mixing zone,

only one live mussel was found. No state listed species (live individuals or dead shell material) were observed in this area.

33. Looking at the pollutant loading report for Pond Creek Mine, for the last seven years, there was at least one year that had incomplete data points, I want to reiterate that it is not just sulfates and chlorides that are important to have complete data on, because there are many other different elements. Whether they are aluminum or boron or various transition metals, it can be toxic in relatively low concentrations.

    The renewed and modified NPDES permit requires monthly effluent monitoring for the first year following the effective date of the permit after which semi-annual sampling for Outfalls 006, 007, 008, and 011 for the parameters listed in Special Condition No. 18 of the NPDES permit. These parameters are: arsenic, barium, cadmium, chromium (hexavalent), chromium, copper, lead, manganese, mercury, nickel, phenols, selenium, silver, and zinc.

    The data collected will be used to determine if a permit limit for any of these parameters is necessary in the next permit cycle.

34. Why was there no mention that this is an outstandingly remarkable value designated river?

    The unnamed tributaries of Pond Creek and Pond Creek itself are not listed as biologically significant streams in the 2008 IDNR Publication Integrating Multiple Taxa in a Biological Stream Rating System, nor are the unnamed tributaries of Pond Creek given an integrity rating in that document. However, Pond Creek itself is rated a "C" stream approximately 7.0 miles downstream of the outfalls.

    Also, the Big Muddy River is not listed as a biologically significant stream in the 2008 IDNR Publication Integrating Multiple Taxa in a Biological Stream Rating System, nor is it given an integrity rating in that document.

    For a detailed response on how the NPDES permit would be protective of the existing uses, see response to question #14.

35. Has the Illinois EPA considered that the river itself should have its own rights?

    The Act and Board regulations require any NPDES permit issued be protective of the designated uses. A detailed discussion of the structure provided by the Board regulations to achieve this mandate is provided below.

    35 Ill. Adm. Code 302.101 divides the uses of Illinois waters into four groups: General Use; Public and Food Processing Water Supply Use; Chicago Area Water System and the Lower Des Plaines River Uses; and Lake Michigan Basin Use. General Use is used throughout the State and is applicable to the Big

Muddy River and Pond Creek. The Board's rules at 35 Ill. Adm. Code 302.202 indicate that the General Use must protect the State's water for the following uses: aquatic life, wildlife, agricultural use, secondary contact use, and most industrial uses.

WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill. Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

This permit has all applicable WQS to ensure that the designated uses are fully protected.

36. I would like to know what the depth of the Big Muddy in that area is currently, because it surely isn't 30 feet deep for the diffusers to be pouring the effluent into the water?

The Big Muddy River has a depth of approximately 8-12 feet at the proposed diffuser site, Outfall 011, during baseline flow conditions, which is sufficient for the diffuser at this location.

In this case, the applicant has proposed to install a diffuser in the Big Muddy River. Based on the Agency's review of the CORMIX model and 35 Ill. Adm. Code 302.102, the Agency determined the size of the mixing zone and ZID. Based on recommendations from the Agency, the outfall structure was reevaluated to provide better mixing. The Agency determined the size of the mixing zone and ZID that is consistent with 35 Ill. Adm. Code 302.102.

The diffuser consists of five individual staged single-port diffusers. This design maximizes the mixing zone for each flow condition in the River while allowing the facility to discharge based on the flow in the River. As the flow in the River decreases or the chloride concentration increases, the larger ports are taken off-line so that the WQS can be maintained at the edge of the mixing zone and ZID, as per 35 Ill. Adm. Code 302.102.

The diffuser will be protected by rip-rap on the bottom of the stream. The individual ports will be angled upwards from the bottom of the stream to provide mixing in the water column.

37. How will the diffuser vents be protected from people continuing to use the location as a dumpsite for large objects? We recommend continuous monitoring like what is being done in Murphysboro.

    The NPDES permit has been modified to require that Outfall 011 include signage on the bank of the Big Muddy River to inform people on the Big Muddy River that the outfall is present at that location. The diffuser ports will be installed in a way to minimize damage due to strikes from natural objects such as logs. The site is not located on a public road, which will reduce the potential for the public from dumping large objects into the river at this location. The opposite bank of the river is also private property, which will minimize the public from dumping large objects into the river at this location.

    The above mentioned practices are sufficient to protect the diffuser ports from damage.

38. We analyzed data and found that the 90th percentile chloride concentration is actually 108 milligrams per liter, so I wanted to ask tonight how did the mine come to use 30 milligrams per liter as the 90th percentile?

    The 90th percentile of the chloride data (30.1 mg/L) was based on data from the dam at Rend Lake. As per the December 12, 2016 memo by Scott Twait to Iwona Ward titled "WQBELs for the Big Muddy River discharge (Outfall 011)", the Agency had originally intended to use the 90th percentile chloride value from the dam at Rend Lake to calculate the upstream chloride concentration.

    However, the public noticed draft permit requires the use of continuous chloride concentration (correlated to the conductivity value). Therefore, the 90th percentile of the chloride data (30.1 mg/L) will not be used to calculate the amount of mixing available.

39. The antidegradation assessment proposes to monitor downstream chloride concentrations in two ways: The calculated, you have a mixing equation as well as physically with the downstream conductivity probe. Is the permit being violated if either of these values are found to be above 500 milligrams per liter of chloride?

    Yes, both, the mixing zone calculations (correlated to conductivity) and the downstream chloride concentration (correlated to conductivity) must be reported on the DMRs as a daily maximum and must be at or below 500 mg/L.

40. Is the mine required to monitor and report the effluent discharge rates and chloride concentrations coming out of the pipe?

    Yes, the effluent discharge rate is required to be reported and the chloride concentration will have a maximum concentration of 5,000 mg/L. Additionally, the permit will ensure that WQS are met at the edge of the mixing zone by the requirements below:

For Outfall 011, in order to determine the chloride concentration at the edge of the mixing zone, the facility will use upstream flow and continuous chloride concentration data and the effluent flow and continuous chloride concentration data to determine the concentration of chloride at the edge of the mixing zone, as per Special Condition No. 15 of the NPDES permit. This value will be reported on the DMR and must not exceed 500 mg/L. The upstream and effluent chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration.

Additionally, the permit also requires the facility to install a continuous monitor within 10 feet downstream of the edge of the mixing zone. The downstream chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration. This value will be reported on the DMR and must not exceed 500 mg/L.

41. How will the mine develop that accurate calibration? Does the Agency have to approve that calibration curve derived by the mine? And are the calibrated values also reported on the DMR? Do we have all of that information that they're using to do that calibration?

The applicant will develop a site-specific database that correlates the conductivity and chloride concentrations for the Big Muddy River and for the treated effluent. The Agency has included a requirement in the NPDES permit that requires monthly chloride samples and conductivity measurements, in the Big Muddy River (upstream and downstream) and in the effluent, to ensure that the calibration curves remain accurate. Additionally, the Agency has included a requirement in the NPDES permit that requires that the calibration curves are to be approved by the Agency, before discharge, after six months of operation, and yearly thereafter.

The chloride values (correlated to the conductivity values) will be reported on the DMRs as chloride in mg/L. The calibration curves will not be reported on the DMRs; however, these curves will be part of the permit record and are available to the public for review via a FOIA request.

42. The Illinois EPA should include a fish survey, a mussel survey and a survey of invertebrates pre-construction as well as long-term monitoring post-construction would be or should be required.

As it is detailed below, the Agency has required a mussel and invertebrates survey prior to the construction of the diffuser and has also required that these surveys be performed one year after commencement of the discharge. No additional fish surveys were required as these are part of the long-term monitoring that is completed by IDNR.

The company has provided the fish data from 1964 to 2018 that has occurred in the Big Muddy River and in the Big Muddy River watershed. The applicant has

also provided a mussel survey performed in the Big Muddy River Basin titled "Freshwater Mussels of the Big Muddy River" and published March 7, 2012.

The mussel survey was conducted April 22-26 and June 5, 2020. The stream discharge rate at the Plumfield, Illinois gauge was between 742 and 855 cfs during this study. The permit has a condition that the mussel survey will be repeated one year after commencement of the discharge.

A total of 46 live individuals of 11 species were collected from the Survey Area. *Megalonaias nervosa* was the most commonly collected species (n=13), followed by *Leptodea fragilis* (n=11) and *Potamilus alatus* (n=5); remaining species were represented by 4 or fewer live individuals each, including the following; *Fusconaia flava* (n=1), *Tritogonia verrucosa* (n=2), *Quadrula quadrula* (n=1), *Lampsilis teres* (n=4), *Truncilla truncata* (n=1), *Lampsilis cardium* (n=1), *Pyganodon grandis* (n=3), and *Lasmigona complanata* (n=4). Abundance was low, with 16 of 37 searched cells yielding no live individuals.

Unionids were scattered throughout the Survey Area; however, abundance appeared to be greater towards the downstream end of the site, as 23 of the 46 live individuals were collected there. Therefore, the greatest concentration of mussels found were approximately 80 meters downstream of the mixing zone. No mussel beds were found in the mixing zone. In the area of the mixing zone, only one live mussel was found. No state listed species (live individuals or dead shell material) were observed in this area.

The company also had Alliance Consulting perform a Benthic Macroinvertebrates Community Survey of the Big Muddy River approximately 0.77 miles downstream of the proposed outfall location. The sampling was done on November 20th, 2019. This survey demonstrated that the diffuser will be located in a pool of the river with poor habitat availability for greater than three-quarters of a mile below the diffuser. Due to the depth of the Big Muddy River and accessibility issues, the wadeable collection method was not possible. The benthic macroinvertebrates were sampled using and Ekman Dredge dropped from an abandoned railroad bridge. The mIBI scored 23.8, which is a rating of fair and 80.7% of the sample was made up of tolerant taxa. The benthic macroinvertebrate community in the downstream sample was dominated by tolerant Chironomidae and Ceratopogonidae. A few mayflies and unionids were collected in this survey which may indicate substrate, not water quality, is the limiting factor in this reach. According to the report, the metrics reflect a stream with poor habitat quality, low biodiversity, and a struggling benthic macroinvertebrate community.

Also, the Big Muddy River basin is sampled by the Illinois EPA and the IDNR as part of the IBS program, a cooperative sampling effort that routinely collects a variety of samples including fish and macroinvertebrate assemblages. IBS sampling is conducted every five years. While the next IBS sampling year for the Big Muddy River basin is 2023, this river system is sampled approximately every six weeks for water chemistry, and additional biological sampling can be

conducted as needed. Big Muddy River sampling locations included in these programs include stations upstream and downstream of the proposed discharge.

The NPDES permit includes a condition that requires a mussel survey and a macroinvertebrate survey one year after commencement of the discharge from Outfall 011.

43. We were able to run some numbers that show if you have chloride coming out of that upstream proposed Sugar Camp discharge as well as this one, have you guys taken into account that potential?

The chloride coming from the Sugar Camp discharge is accounted for in calculating chloride limits for the Pond Creek NPDES permit. Special Condition No. 15 of the NPDES permit requires that the upstream chloride concentration be measured just upstream of the Outfall 011. The upstream chloride concentration is measured by continuous conductivity measurements (correlated to the chloride concentration). This upstream chloride concentration will account for all sources of chloride upstream of the Outfall 011 location, including chloride from Sugar Camp discharges.

44. I'm wondering how will Illinois EPA verify all of these calibrations, and how they will work so that the effluent will stay within the limits of the regulations?

The applicant is required to develop a site-specific database that correlates the conductivity and chloride concentrations for the Big Muddy River and for the treated effluent. The Agency has included a requirement in the NPDES permit that requires monthly chloride samples and conductivity measurements to ensure that the calibration curves remain accurate. Additionally, the Agency has included a requirement in the NPDES permit that requires that the calibration curves are to be approved by the Agency, before discharge, after six months of operation, and yearly thereafter.

45. Even with a diffuser, what gives Illinois EPA any confidence that there will not be acutely high concentrations that can gravely harm the fish, macroinvertebrates, mussels, plants and other wildlife that depend on the Big Muddy River, especially near the 011 Outflow location?

As has been described previously, the WQS are designed to be protective of the designated uses. Since the NPDES permit was public noticed, the following changes have been made to the NPDES permit:

Special Condition No. 15 of the draft permit has been modified to reduce the maximum chloride concentration for Outfall 011 from 12,000 mg/L to 5,000 mg/L.

The NPDES permit defines the mixing zone and ZIDs for each of the ports. The ZID for Ports 1 and 2 has a length of 4.5 feet by a width of 1.12 feet each. The

ZID for Port 3 has a length of 5.68 feet by a width of 1.38 feet. The ZID for Port 4 has a length of 7.64 feet by a width of 1.97 feet. The ZID for Port 5 has a length of 9.18 feet by a width of 2.23 feet. The mixing zone has a length of 46 feet by a width of 25 feet.

Special Condition No. 16 in the final permit requires that the discharge from Outfall 011 cease under certain conditions, such as: 1) when the continuous chloride data (as measured by conductivity) is 40 percent above the chloride WQS more than 20 percent of the time; 2) when the sulfate samples are 40 percent above the sulfate WQS in more than three of the samples taken within the month; 3) when the iron (dissolved) samples are 40 percent above the iron (dissolved) WQS in more than three of the samples taken within the month; 4) when the copper samples are 20 percent above the copper WQS in more than three of the samples taken within the month; or 5) when the nickel samples are 20 percent above the nickel WQS in more than three of the samples taken within the month.

Special Condition No. 16 also requires increased monitoring for sulfate, nickel, copper, and iron (dissolved) to three times per week for Outfall 011 within 10 feet downstream of the edge of the mixing zone.

To address the impaired status of Pond Creek, the permittee will be required to install and operate a 1.0 MGD RO unit by December 31, 2023. The permittee is authorized to discharge the RO permeate (treated water) to one of the eight sedimentation basins that discharge to Pond Creek via Outfalls 001 – 008 and the RO reject water to the Big Muddy River via Outfall 011.

The renewed/modified NPDES permit requires monthly effluent monitoring for the first year following the effective date of the permit after which semi-annual sampling for Outfalls 006, 007, 008, and 011 for the parameters listed in Special Condition No.18 of the NPDES permit. These parameters are: arsenic, barium, cadmium, chromium (hexavalent), chromium, copper, lead, manganese, mercury, nickel, phenols, selenium, silver, and zinc.

At the direction of Illinois EPA, the applicant has conducted additional sampling in response to comments previously received for Outfalls 001-008. Based upon the additional data, the NPDES permit has been modified to include additional NPDES permit limits for mercury at Outfall 001, copper and nickel at Outfall 002, iron (dissolved) at Outfall 003, copper at Outfall 004, nickel at Outfall 006, iron (dissolved), nickel, and zinc at Outfall 007, and cadmium, copper, nickel, and zinc at Outfall 008.

The permit includes additional effluent sampling, for Outfall 011, for sulfate, iron, and chloride will be sampled three times per week.

Additionally, the NPDES permit authorizes a discharge only when the Big Muddy River is between 30 cubic feet per second (cfs) and 2,350 cfs, except after a one-year, 24-hour precipitation event, Outfall 011 can discharge for six consecutive days. The one-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

The permit has a condition that the mussel and invertebrate survey on the Big Muddy River will be repeated one year after commencement of the discharge.

The permit includes monitoring or limits for all parameters that could be present in the mine discharge.

Additionally, the NPDES permit has been modified to incorporate a limit of 32.2 mg/L for Outfall 011 applied as a yearly average.

Based on the above, the Agency concluded that there will not be acutely high concentrations of contaminants that can gravely harm the fish, macroinvertebrates, mussels, plants, and other wildlife that depend on the Big Muddy River.

46. Since these are our common-pool resources and waters of the USA, I am curious if this has taken into consideration the compounding pollutants that were discharged downstream and also considerate of all the other industries that input into streams, because the Gulf of Mexico is currently under hypoxia during the summers, and there's fish die off, and this is a tributary to the Mississippi which discharges into the Gulf of Mexico.

The effluent does not have sufficient deoxygenating chemicals or sufficient phosphorus to contribute to the Dissolved Oxygen impairment or potential impairment of phosphorus and will not cause a violation of the WQS in the receiving streams or the Gulf of Mexico.

WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill. Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

The Agency considered all of the upstream chloride inputs. In order to determine the chloride concentration at the edge of the mixing zone, the facility will use upstream flow and continuous chloride concentration data and the

effluent flow and continuous chloride concentration data to determine the concentration of chloride at the edge of the mixing zone, as per Special Condition No. 15 of the NPDES permit. This value will be reported on the DMR and must not exceed 500 mg/L. The upstream and effluent chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration.

The constituents discharged at the outfall location will be transported downstream by the Big Muddy River. Since all water quality criteria will be met at the edge of the mixing zone and ZID, the Agency does not anticipate downstream impacts.

47. Why are you proposing to grant the mine a mixing zone for chlorides at the Pond Creek Outfall if the Pond Creek is already impaired? Why was the level of chlorides in Pond Creek found by Illinois EPA to no longer be of concern by the recent TMDL assessment when it already has been measured at or near the maximum of 500 milligrams per liter?

The Agency has removed the proposed mixing zone in Pond Creek from the NPDES permit.

The Agency collected chloride data in Pond Creek (NG-02) between May 2019 and October 2019 to supplement the data for the TMDL Program. Six samples for chloride were taken, which ranged from 687 mg/L to 1,100 mg/L. Pond Creek (NG-02) is still listed on the 2018 Illinois Integrated Water Quality Report and Section 303(d) List as impaired for aquatic life use with potential cause given as chloride.

Because of the impaired status, the permit has been modified to not authorize discharges from the proposed Outfalls 009 and 009ES into Pond Creek and the unnamed tributary of Pond Creek respectively. Additionally, to address the impaired status of Pond Creek, the permittee will be required to install and operate a 1.0 MGD RO unit by December 31, 2023. The permittee is authorized to discharge the RO permeate (treated water) to one of the eight sedimentation basins that discharge to Pond Creek via Outfalls 001 – 008 and the RO reject water to the Big Muddy River via Outfall 011.

48. Will the increased chloride and total dissolved solids levels in the Big Muddy River cause higher methyl mercury levels? Will the acid mine drainage allowed in this permit also increase the conversion of mercury to methyl mercury? Can Illinois EPA assure us that it will not?

For the reasons stated below, the Agency concluded that the increased chloride and total dissolved solids levels in the Big Muddy River or the discharge from the mine will not increase the methylmercury levels.

Methylmercury does bond with chloride (Cl-); however, it also bonds with hydroxide (OH-) and nitrate (NO3-).

At the direction of Illinois EPA, the applicant has conducted additional sampling in response to comments previously received for Outfalls 001-008. The minimum detection limit (MDL) in the additional sampling is 0.5 nanograms per liter. Based upon the additional data, at this MDL, the NPDES permit has been modified to include a limit for mercury at Outfall 001. The data indicate that there is no reasonable potential for Outfalls 002 through 008 to exceed the WQS for mercury.

Methylmercury is formed primarily under anaerobic conditions. These conditions are expected in the sediments and not expected in the water column. The deeper sediments that are not directly impacted by the overlying water column are expected to be anaerobic or anoxic. The water column is not expected to interact with the anaerobic or anoxic parts of the sediment where methylation is expected to occur.

Effluent present in the mixing zone, where the greatest concentrations of chlorides are expected is not anticipated to interact with the bottom sediments. Therefore, there is minimal risk of increased release of methylmercury within the mixing zone area. Further downstream, the concentration of chloride will continue to decrease, thus reducing any risk of mercury release.

49. Has Illinois EPA evaluated the possible harm to humans from increased methyl mercury that could be caused by granting this permit?

Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

At the direction of Illinois EPA, the applicant has conducted additional sampling in response to comments previously received for Outfalls 001-008. The MDL in the additional sampling is 0.5 nanograms per liter. Based upon the additional data at this MDL, the NPDES permit has been modified to include a limit of 12 ng/L for mercury at Outfall 001. The data indicate that there is no reasonable potential for Outfalls 002 through 008 to exceed the WQS for mercury.

Additionally, Special Condition No. 18 of the NPDES permit requires that Outfalls 006, 007, 008, and 011 shall be monitored monthly for the first year following the effective date of the permit after which semi-annual sampling for mercury with such monitoring spaced at approximately six-month intervals during the entire five-year term of the NPDES Permit.

Since the NPDES permit has a mercury limit for Outfall 001, and the Agency has determined that there is no reasonable potential to exceed the mercury WQS for the other Outfalls, the discharge from this mine will be fully protective of the existing uses, including protective of human health.

50. I don't see how heavy metals possibly dissolve in water. How does that affect plant life and trees, as well as the animals that use those for habitation?

Heavy metals are regulated in the NPDES permit including cadmium and mercury at Outfall 001, cadmium, copper and nickel at Outfall 002, cadmium and iron (dissolved) at Outfall 003, cadmium and copper at Outfall 004, cadmium at Outfall 005, cadmium, manganese, and nickel at Outfall 006, cadmium, iron (dissolved), nickel, manganese, and zinc at Outfall 007, cadmium, copper, nickel, manganese, and zinc at Outfall 008 and manganese at Outfall 011.

Additionally, the renewed and modified NPDES permit requires monthly effluent monitoring for the first year following the effective date of the permit after which semi-annual sampling for Outfalls 006, 007, 008, and 011 for the parameters listed in Special Condition No. 18 of the NPDES permit. These parameters are: arsenic, barium, cadmium, chromium (hexavalent), chromium, copper, lead, manganese, mercury, nickel, phenols, selenium, silver, and zinc.

For Outfall 011, the Agency performed the reasonable potential analysis to determine that the following contaminants do not have a reasonable potential to exceed the WQS in the effluent: arsenic, chromium (total), cyanide (available), iron (dissolved), lead, manganese, mercury, phenols, silver, zinc, and selenium. The Agency also determined that there is no reasonable potential to exceed the WQS outside of the mixing zone for cadmium, copper, nickel, sulfate, and chloride. Further, the Agency determined that there is no reasonable potential to exceed the acute WQS outside of the ZID for cadmium, copper, and nickel.

As the NPDES permit has limits based on the WQS, the uses of the Big Muddy River and Pond Creek will be fully protected.

51. I noted that you said it's 5,000 gallons a minute maximum flow rate. That's like 7.2 million a day. The permit mentions a rate of 2.7 to 2.9 daily. How is that working out mathematically?

The estimated maximum daily volume of discharge does not appear to agree with the maximum estimated discharge rate because this is not anticipated to be a constant discharge at the maximum flow rate on a daily basis. The discharge rate will at times be significantly less than the maximum allowable, based on the flow in the Big Muddy River, in addition to the discharge possibly being episodic or sporadic rather than constant.

Please note that the NPDES permit authorizes a discharge only when the Big Muddy River is between 30 cfs and 2,350 cfs, except after a one-year, 24-hour precipitation event, Outfall 011 can discharge for six consecutive days. The one-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

52. Has the Illinois EPA done any work to assure that the reasonable potential for mercury has been measured down to where it would measure a violation of the mercury standards?

At the direction of Illinois EPA, the applicant has conducted additional sampling in response to comments previously received for Outfalls 001-008. The MDL in the additional sampling is 0.5 nanograms per liter. Based upon the additional data at this MDL, the NPDES permit has been modified to include a limit for mercury at Outfall 001. The data indicate that there is no reasonable potential for Outfalls 002 through 008 to exceed the WQS for mercury.

53. Did the Illinois EPA use or consider the USEPA technical support document in 1991 which is used in order to calculate a reasonable potential according to guidance from US EPA?

Yes, the Agency considered the 1991 USEPA technical support document.

For Outfall 011, based on the effluent characterization, the Agency did the reasonable potential analysis as required by 35 Ill. Adm. Code 309.141(h)(3) and determined that mercury does not have a reasonable potential to exceed the WQS in the effluent.

At the direction of Illinois EPA, the applicant has conducted additional sampling in response to comments previously received for Outfalls 001-008. The MDL in the additional sampling is 0.5 nanograms per liter. Based upon the additional data at this MDL, the NPDES permit has been modified to include a limit for mercury at Outfall 001. The data indicate that there is no reasonable potential for Outfalls 002 through 008 to exceed the WQS for mercury.

Additionally, Special Condition No. 18 of the NPDES permit requires that Outfalls 006, 007, 008, and 011 shall be monitored monthly for the first year following the effective date of the permit after which semi-annual sampling for mercury with such monitoring spaced at approximately six-month intervals during the entire five-year term of the NPDES Permit.

54. There are six data points listed. As you're aware under the technical support document that asks for a minimum of ten, so you're collecting more data at this point?

The technical support document (EPA/505/2-90-001) does not require 10 samples to perform a reasonable potential analysis. The guidance document recommends a higher multiplier should be used when fewer samples are taken.

As an example, with a coefficient of variation of 0.6, if ten samples are taken, the multiplier is 1.7 and if five samples are taken, the multiplier is 2.3.

However, at the direction of Illinois EPA, the applicant has conducted additional sampling in response to comments previously received for Outfalls 001-008. Based upon the additional data, the NPDES permit has been modified to include additional NPDES permit limits for mercury at Outfall 001, copper and nickel at Outfall 002, iron (dissolved) at Outfall 003, copper at Outfall 004, nickel at Outfall 006, iron (dissolved), nickel, and zinc at Outfall 007, and cadmium, copper, nickel, and zinc at Outfall 008.

55. The mine is going to use conductivity probes in order to determine the chloride level. Doesn't chloride as a percentage of conductivity vary under various conditions?

Because chloride as a percent of conductivity varies under various conditions, the applicant is required to develop a site-specific database that correlates the conductivity and chloride concentrations for the Big Muddy River and for the treated effluent. The Agency has included a requirement in the NPDES permit that requires monthly chloride samples and conductivity measurements to ensure that the calibration curves remain accurate. Additionally, the Agency has included a requirement in the NPDES permit that requires that the calibration curves are to be approved by the Agency, before discharge, after six months of operation, and yearly thereafter.

56. What is the date of the last watershed analysis, and how extensive is it that you have used and its impact on the water source for drinking water for southern Illinois?

The Big Muddy River basin is sampled by the Illinois EPA and the IDNR as part of the IBS program, a cooperative sampling effort that routinely collects a variety of samples including fish and macroinvertebrate assemblages. IBS sampling is conducted every five years. The previous IBS sampling year for the Big Muddy River basin was 2018, however, invertebrate monitoring was not completed due to high river levels. The next IBS sampling year for the Big Muddy River is 2023. Big Muddy River sampling locations included in these programs include stations upstream and downstream of the proposed Outfall 011 discharge. There are no known withdrawal locations on the Big Muddy River for drinking water supply.

Additionally, the Agency has an AWQMN throughout the State. The AWQMN has stations on the Big Muddy River, both upstream and downstream of Outfall 011. The ambient stations are sampled for water quality approximately every six weeks.

57. No assessment is provided for the biological or environmental impacts, cumulative water quality, nor ground water withdrawal impacts. Who is going to make sure the discharge meets WQS and does not exceed the allowable volume? The Big Muddy

River should not be a sewer for corporate greed. The biological diversity of the region must be preserved for the enjoyment of all its people.

Monitoring results are reported on DMRs which are submitted quarterly to the Agency. The DMRs are assessed by the Compliance Assurance Section (CAS). The Agency runs monthly compliance reports using ICIS/ECHO to detect SNC at mine NPDES permits. ICIS/ECHO automatically detects violations such as DMR Non-Receipt, Effluent Limit, or Delinquent Schedules/Reports. If a violation is identified as SNC, CAS, on a weekly basis, determines the appropriate compliance or enforcement action to resolve the SNC violations.

The few private wells in the area are generally less than 200 feet in depth. The formation with the saline water is approximately 450 to 600 feet in depth. Any impact of water withdrawal from this depth on the more shallow private wells would be expected to be minimal. Generally, water recharges into the ground in upland areas and discharges to surface water in lowland areas. Water recharging to the depth of the mine would be coming from upland areas further away, not from local creeks.

58. What chemical would be released and what effects does the discharge have on living organisms through an environmental impact study. What value is the Illinois EPA giving to all the proposed damage and loss in the lower Big Muddy River watershed ecosystem? If we must choose between assisting one coal mine and all that comes with an environmentally sound watershed for generations to come, we must choose the future.

A comprehensive analysis of all chemicals that would be released in the Big Muddy River was performed for Outfall 011.

For Outfall 011, the Agency performed the reasonable potential analysis to determine that the following contaminants do not have a reasonable potential to exceed the WQS in the effluent: arsenic, chromium (total), cyanide (available), iron (dissolved), lead, manganese, mercury, phenols, silver, zinc, and selenium. The Agency also determined that there is no reasonable potential to exceed the WQS outside of the mixing zone for cadmium, copper, nickel, sulfate, and chloride. Further, the Agency determined that there is no reasonable potential to exceed the acute WQS outside of the ZID for cadmium, copper, and nickel. Since the discharge is required to comply with all applicable WQS prior to discharge or after mixing in the mixing zone and ZID, the designated uses of the Big Muddy River will be fully protected. Also, as the WQS will be met in the receiving stream, the Agency does not anticipate any damage or loss.

59. My major concern is how will the public and your organization know if the dilution system is effective, especially if the proposed egress of the wastewater is downstream from the gauging station where water is measured and analyzed? Has the wastewater been tested before and after diluted measures taken place on a normal day, and week of operation? What exactly does diluted measures mean? How effective and how

much of the heavy metals are recovered in the process on a daily, weekly, and monthly period? How dangerous will; this water be for the ecosystem? Is it safe for anyone or anything to consume, bath, and swim? What is the economic impact as it relates to tourism and the recreation industry? What is Williamson Energy's safety and health record for its miners? How have other mines dealt with this similar situation?

35 Ill. Adm. Code 302.101 divides the uses of Illinois waters into four groups: General Use; Public and Food Processing Water Supply Use; Chicago Area Water System and the Lower Des Plaines River Uses; and Lake Michigan Basin Use. General Use is used throughout the State and is applicable to the Big Muddy River and Pond Creek. The Board's rules at 35 Ill. Adm. Code 302.202 indicate that the General Use must protect the State's water for the following uses: aquatic life, wildlife, agricultural use, secondary contact use, and most industrial uses.

WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill. Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

The federal regulations at 40 CFR 131.13 authorize states to use mixing zones and zones of initial dilution to implement WQS. Illinois has adopted mixing zones and zones of initial dilution WQS located at 35 Ill. Adm. Code 302.102.

In the zone immediately surrounding an outfall, both the acute and the chronic criteria may be exceeded, but the acute criterion must be met at the edge of this zone, which is often referred to as the acute mixing zone or the ZID. The acute mixing zone is sized to prevent lethality to passing organisms in order to protect the designated use of the waterbody as a whole. In case of the mixing zone, which is often called the chronic mixing zone, the chronic criterion may be exceeded, but the acute criterion must be met. The chronic criterion is met at the edge of the chronic mixing zone. The chronic mixing zone is sized to protect the designated use of the waterbody as a whole.

A mixing zone is a limited area or volume of water where initial dilution of a discharge takes place and where certain numeric water quality criteria may be exceeded.

In this case, the applicant has proposed to install a diffuser in the Big Muddy River. Based on the Agency's review of the CORMIX model and 35 Ill. Adm. Code 302.102, the Agency determined the size of the mixing zone and ZID. Based on recommendations from the Agency, the outfall structure was reevaluated to provide better mixing. The Agency determined the size of the mixing zone and ZID that is consistent with 35 Ill. Adm. Code 302.102.

The diffuser consists of five individual staged single-port diffusers. This design maximizes the mixing zone for each flow condition in the River while allowing the facility to discharge based on the flow in the River. As the flow in the River decreases or the chloride concentration increases, the larger ports are taken off-line so that the WQS can be maintained at the edge of the mixing zone and ZID, as per 35 Ill. Adm. Code 302.102.

In order to determine the chloride concentration at the edge of the mixing zone, the facility will use upstream flow and continuous chloride concentration data and the effluent flow and continuous chloride concentration data to determine the concentration of chloride at the edge of the mixing zone, as per Special Condition No.15 of the NPDES permit. This value will be reported on the DMR and must not exceed 500 mg/L. The upstream and effluent chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration.

Additionally, the permit also requires the facility to install a continuous monitor within 10 feet downstream of the edge of the mixing zone. The downstream chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration. This value will be reported on the DMR and must not exceed 500 mg/L.

As part of the water treatment on-site, the capture of solids within the retention basin systems does serve to reduce the potential concentration of metals that would be discharged. This is due to the fact that most metals preference to be attached to solids under the conditions found in the holding pond and settling ponds.

The safety and health of the workforce is beyond the scope of Illinois EPAs review of the NPDES permit. The Occupational Safety and Health Administration (OSHA) and the OMM's Mine Safety and Training Division is charged with the health and safety concerns of the state's coal mines and their employees.

Several mines in Illinois have employed mixing zones and allowed mixing in their NPDES permits. While this saltwater aquifer is not unique, it is also not common. Most Illinois mines discharge through stormwater discharges while still meeting the WQS. The option of discharging through the stormwater discharges is not possible because of the high volumes of saltwater into the mine.

60. What is a full assessment of the biological or other environmental impacts of the proposed mixing of this contaminated mine water on the river ecosystem and current uses of the Big Muddy River? The mine should be required to build water treatment plant onsite to ensure their water discharges meet regulations.

35 Ill. Adm. Code 302.101 divides the uses of Illinois waters into four groups: General Use; Public and Food Processing Water Supply Use; Chicago Area Water System and the Lower Des Plaines River Uses; and Lake Michigan Basin Use. General Use is used throughout the State and is applicable to the Big Muddy River and Pond Creek. The Board's rules at 35 Ill. Adm. Code 302.202 indicate that the General Use must protect the State's water for the following uses: aquatic life, wildlife, agricultural use, secondary contact use, and most industrial uses.

WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill. Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

The federal regulations at 40 CFR 131.13 authorize states to use mixing zones and zones of initial dilution to implement WQS. Illinois has adopted mixing zones and zones of initial dilution WQS located at 35 Ill. Adm. Code 302.102.

A mixing zone is a limited area or volume of water where initial dilution of a discharge takes place and where certain numeric water quality criteria may be exceeded.

In this case, the applicant has proposed to install a diffuser in the Big Muddy River. Based on the Agency's review of the CORMIX model and 35 Ill. Adm. Code 302.102, the Agency determined the size of the mixing zone and ZID. Based on recommendations from the Agency, the outfall structure was reevaluated to provide better mixing. The Agency determined the size of the mixing zone and ZID that is consistent with 35 Ill. Adm. Code 302.102.

The diffuser consists of five individual staged single-port diffusers. This design maximizes the mixing zone for each flow condition in the River while allowing the facility to discharge based on the flow in the River. As the flow in the River decreases or the chloride concentration increases, the larger ports are taken

off-line so that the WQS can be maintained at the edge of the mixing zone and ZID, as per 35 Ill. Adm. Code 302.102.

In order to determine the chloride concentration at the edge of the mixing zone, the facility will use upstream flow and continuous chloride concentration data and the effluent flow and continuous chloride concentration data to determine the concentration of chloride at the edge of the mixing zone, as per Special Condition No. 15 of the NPDES permit. This value will be reported on the DMR and must not exceed 500 mg/L. The upstream and effluent chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration.

Additionally, the permit also requires the facility to install a continuous monitor within 10 feet downstream of the edge of the mixing zone. The downstream chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration. This value will be reported on the DMR and must not exceed 500 mg/L.

Additionally, to address the impaired status of Pond Creek, the permittee will be required to install and operate a 1.0 MGD RO unit by December 31, 2023. The permittee is authorized to discharge the RO permeate (treated water) to one of the eight sedimentation basins that discharge to Pond Creek via Outfalls 001 – 008 and the RO reject water to the Big Muddy River via Outfall 011.

Also, see response to question #75.

61. Disposing of the wastewater is part of the mine's cost of doing business. The Shawnee National Forest's famed Snake Road which is in Big Muddy's floodplain could be adversely affected. Who is going to monitor the effluent? Will IDNR have someone there on a daily basis when water is being released?

The Shawnee National Forest's Snake Road is approximately 80 miles downstream of the proposed discharge. Perhaps this area is most famous for the biannual 'Snake Migration' across the LaRue Road at the base of the bluffs, adjacent to LaRue Swamp. The road is closed to vehicular traffic every spring and fall to help protect thousands of reptiles and amphibians during their migration between their summer and winter habitats. The primary source of the swamp's water is runoff from west - facing wooded slopes and bluffs of the adjacent Pine Hills and from springs along the base of the bluffs. Therefore, the source of water for the LaRue Swamp is not the Big Muddy River. The Big Muddy River is approximately 1.9 miles Northwest of the LaRue Swamp with a stream and a levee in-between the LaRue Swamp and the Big Muddy River.

The discharge is required to meet all applicable WQS. Therefore, no impact on the Big Muddy River is anticipated.

WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill. Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

IDNR nor the Agency will be at the mine on a daily basis. The applicant will be required to calculate the maximum chloride concentration and the maximum chloride concentration (correlated to the conductivity value) from the downstream continuous monitor be reported on the DMRs. Monitoring results are reported on DMRs which are submitted quarterly to the Agency. The Agency runs monthly compliance reports using ICIS/ECHO to detect SNC at mine NPDES permits. ICIS/ECHO automatically detects violations such as DMR Non-Receipt, Effluent Limit, or Delinquent Schedules/Reports. If a violation is identified as SNC, CAS, on a weekly basis, determines the appropriate compliance or enforcement action to resolve the SNC violations.

The constituents discharged at the outfall location will be transported downstream by the Big Muddy River. Since all water quality criteria will be met at the edge of the mixing zone and ZID, the Agency does not anticipate downstream impacts. Thus, the Agency does not expect any impacts to the Shawnee National Forest's famed Snake Road.

62. Where is the reference to the cumulative effects of adding chemicals to a river that is impaired and continually receives discharges from other sources? Why has there been no assessment of the cumulative impacts on water quality?

35 Ill. Adm. Code 302.101 divides the uses of Illinois waters into four groups: General Use; Public and Food Processing Water Supply Use; Chicago Area Water System and the Lower Des Plaines River Uses; and Lake Michigan Basin Use. General Use is used throughout the State and is applicable to the Big Muddy River and Pond Creek. The Board's rules at 35 Ill. Adm. Code 302.202 indicate that the General Use must protect the State's water for the following uses: aquatic life, wildlife, agricultural use, secondary contact use, and most industrial uses.

WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill.

Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

According to Section 39(a) of the Act, it shall be the duty of the Agency to issue such a permit upon proof by the applicant that the facility will not cause a violation of this Act or of regulations hereunder 415 ILCS 5/39. The Illinois WQS are based on individual constituents; therefore, the individual constituents do not address cumulative impacts on designated uses.

Since the discharge is required to comply with all applicable WQS prior to discharge or after mixing in the mixing zone and ZID, the designated uses will be fully protected.

63. Why would the permittee determine the effluent limitation for chloride and the maximum effluent flow? How would this be monitored? Given the violations related to this company concerning its outfall sites, why would you trust that regulations will be followed?

In order to determine the chloride concentration at the edge of the mixing zone, the facility will use upstream flow and continuous chloride concentration data and the effluent flow and continuous chloride concentration data to determine the concentration of chloride at the edge of the mixing zone, as per Special Condition No. 15 of the NPDES permit. This value will be reported on the DMR and must not exceed 500 mg/L. The upstream and effluent chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration.

Additionally, the permit also requires the facility to install a continuous monitor within 10 feet downstream of the edge of the mixing zone. The downstream chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration. This value will be reported on the DMR and must not exceed 500 mg/L.

The applicant will develop a site-specific database that correlates the conductivity and chloride concentrations for the Big Muddy River and for the treated effluent. The Agency has included a requirement in the NPDES permit that requires monthly chloride samples and conductivity measurements, in the Big Muddy River (upstream and downstream) and in the effluent, to ensure that the calibration curves remain accurate. Additionally, the Agency has included a requirement in the NPDES permit that requires that the calibration curves are to be approved by the Agency, before discharge, after six months of operation, and yearly thereafter.

Monitoring results are reported on DMRs which are submitted quarterly to the Agency. The Agency runs monthly compliance reports using ICIS/ECHO to detect SNC at mine NPDES permits. ICIS/ECHO automatically detects violations such as DMR Non-Receipt, Effluent Limit, or Delinquent Schedules/Reports. If a violation is identified as SNC, CAS, on a weekly basis, determines the appropriate compliance or enforcement action to resolve the SNC violations.

The Agency typically collects samples at NPDES permitted facilities during routine mine inspections. These samples are analyzed by either the Agency laboratory or an outside third-party laboratory. IDNR also inspects the sites and periodically collects samples.

64. Who is going to monitor the dilution process?

The applicant will be required to calculate the maximum chloride concentration and the maximum chloride concentration (correlated to the conductivity value) from the downstream continuous monitor be reported on the DMRs.

Also, see response to question #63 for details on determination of chloride limit in the NPDES permit.

65. Has there been a chemical assay performed in the effluent? If so, is there adequate data from samples from above and below the proposed discharge location to show there is no impact on water quality?

The Agency used the applicant's effluent characterization of the proposed discharge, the AWQMN station data, as well as the Integrated Report to assess the impacts on water quality.

Also, the Big Muddy River basin is sampled by the Illinois EPA and the IDNR as part of the IBS program, a cooperative sampling effort that routinely collects a variety of samples including fish and macroinvertebrate assemblages. IBS sampling is conducted every five years. While the next IBS sampling year for the Big Muddy River basin is 2023, this river system is sampled approximately every six weeks for water chemistry, and additional biological sampling can be conducted as needed. Big Muddy River sampling locations included in these programs include stations upstream and downstream of the proposed discharge.

For Outfall 011, the Agency performed the reasonable potential analysis to determine that the following contaminants do not have a reasonable potential to exceed the WQS in the effluent: arsenic, chromium (total), cyanide (available), iron (dissolved), lead, manganese, mercury, phenols, silver, zinc, and selenium. The Agency also determined that there is no reasonable potential to exceed the WQS outside of the mixing zone for cadmium, copper, nickel, sulfate, and

chloride. Further, the Agency determined that there is no reasonable potential to exceed the acute WQS outside of the ZID for cadmium, copper, and nickel. Since the discharge is required to comply with all applicable WQS prior to discharge or after mixing in the mixing zone and ZID, the designated uses will be fully protected.

66. What is the daily water quality biological, and downstream impacts of this proposal on the Big Muddy?

This discharge will be required to meet the WQS outside of the mixing zone and ZID, therefore, the Agency does not anticipate and biological impacts in the Big Muddy River outside of the mixing zone and ZID.

As a background, WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill. Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

67. What are the actual discharges and pollutant levels for the last five years?

Williamson Energy has had permit violations noted on the NPDES DMRs. The data can be found by going to the ECHO website: https://echo.epa.gov/trends/loading-tool/get-data/monitoring-data-download and clicking on the date range to change and then entering "IL0077666" into the NPDES ID box. After pressing "Submit", the website will open an Excel worksheet with the data.

68. What will the proposed daily discharge of high levels of sulfates and chlorides do to the aquatic life?

35 Ill. Adm. Code 302.101 divides the uses of Illinois waters into four groups: General Use; Public and Food Processing Water Supply Use; Chicago Area Water System and the Lower Des Plaines River Uses; and Lake Michigan Basin Use. General Use is used throughout the State and is applicable to the Big Muddy River and Pond Creek. The Board's rules at 35 Ill. Adm. Code 302.202 indicate that the General Use must protect the State's water for the following uses: aquatic life, wildlife, agricultural use, secondary contact use, and most industrial uses.

The Board's WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill. Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

Since the discharge is required to comply with WQS for sulfate and chloride prior to discharge or after mixing in the mixing zone and ZID, the designated uses will be fully protected.

69. What volume of water will be discharged into the river?

The volume of water discharged to the Big Muddy River is dependent upon the flow rate and duration of discharge; however, under no circumstances shall the maximum discharge rate exceed 5,000 GPM (gallons per minute). The NPDES permit authorizes a discharge only when the Big Muddy River is between 30 cfs and 2,350 cfs, except after a one-year, 24-hour precipitation event, Outfall 011 can discharge for six consecutive days. The one-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

70. Will there be violations of water standards due to the excessive amount of mine waste?

No, as the permit contains limits and conditions based on the Board's WQS.

The Agency performed the reasonable potential analysis to determined that the following contaminants do not have a reasonable potential to exceed the WQS in the effluent: arsenic, chromium (total), cyanide (available), iron (dissolved), lead, manganese, mercury, phenols, silver, zinc, and selenium. The Agency also determined that there is no reasonable potential to exceed the WQS outside of the mixing zone for cadmium, copper, nickel, sulfate, and chloride. Further, the Agency determined that there is no reasonable potential to exceed the acute WQS outside of the ZID for cadmium, copper, and nickel.

Also, the NPDES permit has been modified to include additional NPDES permit limits for mercury at Outfall 001, copper and nickel at Outfall 002, iron (dissolved) at Outfall 003, copper at Outfall 004, nickel at Outfall 006, iron (dissolved), nickel, and zinc at Outfall 007, and cadmium, copper, nickel, and zinc at Outfall 008.

71. Is the water monitoring of the applicants effluent adequate to determine potential effect?

Yes, the monitoring of the applicant's effluent was placed in the NPDES permit to adequately characterize the effluent and ensure that WQS will be met in the receiving stream. The Agency placed terms and conditions in the NPDES permit to ensure that WQS are met.

For Outfall 011, the Agency performed the reasonable potential analysis to determine that the following contaminants do not have a reasonable potential to exceed the WQS in the effluent: arsenic, chromium (total), cyanide (available), iron (dissolved), lead, manganese, mercury, phenols, silver, zinc, and selenium. The Agency also determined that there is no reasonable potential to exceed the WQS outside of the mixing zone for cadmium, copper, nickel, sulfate, and chloride. Further, the Agency determined that there is no reasonable potential to exceed the acute WQS outside of the ZID for cadmium, copper, and nickel.

The renewed and modified NPDES permit requires monthly effluent monitoring for the first year following the effective date of the permit after which semi-annual sampling for Outfalls 006, 007, 008, and 011 for the parameters listed in Special Condition No. 18 of the NPDES permit. These parameters are arsenic, barium, cadmium, chromium (hexavalent), chromium, copper, lead, manganese, mercury, nickel, phenols, selenium, silver, and zinc.

For Outfall 011, in order to determine the chloride concentration at the edge of the mixing zone, the facility will use upstream flow and continuous chloride concentration data and the effluent flow and continuous chloride concentration data to determine the concentration of chloride at the edge of the mixing zone, as per Special Condition No. 15 of the NPDES permit. This value will be reported on the DMR and must not exceed 500 mg/L. The upstream and effluent chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration.

Additionally, the permit also requires the facility to install a continuous monitor within 10 feet downstream of the edge of the mixing zone. The downstream chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration. This value will be reported on the DMR and must not exceed 500 mg/L.

The Agency has included a Special Condition to address this comment. Special Condition No. 16 in the final permit requires that the discharge from Outfall 011 cease under certain conditions, such as: 1) when the continuous chloride data (as measured by conductivity) is 40 percent above the chloride WQS more than 20 percent of the time; 2) when the sulfate samples are 40 percent above the sulfate WQS in more than three of the samples taken within the month; 3) when the iron (dissolved) samples are 40 percent above the iron (dissolved) WQS in more than three of the samples taken within the month; 4) when the copper

samples are 20 percent above the copper WQS in more than three of the samples taken within the month; or 5) when the nickel samples are 20 percent above the nickel WQS in more than three of the samples taken within the month.

Special Condition No. 16 also requires increased monitoring for sulfate, nickel, copper, and iron (dissolved) to three times per week for Outfall 011 within 10 feet downstream of the edge of the mixing zone.

Based on the above, the monitoring of the applicants' effluent is adequate to determine the potential effect of the discharge.

72. Are there any locations downstream that have mussel populations?

Yes, mussels live in the Big Muddy River and the Big Muddy River basin. A basin-wide study was issued March 7, 2012 entitled "Freshwater Mussels of the Big Muddy River" prepared by the Illinois Natural History Survey: Prairie Research Institute, which detail the mussel population found in the Big Muddy River and its' basin. According to the study, no threatened or endangered mussels were found in the Big Muddy River or the Big Muddy River basin.

For a more detailed response on mussel survey and findings, see the response to question #42.

73. What other water downstream may be adversely affected?

Regarding downstream impacts of the Snake Road and LaRue Swamp, please see the responses to questions #61 and #100. Regarding downstream impact of dissolved oxygen, phosphorus, methyl mercury, and the narrative standard, please see response to question #104.

Since the discharge is required to comply with all applicable WQS prior to discharge or after mixing in the mixing zone and ZID, the designated uses will be fully protected. Thus, other water downstream will not be adversely affected.

74. Should there be a total dissolved solids or conductivity limit?

No, because there are no WQS for total dissolved solids or conductivity. The IPCB removed the total dissolved solids WQS and replaced it with a sulfate WQS. In this case, conductivity will be monitored in the effluent, upstream, and downstream for Outfall 011 to ensure that the chloride WQS is met.

75. Are there alternatives to discharging wastewater into streams?

The company provided supplemental information on the alternatives for the antidegradation analysis on December 17, 2019. A summary of the additional information is provided below:

Reverse Osmosis

Reverse Osmosis (RO) is a water purification process that uses partially permeable membranes to remove dissolved salt and other unwanted particles in suspension from the water stream. The RO process includes a pre-treatment pond, ultra-filtration system, high-pressure pumps, membrane assembly, clean water discharge, and wastewater discharge. The concentrated brackish water must then be treated through an additional process for long-term management such as Deep Well Injection or Crystallization or solid waste landfill.

A single plant could be designed to meet the required capacity to treat the initial proposed discharge. After the RO process is completed a highly concentrated waste stream of brackish water is created and requires the development of additional technology to dispose of the highly concentrated brackish water utilizing Deep Well Injection or Crystallization.

RO technology creates a waste stream more hazardous than the water prior to treatment that creates another set of disposal problems. Managing the waste stream from 3.5 MGD RO unit could be problematic as can be seen in the discussions below. Therefore, RO is not considered applicable or feasible as a long-term solution for a mine with a flow of 3.5 million gallons per day.

However, to address the impaired status of Pond Creek, a portion of the flow will be treated by an RO system. A 1.0 MGD RO unit will be required by December 31, 2023, that will discharge the permeate from the RO unit (treated water) to one of the eight sedimentation basins that discharge to Pond Creek via Outfalls 001 – 008 and the RO reject water will be discharged to the Big Muddy River via Outfall 011.

Deep Well Injection of the Mine Infiltration Water

The mine infiltration water could be discharged directly to a UIC well (often referred to as a deep well). The injection wells must be installed at extreme depths to ensure they do not affect potential aquifers used for public consumption and into a geologic formation that is capable of receiving excess water.

The receiving underground formation at this mine site has a limited amount of volume it can receive instantaneously and long term. As the underground formation is filled with excess water, its acceptance can be diminished. Consequently, multiple wells cannot be installed in close proximity to one another or they will negatively influence one another and restrict flow. In order to completely utilize this technology at Pond Creek mine, it is estimated that nine deep injection wells spaced an adequate distance apart would be needed. Additionally, miles of pipeline conveying water to each individual well. An ultra-

filtration system would also be needed to remove any suspended solids from the water prior to injection.

Because of reasons stated above, Deep Well Injection is not practicable for large flows. Deep Well Injection is an unreliable and impractical alternative to dispose of the amount of water infiltrating the Pond Creek mine. Considering the operational difficulties that can be experienced when attempting to discharge to a deep well, Deep Well Injection of the mine infiltration water is not considered either applicable or feasible for the operation of the Mine.

Evaporation

Evaporation works by constructing ponds with large surface area, filling the ponds with water and exposing water to the forces of nature. The groundwater would be evaporated, leaving a TDS residue in a constructed evaporation pond. In the conceptual design, it was assumed the evaporators would be placed on floating platforms along the outside of the water storage lake and operated 214 days per year.

Evaporation ponds require large land areas, and the area would not be expected to be productive once it is used for this purpose (salt accumulation). In order to evaporate 3.5 million gallons per calendar day during the estimated 214-day period, 1,621 evaporators would be required. During the non-evaporative season, a 1,600 acre-ft pond would have to be constructed to store the excess water during this time. This extremely large pond would have an enormous footprint (approximately 160 surface acres, 10-feet deep) because it would have to collect unevaporated water and salt that falls back to the surface.

The climate at the Pond Creek mine is not conducive to evaporation techniques because it is not considered moisture deficient. After the evaporators have finished concentrating the salt water then some additional technology is required to dispose of the salt concentrates (Ex: Deep well injection or Crystallization and Solid Waste Land Fill). Given the inefficient system, operational difficulties to maintain a system of this magnitude, and additional alternatives to dispose of the salt mechanical evaporation is not a viable alternative. This option is not considered applicable or feasible to dispose of water at the Pond Creek mine.

Crystallization

Crystallization is the process that converts the concentrated brackish water generated in a mechanical evaporator or reverse osmosis process to create a disposable salt cake. This process offers an alternative to Deep Well Injection for the brackish reject stream from a reverse osmosis or mechanical evaporator system.

It is possible that the salt cake could be sold, but unlikely, due to the various salt compositions that are captured in a mine related RO process. This process usually culminates in the utilization of a large lined landfill to dispose of the waste that consumes large tracts of land that would otherwise not be impacted. Using crystallization equipment to reduce the RO reject water has a high energy demand.

Considering the above, crystallization is not a standalone treatment option and it is not considered either applicable or feasible as a treatment system for the operation of the mine as a long-term solution.

76. How did Williamson Energy LLC dispose of high chloride/ sulfate water in the past?

See response to question #18(e).

77. Can you require a new Antidegradation Statement that includes the current commercial, recreational, environmental and ecosystem social and economic benefits and has more of a total assessment instead of only what is of benefit to the mine?

An antidegradation assessment was completed as per 35 Ill. Adm. Code 302.105. The company updated and enhanced the data provided for the alternative analysis that is required in the antidegradation assessment (see response to question #75).

The applicant indicates that the discharge will support a mining operation that employs over 235 direct jobs with a payroll of approximately $20.2 million annually. In addition to the direct employees, approximately 100 additional persons such as truck drivers, engineers, and support personnel are employed full time through operation of the mine. Further, based on an economic formula widely accepted in the state of three persons employed in indirect or induced jobs per each direct coal industry job, an additional 705 persons are employed as a result of this mine. Williamson Energy contributes approximately $1.5 million in federal taxes and approximately $0.7 million in local and state taxes.

The company has summarized the fish data from 1964 to 2018 that has occurred in the Big Muddy River and in the Big Muddy River watershed. The company has provided a mussel survey performed in the Big Muddy River Basin titled "Freshwater Mussels of the Big Muddy River" and published March 7, 2012.

For a more detailed response on mussel and macroinvertebrates survey and findings, see the response to question #42.

Based on the above, the Agency concludes that the antidegradation assessment satisfied all of the requirements of 35 Ill. Adm. Code 302.105.

78. Can Illinois EPA require an Environmental Impact Statement for this permit? I'm concerned about pollution loading to area surface and groundwater resources and the alarming impacts downstream affecting the Mississippi River.

The environmental impact statement is mandated by the National Environmental Policy Act of 1969 and involves projects that constitute federal action, as defined by law, including those that use federal land, federal tax dollars under federal agency jurisdiction.

Illinois EPA evaluates permit applications based on the standards and requirements of the Illinois Environmental Protection Act, the Clean Water Act and appropriate state and federal regulations to issue a NPDES permit that addresses pollution loading as well as impacts to groundwater and downstream waters.

79. What will be the impact from increased water volume and toxins contained in floodwaters on the rare floodplain fauna and flora?

35 Ill. Adm. Code 302.101 divides the uses of Illinois waters into four groups: General Use; Public and Food Processing Water Supply Use; Chicago Area Water System and the Lower Des Plaines River Uses; and Lake Michigan Basin Use. General Use is used throughout the State and is applicable to the Big Muddy River and Pond Creek. The Board's rules at 35 Ill. Adm. Code 302.202 indicate that the General Use must protect the State's water for the following uses: aquatic life, wildlife, agricultural use, secondary contact use, and most industrial uses.

WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill. Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

For Outfall 011, the Agency performed the reasonable potential analysis to determine that the following contaminants do not have a reasonable potential to exceed the WQS in the effluent: arsenic, chromium (total), cyanide (available), iron (dissolved), lead, manganese, mercury, phenols, silver, zinc, and selenium. The Agency also determined that there is no reasonable potential to exceed the WQS outside of the mixing zone for cadmium, copper, nickel, sulfate, and

chloride. Further, the Agency determined that there is no reasonable potential to exceed the acute WQS outside of the ZID for cadmium, copper, and nickel.

Since the discharge is required to comply with all applicable WQS prior to discharge or after mixing in the mixing zone and ZID, the designated uses will be fully protected. Thus, other water downstream will not be adversely affected.

80. Has Illinois EPA considered the cumulative impacts from the discharge along with eight existing outfall discharge locations and will it create more suspended solids in the river?

The discharge from each of the eight outfalls is required to comply with the WQS, therefore, there will not be any cumulative effects of discharges from these eight outfalls.

Because of the impaired status, the permit has been modified to not authorize discharges from the proposed Outfalls 009 and 009ES into Pond Creek and the unnamed tributary of Pond Creek respectively. Additionally, to address the impaired status of Pond Creek, the permittee will be required to install and operate a 1.0 MGD RO unit by December 31, 2023. The permittee is authorized to discharge the RO permeate (treated water) to one of the eight sedimentation basins that discharge to Pond Creek via Outfalls 001 – 008 and the RO reject water to the Big Muddy River via Outfall 011.

Additionally, the NPDES permit has been modified to incorporate a limit of 32.2 mg/L for Outfall 011 applied as a yearly average.

81. Why is the WQS for iron listed on the draft permit for the pond Creek pipeline as 3 mg/6mgL when the standard on the EPA WQS report 2019 states that the acceptable level is 1 mg/L?

The 3 mg/L monthly average and 6 mg/L daily maximum effluent limitations for iron (total) are effluent standards which must be met at the end of the pipe whereas, the WQS is 1.0 mg/L for iron (dissolved). As there was no reasonable potential to exceed WQS for iron (dissolved), no permit limit is necessary except as noted below.

At the direction of Illinois EPA, the applicant has conducted additional sampling in response to comments previously received for Outfalls 001-008. Based upon the additional data, the NPDES permit has been modified to include additional NPDES permit limits for iron (dissolved) at Outfall 003 and Outfall 007.

82. Why has the Mercury advisory suddenly been lifted?

The mercury advisory has not been lifted. When the Agency checked the Illinois Department of Public Health website, Common Carp, Crappie, Largemouth

Bass, and Channel Catfish were listed under the Big Muddy River and its tributaries. The fish consumption advisory due to mercury are still in place. The IDPH listings can be found at: http://www.dph.illinois.gov/topics-services/environmental-health-protection/toxicology/fish-advisories/map/bigmuddy-river-multicounty.

83. How can the Illinois EPA allow such a violation of its own and national regulations for chloride levels?

The NPDES permit requires the permittee to comply with the State's WQS for chloride. The NPDES permit, as drafted, contains limits and conditions to ensure that the discharge meets the WQS, which are protective of the existing uses of the Big Muddy River.

The permit also requires the facility to install a continuous monitor within 10 feet downstream of the edge of the mixing zone. The downstream chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration. This value will be reported on the DMR and must not exceed 500 mg/L. Since the chloride WQS will be met at the edge of the mixing zone, the Agency will not be allowing violations of the chloride WQS.

Also, it should be noted, that in order to determine the chloride concentration at the edge of the mixing zone, the facility will use upstream flow and continuous chloride concentration data and the effluent flow and continuous chloride concentration data to determine the concentration of chloride at the edge of the mixing zone, as per Special Condition No. 15 of the NPDES permit. This value will be reported on the DMR and must not exceed 500 mg/L. The upstream and effluent chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration.

84. How's the Illinois EPA taking into consideration current studies regarding effects of salination on aquatic animals?

The Agency did not consider the chloride concentrations in these studies as the concentrations recommended by these studies have not been adopted by the Board.

Under the Act, the Illinois EPA is required to issue a permit to an applicant upon proof that the proposed facility or equipment will not cause a violation of the Act or promulgated regulations. See, 415 ILCS 5/39(a). This standard is a mandatory one, expressed in the language of the provision as a "duty" that is imposed upon the Illinois EPA. While agency deliberation of certain aspects of the permit may be grounded in the exercise of discretion, the broader legal standard governing permit issuance or denial limits the discretion of the Illinois

EPA. The Illinois EPA finds that the legal standard noted above has been met. Nothing in the record, including the public comments on the draft permit, adduces otherwise.

In this case, the applicant provided data and the antidegradation assessment to show that its discharge will comply with all applicable WQS. The NPDES permit, as drafted, contains limits and conditions to ensure that the discharge meets the WQS, which are protective of the existing uses of the Big Muddy River.

85. Mixing is not allowed in waters containing mussel beds an endangered species habitat has this been determined by the EPA and IDNR? How's the current state of the river as well as the Sugar Creek mine discharge pipeline been considered in determining this?

On November 2, 2016, the IDNR EcoCAT web-based tool was used, which indicated that there were no records of aquatic threatened or endangered species present in the vicinity of the discharge. While the IDNR EcoCAT web-based tool did not terminate the consultation because of the nearby presence of Chuck-Will's-Willow (*Caprimulgus carolinensis*), IDNR evaluated the information and terminated the consultation on September 26, 2019, which was reevaluated and terminated again on October 22, 2021. In their termination letters, IDNR reiterated that there were no records of threatened or endangered species present. However, the termination letters indicated that there were 11 species designated in the Illinois Wildlife Action Plan as "Species in Greatest Need of Conservation" (SGNC). The SGNC that occur in the Big Muddy River include the Alligator Gar (*Atractosteus spatula*), Blacktail Shiner (*Cyprinella venusta*), Brown Bullhead (*Ameiurus Nebulosus*), Flier (*Centrarchus macropterus*), Mooneye (*Hiodon tergisus*), Paddlefish (*Polyodon spathula*), Pugnose Minnow (*Opsopoeodus emiliae*), Ribbon Shiner (*Lythrurus fumeus*), River Darter (*Percina shumardi*), Spottail Darter (*Etheostoma squamiceps*), and Stripetail Darter (*Etheostoma kennicotti*). IDNR also noted that the Pistolgrip (*Tritogonia verrucose*) has also been found in the Big Muddy River. In conclusion, IDNR indicated that "strict adherence to all effluent limits and all effluent monitoring requirements in accordance with NPDES Permit IL0077666 is requested."

A basin-wide study was issued March 7, 2012 entitled "Freshwater Mussels of the Big Muddy River" prepared by the Illinois Natural History Survey: Prairie Research Institute, which detail the mussel population found in the Big Muddy River and its' basin. According to the study, no threatened or endangered mussels were found in the Big Muddy River or the Big Muddy River basin.

The mussel survey was conducted April 22-26 and June 5, 2020. The stream discharge rate at the Plumfield, Illinois gauge was between 742 and 855 cfs during this study. The permit has a condition that the mussel survey will be repeated one year after commencement of the discharge.

The survey area encompassed the width of the river from 50 m upstream to 150 m downstream of the proposed outfall location. The mixing zone has a length of 46 feet (13.3 meters) by a width of 25 feet (7.62 meters). The Survey Area was divided into 40 approximately 10x10 m cells. Four 5-minute qualitative samples were collected within each cell. Qualitative sampling entailed a diver searching the substrate, collecting all unionids encountered within the time period. Substrate composition (Wentworth scale) and water depth (meters) were recorded at the beginning of each sample. Unionids were classified as live, fresh dead, and weathered dead. Live individuals were identified to species, aged, and measured (length in millimeters). At least one individual of each live species was photographed, and (if available) a dead shell of each species was retained as a voucher specimen. All live individuals of non-listed species were relocated to a Recipient Area upstream of the project area with a similar substrate and depth profile as the Survey Area.

A total of 46 live individuals of 11 species were collected from the Survey Area. *Megalonaias nervosa* was the most commonly collected species (n=13), followed by *Leptodea fragilis* (n=11) and *Potamilus alatus* (n=5); remaining species were represented by 4 or fewer live individuals each, including the following; *Fusconaia flava* (n=1), *Tritogonia verrucosa* (n=2), *Quadrula quadrula* (n=1), *Lampsilis teres* (n=4), *Truncilla truncata* (n=1), *Lampsilis cardium* (n=1), *Pyganodon grandis* (n=3), and *Lasmigona complanata* (n=4). Abundance was low, with 16 of 37 searched cells yielding no live individuals.

Unionids were scattered throughout the Survey Area; however, abundance appeared to be greater towards the downstream end of the site, as 23 of the 46 live individuals were collected there. Therefore, the greatest concentration of mussels found were approximately 80 meters downstream of the mixing zone. No mussel beds were found in the mixing zone. In the area of the mixing zone, only one live mussel was found. No state listed species (live individuals or dead shell material) were observed in this area.

Since no mussel beds were found within the mixing zone, the Agency has determined that the mixing zone satisfies 35 Ill. Adm. Code 302.102(b)(4) which states, "Mixing is not allowed in waters containing mussel beds, endangered species habitat, fish spawning areas, areas of important aquatic life habitat, or any other natural features vital to the well-being of aquatic life in such a manner that the maintenance of aquatic life in the body of water as a whole would be adversely affected."

Also, as the discharge is required to meet all WQS and permit conditions, which addresses the request from IDNR that "strict adherence to all effluent limits and all effluent monitoring requirements in accordance with NPDES Permit IL0077666 is requested."

86. Given the Big Muddy River already has elevated levels of sulfates, and manganese, mixing would be violating this regulation how can a permit be granted for a mixing zone?

Please see response to question #7.

87. What is the current state of the fish population in the Big Muddy? Has the Illinois EPA taken into consideration the numerous sections of the Big Muddy River downstream from the pipeline are listed not only on the National Rivers Inventory but also in the sub several state and federally listed special environmental zones and therefore has special protections?

The Big Muddy River and tributaries are routinely sampled every five years as part of the IBS program, with the most recent sampling conducted in 2018. While there is always variability between samples due to a variety of factors including fluctuating river levels, fish populations in the mainstem Big Muddy River as well as Pond Creek are considered to be relatively stable at this time. The next IBS sampling is scheduled for 2023.

In IDNR's EcoCAT termination letters, IDNR indicated that there were no records of state-listed species or protected natural areas in the vicinity of the discharge of the Big Muddy River. However, IDNR did note that there were 96 species of fish in the Big Muddy River, as well as eleven fish species and one mussel designated in the Illinois Wildlife Action Plan as "Species in Greatest Need of Conservation". Please see the response to question #32 for details of Species in Greatest Need of Conservation.

35 Ill. Adm. Code 302.101 divides the uses of Illinois waters into four groups: General Use; Public and Food Processing Water Supply Use; Chicago Area Water System and the Lower Des Plaines River Uses; and Lake Michigan Basin Use. General Use is used throughout the State and is applicable to the Big Muddy River and Pond Creek. The Board's rules at 35 Ill. Adm. Code 302.202 indicate that the General Use must protect the State's water for the following uses: aquatic life, wildlife, agricultural use, secondary contact use, and most industrial uses.

WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill. Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

The Big Muddy River has no special designation or protection. As the Agency determined that there is no reasonable potential to exceed the WQS in the effluent for arsenic, chromium (total), cyanide (available), iron (dissolved), lead, manganese, mercury, phenols, silver, zinc, and selenium. The Agency also determined that there is no reasonable potential to exceed the WQS outside of the mixing zone for cadmium, copper, nickel, sulfate, and chloride. Further, the Agency determined that there is no reasonable potential to exceed the acute WQS outside of the ZID for cadmium, copper, and nickel.

Since the discharge is required to comply with all applicable WQS prior to discharge or after mixing in the mixing zone and ZID, the designated uses will be fully protected. Thus, downstream uses will also be protected.

As all of the WQS will be met in the receiving stream, there will not be any impacts to the fish population in the Big Muddy River.

88. Has Illinois EPA fully considered whether granting this permit for dumping more pollutants into the already impaired big muddy River will violate the law as stated in Article XI of our state constitution?

Article XI of the state constitution establishes "a healthful environment" as a public policy of Illinois and mandates the General Assembly to pass legislation to implement and enforce that policy.

The Act provides the criteria that the Agency must consider in allowing discharge into Illinois waters.

Under the Act, the Illinois EPA is required to issue a permit to an applicant upon proof that the proposed facility or equipment will not cause a violation of the Act or promulgated regulations. See, 415 ILCS 5/39(a). This standard is a mandatory one, expressed in the language of the provision as a "duty" that is imposed upon the Illinois EPA. While Agency deliberation of certain aspects of the permit may be grounded in the exercise of discretion, the broader legal standard governing permit issuance or denial limits the discretion of the Illinois EPA. The Illinois EPA finds that the legal standard noted above has been met. Nothing in the record, including the public comments on the draft permit, adduces otherwise.

In this case, the applicant provided data to show that its discharge will comply with all applicable WQS. The NPDES permit, as drafted, contains limits and conditions to ensure that the discharge meets the applicable WQS, which are protective of the existing uses of the Big Muddy River.

89. How will the Illinois EPA verify all these calibrations will work so that the effluent stays within the limits of the regulations?

In order to determine the chloride concentration at the edge of the mixing zone, the facility will use upstream flow and continuous chloride concentration data and the effluent flow and continuous chloride concentration data to determine the concentration of chloride at the edge of the mixing zone, as per Special Condition No. 15 of the NPDES permit. This value will be reported on the DMR and must not exceed 500 mg/L. The upstream and effluent chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration.

Additionally, the permit also requires the facility to install a continuous monitor within 10 feet downstream of the edge of the mixing zone. The downstream chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration. This value will be reported on the DMR and must not exceed 500 mg/L.

The applicant will develop a site-specific database that correlates the conductivity and chloride concentrations for the Big Muddy River and for the treated effluent. The Agency has included a requirement in the NPDES permit that requires monthly chloride samples and conductivity measurements, in the Big Muddy River (upstream and downstream) and in the effluent, to ensure that the calibration curves remain accurate. Additionally, the Agency has included a requirement in the NPDES permit that requires that the calibration curves are to be approved by the Agency, before discharge, after six months of operation, and yearly thereafter.

Monitoring results are reported on DMRs which are submitted quarterly to the Agency. The Agency runs monthly compliance reports using ICIS/ECHO to detect SNC at mine NPDES permits. ICIS/ECHO automatically detects violations such as DMR Non-Receipt, Effluent Limit, or Delinquent Schedules/Reports. If a violation is identified as SNC, CAS, on a weekly basis, determines the appropriate compliance or enforcement action to resolve the SNC violations.

The Agency will verify that the effluent stays within the limits of the regulations, by reviewing the DMRs for the mixing calculation and downstream monitor to ensure that the chloride WQS is met in the receiving stream.

90. What gives Illinois EPA confidence that there will not be acutely high concentrations that could hurt fish, mussels, plants, macroinvertebrates, and other wildlife?

Please see the response to question #45.

91. How current are the surveys of fish and macroinvertebrates in Pond Creek and Big Muddy River?

The fish surveys are part of a long-term monitoring program and was sampled in 2018. The company performed a macroinvertebrate survey in 2019 and are required by the NPDES permit to resample one year from the commencement of discharge from Outfall 011.

The previous IBS sampling year for the Big Muddy River basin was 2018, however, invertebrate monitoring was not completed on the Big Muddy River due to high river levels. Pond Creek was sampled in 2018 for fish and macroinvertebrates. The next IBS sampling year for the Big Muddy River basin is 2023.

The company also had Alliance Consulting perform a Benthic Macroinvertebrates Community Survey of the Big Muddy River approximately 0.77 miles downstream of the proposed outfall location. The sampling was done on November 20th, 2019. Due to the depth of the Big Muddy River and accessibility issues, the wadeable collection method was not possible. The benthic macroinvertebrates were sampled using and Ekman Dredge dropped from an abandoned railroad bridge. The mIBI scored 23.8, which is a rating of fair and 80.7% of the sample was made up of tolerant taxa. According to the report, the metrics reflect a stream with poor habitat quality, low biodiversity, and a struggling benthic macroinvertebrate community.

92. Why is Williamson Energy not required to put up a bond for repairing damage that may be caused by their operations?

IDNR/OMM does in fact require a bond to be posted for the Pond Creek facility. That Department should be contacted regarding the specifics of the bonding requirements and what material damages are covered. As noted in the response to question #6, bonding requirements are covered by 62 Ill. Adm. Code Part 1800.

93. Can Williamson Energy be responsible for restoring the fish population?

Williamson Energy is prohibited from causing water pollution that harms or kills fish or other aquatic life. If such harm occurs the Agency and the IDNR can pursue an enforcement action which may include remedies authorized under the Act and other environmental laws.

94. How do we know what contaminants could be deposited without at least a full analysis prior to permit being issued?

The contaminants of the mine's discharge are known because the facility has been discharging to the surface for over five years and has characterized the effluent in the application and antidegradation assessment.

Because of the impaired status of Pond Creek, the permit does not authorize discharges from the proposed Outfall 009 to Pond Creek or the proposed Outfall 009ES to an unnamed tributary of Pond Creek. The proposed Outfalls 009 and 009ES have been removed from the NPDES permit.

For Outfall 011, the Agency performed the reasonable potential analysis to determine that the following contaminants do not have a reasonable potential to exceed the WQS in the effluent: arsenic, chromium (total), cyanide (available), iron (dissolved), lead, manganese, mercury, phenols, silver, zinc, and selenium. The Agency also determined that there is no reasonable potential to exceed the WQS outside of the mixing zone for cadmium, copper, nickel, sulfate, and chloride. Further, the Agency determined that there is no reasonable potential to exceed the acute WQS outside of the ZID for cadmium, copper, and nickel.

Since the discharge is required to comply with all applicable WQS prior to discharge or after mixing in the mixing zone and ZID, the designated uses will be fully protected.

95. What happens to the wildlife that lives in these backflow areas? Why do corporations get away with dumping the true costs of their for-profit operations? Who's going to pay to clean up our waterways or deal with the cancer that will surely develop form this pollution?

The NPDES permit requires Williamson to comply with the WQS in the waters in the Big Muddy River as well as Pond Creek and their tributaries. As these WQS are protective of the wildlife, the Agency does not expect wildlife to be impacted.

The Act and Board regulations require the Agency to ensure that the discharge complies with all applicable standards irrespective of cost. In this permit, the discharge is required to comply with all applicable WQS prior to discharge or after mixing in the mixing zone and ZID, thus the designated uses will be fully protected.

For a detailed response for permit requirements, please see the response to question # 17.

As described in the response to question #59, if the discharge complies with the WQS, then the designated uses such as human health will be protected. In this case, the WQS will be met outside the mixing zone and zone and initial

96. Foresight Energy is near bankrupt, who will pay for the cleanup when the company goes down? Who determines what is economically acceptable?

See response to question #19.

97. How will this stagnation of river water during floods impact assumptions and projections on dilution process and the distribution of polluted mine water across the landscape?

The NPDES permit authorizes a discharge only when the Big Muddy River is between 30 cfs and 2,350 cfs, except after a one-year, 24-hour precipitation event, Outfall 011 can discharge for six consecutive days. The one-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

Flooding will further reduce the concentration of the parameters.

98. Will the applicant be allowed to pump contaminants into the Big Muddy during periods when it is flowing backwards? How will the applicant monitor dilution of mine wastes in the water column during periods of backwards flow and stagnation?

There are two scenarios where the Agency is aware of a stream or river flowing "backward". The first is when the parent stream is low and a tributary is flowing hard, the parent will back up and flow backward on a very localized level. This is usually less than 100 yards or so from where the tributary enters. The second is when the parent stream (e.g. the Mississippi River) is rising and the tributary (in this case, the Big Muddy River) is low, the rising waters can back up into the tributary which effectively makes it flow backwards. In the case of the Big Muddy, the Agency has witnessed this occur up to several miles from the mouth of the Big Muddy. However, this discharge is approximately 85 miles from the Mississippi River, so backflow from the Mississippi River is not possible.

It is important to note that neither of the two situations described above are typically representative of the Big Muddy River at Outfall 011.

Additionally, the NPDES permit authorizes a discharge only when the Big Muddy River is between 30 cfs and 2,350 cfs, except after a one-year, 24-hour precipitation event, Outfall 011 can discharge for six consecutive days. The one-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

If the Big Muddy River is flowing backwards, the flow will be less than 30 cfs, therefore, any discharge while the Big Muddy River is flowing backward would be prohibited.

99. If the mine waste contaminants don't go down stream, will they spread out over fields and forests and how will the applicant monitor the distribution of mine wastes? Will contaminants become more concentrated as flood water recede? What will be the impact of these mine contaminates on farm soils and wildlife?

The constituents discharged at the outfall location will be transported downstream by the Big Muddy River. Flood waters are not expected to

concentrate the discharge. In fact, flooding will further reduce the concentration of the parameters.

The dissolved constituents in the water, as the flood waters recede, will move with the water.

For a detailed response to uses, how WQS are protective of those uses, and how the diffuser meets the WQS in the mixing zone and ZID, please see the response to question #59.

Since WQS are met outside of the mixing zone and ZID, farm soils and wildlife are not expected to be impacted by the constituents. The additional floodwaters that will be present during floods will further reduce the concentrations.

100. What are the impacts to the LaRue Swamp if polluted mine water seeps under the Big Muddy Levy?

LaRue Swamp is approximately 80 miles downstream of the proposed discharge. La Rue Swamp in combination with the adjacent Pine Hills is one of the richest, most biologically diverse areas in Illinois. The Pine Hills/La Rue Swamp area contains 43% of all the plant species known from Illinois. The primary source of the swamps' water is runoff from west - facing wooded slopes and bluffs of the adjacent Pine Hills and from springs along the base of the bluffs. Therefore, the source of water for the LaRue Swamp is not the Big Muddy River. The Big Muddy River is approximately 1.9 miles Northwest of the LaRue Swamp with a levee and a stream in-between the LaRue Swamp and the Big Muddy River.

The constituents discharged at the outfall location will be transported downstream by the Big Muddy River. Since all water quality criteria will be met at the edge of the mixing zone and ZID, the Agency does not anticipate any downstream impacts. Thus, the Agency does not expect any impacts to the LaRue Swamp.

101. What is the total and exact chemical composition, as well as the safety and inspection proposed by this pipeline?

The pipeline will be constructed of high-density polyethylene (HDPE) material. Special Condition #15 has additional requirements for the pipeline including construction with new material, pressure control sensors (or other type of equipment) to stop the pumps when there is a loss of pressure the in the pipeline and inspection reports available to the inspectors when requested.

102. Why would the Illinois EPA issue a permit to a company when a company is going into bankruptcy and leave the burden of clean up on the backs of taxpayers?

See response to question #19.

103. The NPDES permit does not ensure compliance as written with Illinois WQS 35 Ill. Adm. Code 302. 105(a) by allowing increased discharge of chloride, sulfate, total suspended solids and other pollutants that will adversely affect existing uses of the Big Muddy River and Pond Creek and other creeks in the area. The applicants plan to prevent violations of Illinois WQS outside the mixing zone for numerous pollutants is unlikely to be implemented. Among the ways in which existing uses will be impacted will be through chemical and biological processes resulting from allowed discharges that will cause increased methyl mercury, increased phosphorus, increased cyanobacteria and decreased dissolved oxygen (DO) in the water column. Damage to existing uses may also occur through damage to creeks not receiving discharges from the mine but that may be affected in quality from reduced stream flow caused by groundwater moving downward to fill areas vacated by groundwater filling the mine.

The permit doesn't violate 35 Ill. Adm. Code 302.105(a) because 35 Ill. Adm. Code 302.101 divides the uses of Illinois waters into four groups: General Use; Public and Food Processing Water Supply Use; Chicago Area Water System and the Lower Des Plaines River Uses; and Lake Michigan Basin Use. General Use is used throughout the State and is applicable to the Big Muddy River and Pond Creek. The Board's rules at 35 Ill. Adm. Code 302.202 indicate that the General Use must protect the State's water for the following uses: aquatic life, wildlife, agricultural use, secondary contact use, and most industrial uses.

WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill. Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

The federal regulations at 40 CFR 131.13 authorize states to use mixing zones and zones of initial dilution to implement WQS. Illinois has adopted mixing zones and zones of initial dilution WQS located at 35 Ill. Adm. Code 302.102.

In the zone immediately surrounding an outfall, both the acute and the chronic criteria may be exceeded, but the acute criterion must be met at the edge of this zone, which is often referred to as the acute mixing zone or the ZID. The acute mixing zone is sized to prevent lethality to passing organisms in order to protect the designated use of the waterbody as a whole. In case of the mixing zone, which is often called the chronic mixing zone, the chronic criterion may be

exceeded, but the acute criterion must be met. The chronic criterion is met at the edge of the chronic mixing zone. The chronic mixing zone is sized to protect the designated use of the waterbody as a whole.

A mixing zone is a limited area or volume of water where initial dilution of a discharge takes place and where certain numeric water quality criteria may be exceeded.

In this case, the applicant has proposed to install a diffuser in the Big Muddy River. Based on the Agency's review of the CORMIX model and 35 Ill. Adm. Code 302.102, the Agency determined the size of the mixing zone and ZID. Based on recommendations from the Agency, the outfall structure was reevaluated to provide better mixing. The Agency determined the size of the mixing zone and ZID that is consistent with 35 Ill. Adm. Code 302.102.

The diffuser consists of five individual staged single-port diffusers. This design maximizes the mixing zone for each flow condition in the River while allowing the facility to discharge based on the flow in the River. As the flow in the River decreases or the chloride concentration increases, the larger ports are taken off-line so that the WQS can be maintained at the edge of the mixing zone and ZID, as per 35 Ill. Adm. Code 302.102.

In order to determine the chloride concentration at the edge of the mixing zone, the facility will use upstream flow and continuous chloride concentration data and the effluent flow and continuous chloride concentration data to determine the concentration of chloride at the edge of the mixing zone, as per Special Condition No. 15 of the NPDES permit. This value will be reported on the DMR and must not exceed 500 mg/L. The upstream and effluent chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration.

Additionally, the permit also requires the facility to install a continuous monitor within 10 feet downstream of the edge of the mixing zone. The downstream chloride concentration will be determined from the use of a continuous conductivity monitor that has been correlated to the chloride concentration. This value will be reported on the DMR and must not exceed 500 mg/L.

The Agency has included a Special Condition to address this comment. Special Condition No. 16 in the final permit requires that the discharge from Outfall 011 cease under certain conditions, such as: 1) when the continuous chloride data (as measured by conductivity) is 40 percent above the chloride WQS more than 20 percent of the time; 2) when the sulfate samples are 40 percent above the sulfate WQS in more than three of the samples taken within the month; 3) when the iron (dissolved) samples are 40 percent above the iron (dissolved) WQS in more than three of the samples taken within the month; 4) when the copper samples are 20 percent above the copper WQS in more than three of the

samples taken within the month; or 5) when the nickel samples are 20 percent above the nickel WQS in more than three of the samples taken within the month.

Monitoring results are reported on DMRs which are submitted quarterly to the Agency. The Agency runs monthly compliance reports using ICIS/ECHO to detect significant non-compliance (SNC) at mine NPDES permits. ICIS/ECHO automatically detects violations such as DMR Non-Receipt, Effluent Limit, or Delinquent Schedules/Reports. If a violation is identified as SNC, CAS, on a weekly basis, determines the appropriate compliance or enforcement action to resolve the SNC violations.

Because of the impaired status of Pond Creek, the permit does not authorize discharges from the proposed Outfall 009 to Pond Creek or the proposed Outfall 009ES to an unnamed tributary of Pond Creek. The proposed Outfalls 009 and 009ES have been removed from the NPDES permit.

Generally, water recharges into the ground in upland areas and discharges to surface water in lowland areas. Water recharging to the depth of the mine would be coming from upland areas further away, not from local creeks.

Cyanobacteria have the ability to convert nitrogen gas into inorganic forms of nitrogen needed for growth. The claim that there will be an increase in cyanobacteria is based on the assumption that there will be an increase in phosphorus. There will be no increase in phosphorus because the mine discharge doesn't contain phosphorus. Thus, there will not be an increase of cyanobacteria.

The effluent does not have sufficient deoxygenating chemicals or sufficient phosphorus to contribute to the DO impairment or potential impairment of phosphorus and will not cause a violation of the WQS.

Since the discharge is required to comply with all applicable WQS prior to discharge or after mixing in the mixing zone and ZID, the designated uses will be fully protected. Thus, the NPDES permit ensures compliance with the applicable WQS and uses. Regarding methyl mercury, please see response #49.

a.) Nickel has not been properly considered and the cumulative effect of the increased concentrations of all these pollutants togethers has been ignored. The limits of the testing and the sensitivity of the testing methods is such that increased loading of a number of other pollutants is probable.

The Agency did consider the additional loading for nickel in the December 12, 2016 antidegradation assessment. The antidegradation memo indicated that nickel loading would increase from 1 to 8 lbs/day with a concentration ranging from 0.004 to 0.014 mg/L.

As part of the permitting process, the mine sampled its expected effluent for total and dissolved nickel, each with a MDL of 0.005 mg/L. For Outfall 011, the Agency determined that there is no reasonable potential to exceed the WQS outside of the mixing zone for nickel. Further, the Agency determined that there is no reasonable potential to exceed the acute WQS outside of the ZID for nickel.

Nickel has a reasonable potential to exceed the WQS at Outfalls 002, 006, 007, and 008 and the NPDES permit has been modified to include a nickel permit limit at each of these outfalls.

The renewed and modified NPDES permit requires monthly effluent monitoring for the first year following the effective date of the permit after which semi-annual sampling for Outfalls 006, 007, 008, and 011 for the parameters listed in Special Condition No. 18 of the NPDES permit, which includes nickel.

Also, because of the impaired status, the permit has been modified to not authorize discharges from the proposed Outfalls 009 and 009ES into Pond Creek and the unnamed tributary of Pond Creek respectively. Additionally, to address the impaired status of Pond Creek, the permittee will be required to install and operate a 1.0 MGD RO unit by December 31, 2023. The permittee is authorized to discharge the RO permeate (treated water) to one of the eight sedimentation basins that discharge to Pond Creek via Outfalls 001 – 008 and the RO reject water to the Big Muddy River via Outfall 011.

104. The NPDES permit does not ensure compliance as written with Illinois WQS 35 Ill. Adm. Code 302.105, and 309.141(d) and 309.143. by increasing the levels of methyl mercury and phosphorus, decreasing DO levels, and causing violations of narrative standards in the Big Muddy. The Big Muddy is already listed as impaired by methyl mercury, low DO and TSS in the receiving segment and numerous downstream segments and as potentially impaired by phosphorus.

The permit doesn't violate 35 Ill. Adm. Code 302.105 because 35 Ill. Adm. Code 302.101 divides the uses of Illinois waters into four groups: General Use; Public and Food Processing Water Supply Use; Chicago Area Water System and the Lower Des Plaines River Uses; and Lake Michigan Basin Use. General Use is used throughout the State and is applicable to the Big Muddy River and Pond Creek. The Board's rules at 35 Ill. Adm. Code 302.202 indicate that the General Use must protect the State's water for the following uses: aquatic life, wildlife, agricultural use, secondary contact use, and most industrial uses.

WQS are a set of water quality criteria sufficient to support the designated uses of each waterbody. If a waterbody has multiple use designations, the criteria must support the most sensitive use. Numeric WQS are developed for specific parameters to protect aquatic life and human health and, in some cases, wildlife

from the deleterious effects of pollutants. Illinois' numeric WQS are at 35 Ill. Adm. Code Parts 302 and 303. Human health criteria for toxic pollutants are designed to protect people from exposure resulting from consumption of fish or other aquatic organisms (e.g., mussels, crayfish) or from consumption of both water and aquatic organisms. These criteria express the highest concentrations of a pollutant that are not expected to pose significant long-term risk to human health.

For further information on the antidegradation, please see response to question #77.

The permit doesn't violate 35 Ill. Adm. Code 309.141(d) because the Upper Big Muddy River TMDL prepared a load reduction strategy to address the sedimentation/siltation impairment. The Load Reduction Strategy (LRS) identified a target of 32.2 mg/L for TSS as an average concentration. The NPDES permit has been modified to incorporate a limit of 32.2 mg/L for Outfall 011 applied as a yearly average.

The permit doesn't violate 35 Ill. Adm. Code 309.143 because for Outfall 011, the Agency performed the reasonable potential analysis to determine that the following contaminants do not have a reasonable potential to exceed the WQS in the effluent: arsenic, chromium (total), cyanide (available), iron (dissolved), lead, manganese, mercury, phenols, silver, zinc, and selenium. The Agency also determined that there is no reasonable potential to exceed the WQS outside of the mixing zone for cadmium, copper, nickel, sulfate, and chloride. Further, the Agency determined that there is no reasonable potential to exceed the acute WQS outside of the ZID for cadmium, copper, and nickel.

The federal regulations at 40 CFR 131.13 authorize states to use mixing zones and zones of initial dilution to implement WQS. Illinois has adopted mixing zones and zones of initial dilution WQS located at 35 Ill. Adm. Code 302.102.

In the zone immediately surrounding an outfall, both the acute and the chronic criteria may be exceeded, but the acute criterion must be met at the edge of this zone, which is often referred to as the acute mixing zone or the ZID. The acute mixing zone is sized to prevent lethality to passing organisms in order to protect the designated use of the waterbody as a whole. In case of the mixing zone, which is often called the chronic mixing zone, the chronic criterion may be exceeded, but the acute criterion must be met. The chronic criterion is met at the edge of the chronic mixing zone. The chronic mixing zone is sized to protect the designated use of the waterbody as a whole.

Since the discharge is required to comply with all applicable WQS prior to discharge or after mixing in the mixing zone and ZID, the designated uses will be fully protected.

The narrative standard requires "Waters of the State shall be free from sludge or bottom deposits, floating debris, visible oil, odor, plant or algal growth, color or turbidity of other than natural origin." Nothing in this discharge that would cause a narrative standard violation.

The effluent does not have sufficient deoxygenating chemicals or sufficient phosphorus to contribute to the DO impairment or potential impairment of phosphorus and will not cause a violation of the WQS. Regarding methyl mercury, please see response to question #49. Regarding phosphorus and dissolved oxygen, please see response to question #103.

a.) The antidegradation assessment makes no attempt to address impacts to mussels or even assess if mussels are present in the area, despite clear direction that Illinois' antidegradation policy calls for the maintenance and protection of existing uses, including the prevention of a shift from pollution-sensitive to more pollution-tolerant community and the loss of species diversity (Section 302.105(a)(1).

Because of the impaired status of Pond Creek, the permit does not authorize discharges from the proposed Outfall 009 to Pond Creek or the proposed Outfall 009ES to an unnamed tributary of Pond Creek. The proposed Outfalls 009 and 009ES have been removed from the NPDES permit.

A mussel survey was conducted April 22-26 and June 5, 2020 to satisfy the antidegradation regulation. The stream discharge rate at the Plumfield, Illinois gauge was between 742 and 855 cfs during this study. The permit has a condition that the mussel survey will be repeated one year after commencement of the discharge.

The survey area encompassed the width of the river from 50 m upstream to 150 m downstream of the proposed outfall location. The mixing zone has a length of 46 feet (13.3 m) by a width of 25 feet (7.62 m). The Survey Area was divided into 40 approximately 10x10 m cells. Four 5-minute qualitative samples were collected within each cell. Qualitative sampling entailed a diver searching the substrate, collecting all unionids encountered within the time period. Substrate composition (Wentworth scale) and water depth (meters) were recorded at the beginning of each sample. Unionids were classified as live, fresh dead, and weathered dead. Live individuals were identified to species, aged, and measured (length in millimeter). At least one individual of each live species was photographed, and (if available) a dead shell of each species was retained as a voucher specimen. All live individuals of non-listed species were relocated to a Recipient Area upstream of the project area with a similar substrate and depth profile as the Survey Area.

Unionids were scattered throughout the Survey Area; however, abundance appeared to be greater towards the downstream end of the site, as 23 of the 46 live individuals were collected there. Therefore, the greatest

concentration of mussels found were approximately 80 meters downstream of the mixing zone. No mussel beds were found in the mixing zone. In the area of the mixing zone, only one live mussel was found. No state listed species (live individuals or dead shell material) were observed in this area.

105. The NPDES permit violates 35 Ill Adm. Code 302 105(c) by allowing new discharges to the Big Muddy River and Pond Creek that are not necessary to accommodate important social or economic development but, on the contrary, will harm social and economic development by further wedding the local economy to an industry without a long term future and a company likely to leave the community with a large environmental hazard that will have to be cleaned up with public funds. Neighbors of the mine will continue to be harmed by the mining operations. Further, the mining of coal, to the extent it occurs, and the coal is burned in China or elsewhere, will harm the local economy (and the world economy) by increasing the emission of greenhouse gases.

As detailed in the response to the response to question #77, the applicant has provided all necessary information to satisfy the requirements of Section 302.105(c) of the Board regulations.

The information provided by the applicant satisfies the requirements of 35 Ill. Adm. Code 302.105(c).

106. The NPDES permit violates 35 Ill. Adm. Code 302.105(a), 35 Ill. Adm. Code 304.105, and 309.141(d), 309.143, and 309.146 by allowing a mixing zone that (the misrepresentations made in the record by the applicant notwithstanding) will in fact result in violations of applicable WQS outside the mixing zone by allowing increased discharges subject to implementation of a complex dilution and monitoring formula by an applicant that has proven itself utterly incapable of complying with the limits and reporting requirements of its current relatively simple permit and by allowing a mixing zone in Pond Creek where no dilution is available.

The question referencing mixing is related to the proposed discharge to Pond Creek. The permit doesn't violate 35 Ill. Adm. Code 302.105(a), 304.105, 309.141(d), 309.143, or 309.146 because the permit has been modified to not authorize discharges from the proposed Outfalls 009 and 009ES into Pond Creek and the unnamed tributary of Pond Creek respectively. Additionally, to address the impaired status of Pond Creek, the permittee will be required to install and operate a 1.0 MGD RO unit by December 31, 2023. The permittee is authorized to discharge the RO permeate (treated water) to one of the eight sedimentation basins that discharge to Pond Creek via Outfalls 001 – 008 and the RO reject water to the Big Muddy River via Outfall 011.

Also, at the direction of Illinois EPA, the applicant has conducted additional sampling in response to comments previously received for Outfalls 001-008. Based upon the additional data, the NPDES permit has been modified to include

additional NPDES permit limits for mercury at Outfall 001, copper and nickel at Outfall 002, iron (dissolved) at Outfall 003, copper at Outfall 004, nickel at Outfall 006, iron (dissolved), nickel, and zinc at Outfall 007, and copper, nickel, and zinc at Outfall 008.

107. The NPDES permit violates 35 Ill. Adm. Code 309.146 by failing to require monitoring adequate to determine compliance with the complex dilution scheme contemplated by the permit.

The monitoring requirements in the NPDES permit satisfy the requirements of Section 309.146 as the permit requires the following monitoring: TSS, iron (total), and manganese are required to be reported on the DMRs as a daily maximum and monthly average values. Alkalinity must be greater than acidity while pH, hardness, and flow must also be measured and reported on the DMR. The chloride (correlated to the conductivity values) is measured on a continuous basis when discharging and calculated at the edge of the mixing zone. The calculated chloride value (correlated to the conductivity values) and the downstream chloride concentration (correlated to the conductivity values) and reported on the DMR as a daily maximum value.

For dilution scheme for Outfall 011, please see response to question #45. For outfalls 001 through 008, please see response to question #54. For the proposed Outfall 009 and the discharges to Pond Creek, please see response to question #47.

108. The NPDES permit violates 35 Ill. Adm. Code 302.102, 302.105(a), 35 Ill. Adm. Code 304.105, and 309.141(d) and 309.143 because the reasonable potential test on which the public document relies was not properly performed at least with regard to mercury, copper, iron, nickel, and selenium. It appears that cadmium and manganese have also not been tested properly.

At the direction of Illinois EPA, the applicant has conducted additional sampling in response to comments previously received for Outfalls 001-008. Based upon the additional data, the NPDES permit has been modified to include additional NPDES permit limits for mercury at Outfall 001, copper and nickel at Outfall 002, iron (dissolved) at Outfall 003, copper at Outfall 004, nickel at Outfall 006, iron (dissolved), nickel, and zinc at Outfall 007, and cadmium, copper, nickel, and zinc at Outfall 008.

Because of the impaired status, the permit has been modified to not authorize discharges from the proposed Outfalls 009 and 009ES into Pond Creek and the unnamed tributary of Pond Creek respectively. Additionally, to address the impaired status of Pond Creek, the permittee will be required to install and operate a 1.0 MGD RO unit by December 31, 2023. The permittee is authorized to discharge the RO permeate (treated water) to one of the eight sedimentation

basins that discharge to Pond Creek via Outfalls 001 – 008 and the RO reject water to the Big Muddy River via Outfall 011.

The renewed and modified NPDES permit requires monthly effluent monitoring for the first year following the effective date of the permit after which semi-annual sampling for Outfall 011 for the parameters listed in Special Condition No. 18 of the NPDES permit. These parameters are: arsenic, barium, cadmium, chromium (hexavalent), chromium, copper, lead, manganese, mercury, nickel, phenols, selenium, silver, and zinc.

Manganese is regulated in the permit at Outfalls 006, 007, 008 and 011.

Thus, the permit, as drafted, meets the requirements of 35 Ill. Adm. Code 302.102, 302.105(a), 304.105, 309.141(d) and 309.143. Also see response to questions #17, #60, #104, and #106.

109. The NPDES permit violates 35 Ill. Adm. Code 302.102, 302.105(a), 35 Ill. Adm. Code 304.105, and 309.141(d) and 309.143 because the testing done for mercury was not done with sufficient sensitivity to determine whether there is a reasonable potential for the discharge to cause or contribute to violations of the applicable 12 n[g/L WQS (35 Ill. Adm. Code 302.208(f)

At the direction of Illinois EPA, the applicant has conducted additional sampling for mercury in response to comments previously received for Outfalls 001 through 008. The MDL in the additional sampling is 0.5 nanograms per liter. Based upon the additional data at this MDL, the NPDES permit has been modified to include a limit for mercury at Outfall 001. The data indicate that there is no reasonable potential for Outfalls 002 through 008 to exceed the WQS for mercury. Thus, the permit, as drafted, meets the requirements of 35 Ill. Adm. Code 302.102, 302.105(a), 304.105, and 309.141(d) and 309.143.

General Statements Regarding the NPDES Permit

The Illinois EPA received hundreds of comments during the public comment period of the draft permit and during the comment period from the public hearing. Below is the categorized summary of those comments received.

Flooding

Short & long-term impacts of volume & contaminants on Wildlife

- Mussels
- Illinois Chorus Frog
- Bald Eagle
- Egrets & Herons
- Red Headed woodpecker

- River otter
- Migrating waterfowl

Impact to Aquatic Life
- Long-term exposure
- Micro/Macro-Invertebrate abundance & diversity
- Fish reproduction, abundance & edibility
- Microbial communities

Human health/social costs

Overall environmental impact

Require Treatment & Economic Feasibility of Alternatives
- Reverse Osmosis
- Crystallization

Impact to recreational uses/tourism/economic development

Cumulative water quality impacts
- Considering all outfalls
- Considering other sources
- Segment already impaired for TSS/sediment/iron/mercury/others
    - Sedimentation
    - TSS

Acronyms and Initials

CFR	Code of Federal Regulations
DMR	Discharge Monitoring Report
ECHO	Enforcement and Compliance History Online
IBS	Intensive Basin Survey
IDNR	Illinois Department of Natural Resources
Illinois EPA	Illinois Environmental Protection Agency
ILCS	Illinois Compiled Statutes
Ill. Adm. Code	Illinois Administrative Code
MDL	Minimum Detection Limit

NPDES	National Pollutant Discharge Elimination System
pH	A Measure of Acidity or Alkalinity of a Solution
RO	Reverse Osmosis
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Illinois EPA
ZID	Zone of Initial Dilution

Distribution of Responsiveness Summary

An announcement that the NPDES permit decision and accompanying responsiveness summary is available on the Illinois EPA website, was mailed or e-mailed to all who registered at the hearing and to all who sent in written comments. Printed copies of this responsiveness summary are available from Barb Lieberoff, 217-524-3038, e-mail: barb.lieberoff@illinois.gov.

Who Can Answer Your Questions

Illinois EPA NPDES Permit:

NPDES Permit	Iwona Ward	217-782-3362
Legal questions	Stefanie Diers	217-782-5544
Water Quality Standards Unit	Scott Twait	217-782-0610
Public hearing of December 18, 2019	Jeff Guy	217-785-8724

The public hearing notice, the Public Notice, the hearing transcript, the NPDES permit and the responsiveness summary are available on the Illinois EPA website (it may be necessary to paste the web address into the window of your internet browser and then enter "IL0077666" in the search box):

https://www2.illinois.gov/epa/public-notices/Pages/npdes-individual-notices.aspx

DOCUMENT

3

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY
1021 NORTH GRAND AVENUE EAST, P.O. BOX 19276, SPRINGFIELD, ILLINOIS 62794-9276 · (217) 782-3397
JB PRITZKER, GOVERNOR JOHN J. KIM, DIRECTOR

MEMORANDUM

Date: March 28, 2022

To: John J. Kim, Director

From: Jeffrey J. Guy, Hearing Officer

Subject: Williamson Energy, LLC
NPDES Permit No. IL0077666
Williamson and Franklin Counties
4 Miles East of Johnston City, Illinois

NPDES Board Recommendation

As Hearing Officer and Chairman of the NPDES Board and pursuant to 35 Ill. Adm. Code Sections 166.150(b) and 166.180(c)(7), I recommend that NPDES Permit No. IL0077666 **be granted** to Williamson Energy, LLC to allow discharge into waters of the state, including Pond Creek, unnamed tributaries of Pond Creek, and the Big Muddy River. Please refer to the NPDES permit (Attachment A).

The Illinois EPA held a public hearing in this matter on December 18, 2019, at the Diamond Club, Rent One Park in Marion, Illinois.

Background information for this permitting action, public comments made at the hearing and submitted during the comment period, and the Illinois EPA's responses to the public comments are provided in the attached Responsiveness Summary (Attachment B).

If you agree with this recommendation, please sign and date below and return to Jeffrey J. Guy, Hearing Officer, Office of Community Relations. Thank you.

I hereby approve that NPDES Permit No. IL0077666 **be granted** to Williamson Energy, LLC.

Date: 4/15/22, 2022

John J. Kim
Director

2125 S. First Street, Champaign, IL 61820 (217) 278-5800
1101 Eastport Plaza Dr., Suite 100, Collinsville, IL 62234 (618) 346-5120
9511 Harrison Street, Des Plaines, IL 60016 (847) 294-4000
595 S. State Street, Elgin, IL 60123 (847) 608-3131
2309 W. Main Street, Suite 116, Marion, IL 62959 (618) 993-7200
412 SW Washington Street, Suite D, Peoria, IL 61602 (309) 671-3022
4302 N. Main Street, Rockford, IL 61103 (815) 987-7760

DOCUMENT

4

Twait, Scott

From: Twait, Scott
Sent: Wednesday, December 09, 2015 4:39 PM
To: Stitely, Joe; Ward, Iwona
Cc: Mosher, Bob (Bob.Mosher@Illinois.gov)
Subject: Williamson Energy - Pond Creek Mine

Joe,

I am sorry that it took so long to review the request that you sent September 30th. I thought it was an antidegradation review, but it was a Subtitle D permit application. They are not proposing to discharge from the Refuse Disposal Facility at this time. My understanding is that they will be applying for an NPDES permit before it starts to discharge. In the transmittal letter you asked "Is this submittal acceptable to what was agreed upon in your previous meeting?" The Subtitle D application has lots of stuff that we did not talk about, such as thickness of clay liners, QA/QC, etc. However, this application is in line with what we discussed at the previous meeting; the site location was adjacent to the existing RDA, the facility would construct a basin for water storage that would allow the facility to operate in such a manner that there was no discharge, and that the new RDA would be designed such that it would be able to be permitted under the Subtitle D permit.

If you have any questions, please let me know.

Scott

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY **MEMORANDUM**

DATE: September 30, 2015

TO: Bob Mosher

FROM: Joe Stitely

SUBJECT: Williamson Energy, LLC – Pond Creek Mine No. 1
NPDES Permit No. IL0077666
IEPA Log No. 3403-15
Permit Application for Refuse Placement at Refuse Disposal Facility No. 3

Attached please find a copy of information from the application for Refuse Placement Disposal Facility No. 3. This project was previously discussed in Springfield by the Applicant in a power point presentation title "Pond Creek Mine Management Challenges and Solutions." Is this submittal acceptable to what was agreed upon in your previous meeting? The Applicant has also indicated that they would like to meet with you again to discuss the proposed project for approval of a Subtitle D permit. If additional information is needed you may obtain such information directly from the Applicant. The Applicant's name and address is included in the attached documentation.

Thank you.

RECEIVED
OCT - 1 2015
shed Management Section

Let Thad know when it gets closer

Big Muddy Mining Zone

Table 1. Summary of Potential Discharges to Middle Fork Big Muddy River

		Middle Fork Big Muddy River Flows Predicted in Drainage Basin (cfs)		Maximum Allowable Discharge at Peak Flow in Stream ± flow		Discharge Allowed based on 24-Hour Average Stream Flow
	Rainfall Amount	Peak Drainage Basin Flow	Average Discharge 24 hours	(cfs)	(gpm)	(gpm)
6-hr Storm	0.5"	4,165	1,494	262	117,382	42,104
	1.0"	4,915	1,848	309	138,498	52,067
	1.5"	5,459	2,217	343	153,829	62,484
	2.0"	5,869	2,666	369	165,398	75,137
	2-yr (2.4")	6,134	3,043	385	172,863	85,762
	2.5"	6,198	3,149	389	174,681	88,742
	5-yr (2.98")	6,437	3,603	404	181,416	101,551
	3.0"	6,451	3,633	405	181,799	102,379
	10-yr (3.45")	6,912	4,067	434	194,777	114,623
	25-yr (4.11")	9,528	4,731	598	268,520	133,320
	50-yr (4.66")	11,765	5,293	739	331,548	149,153
	100-yr (5.22")	14,204	5,882	892	400,300	165,760
24-hr Storm	0.5"	0	0	0	0	-
	1.0"	119	42	7	3,354	1,191
	1.5"	691	238	43	19,462	6,701
	2.0"	1,507	515	95	42,467	14,510
	2.5"	2,413	826	152	67,997	23,275
	3.0"	3,426	1,215	215	96,556	34,234
	2-yr (3.37")	4,186	1,504	263	117,957	42,387
	5-yr (4.18")	5,976	2,178	375	168,413	61,385
	10-yr (4.84")	7,582	2,798	476	213,681	78,855
	25-yr (5.76")	9,809	3,650	616	276,425	102,860
	50-yr (6.51")	11,693	4,385	734	329,538	123,581
	100-yr (7.29")	13,653	5,161	857	384,757	145,436

Note: The Maximum Discharge allowable is based on the more stringent standard. In this case, it is the chloride standard.

Based on 100% mixing.

Should only get 25% of receiving stream.

R00120

Twait, Scott

From: Mosher, Bob
Sent: Monday, April 27, 2015 9:10 AM
To: Twait, Scott
Subject: FW: Segments IL_N-06 and IL_NG-02

Bob Mosher
Manager, Water Quality Standards Section
Division of Water Pollution Control
Illinois Environmental Protection Agency
1021 North Grand Ave. East
P.O. Box 19276
Springfield, IL 62794-9276
217/558-2012

From: Muir, David
Sent: Thursday, April 23, 2015 12:01 PM
To: Mosher, Bob
Cc: Johnson, Kent A.
Subject: Segments IL_N-06 and IL_NG-02

The current aquatic life assessment for IL_N-06 was made in 2010 based on data collected at station N-06 in 2008 from the INTB and AWQMN programs. The fish IBI score was 36, the Bug IBI score was 17.7. The listing of sedimentation/siltation as a cause of impairment was based on field observations on 8/20/08 of 66% bottom coverage of silt and an average depth of silt of 12 inches.

The current aquatic life assessment for IL_NG-02 was made in 2010 based on INTB data collected at NG-05 in 2008 and from AWQMN data collected at NG-02 from 2006-2008. The fish IBI score was 30, the Bug IBI score was 25. Chloride was listed as a cause of impairment based on a single exceedance of the chloride standard (1420 mg/L) collected at NG-05 on 7/24/2008.

If you have any other questions regarding these two assessments let me know.

David Muir
Illinois EPA
Marion Regional Office
618-993-7200

R00122

Illinois
Department of
Natural Resources

http://dnr.state.il.us

One Natural Resources Way, Springfield, IL 62702-1271

CONSULTATION AGENCY ACTION REPORT

(Illinois Administrative Code Title 17 Part 1075)
Division of Resource Review and Coordination

Date submitted: 5-9-05
If this is a resubmittal, include previous IDNR response if available.

FOR DEPARTMENT USE ONLY
PROJCODE: 0504253
Date Due: 6-8-05

Applicant Name: IEPA
Contact Person: Scott Twait
Applicant Address: 1021 N. Grand East
Springfield, Illinois 62702
Phone:
Fax:
E-mail:

LOCATION OF PROPOSED ACTION
A MAP SHOWING LOCATION OF PROPOSED ACTION IS REQUIRED
Project Name: Pond Creek Mine #1 County: Williamson
Project Address (if available):
City, State, Zip:
Township/Range/Section (e.g. T45N,R9E,S2): 08S 03E Sec 12
Brief Description of Proposed Action: New Coal Mine with eight new outfalls
Projected Start Date and End Date of Proposed Action:

Will state funds or technical assistance support this action? [Yes | (No)] If Yes, the Interagency Wetlands Policy Act will apply. Contact the funding agency or this Division for details.

Local/State Agency with Project Jurisdiction: Same as above
Contact:
Address:
Phone:
Fax:
E-mail:

FOR DEPARTMENT USE ONLY
Are endangered/threatened species or Natural Areas present in the vicinity of the action? [YES (NO)]
Could the proposed action affect the threatened/endangered species or Natural Area? [YES (NO)]
Is consultation terminated? [(YES) NO]
Comments:

Evaluated by:
Michael R. Brandt
Division of Resource Review and Coordination (217) 785-5500
Date: 6-8-05

Visit our website at http://dnr.state.il.us/orep/nrrc/aar.htm

****************** -COMM. JOURNAL- ******************* DATE JUN-23-2005 ****** TIME 10:32 **********

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-IEPA BOW -

*** - - ****** - 217 785 1225- **********

PLEASE DELIVER THIS FAX TO:

Larry Crislip

Fax #: 618-997-1281

From: Scott Twait

Date: 23 June 2005

Number of Pages (Including Cover Sheet): 2

Message:

Larry,

Attached is the consultation report sent by IDNR. Normally, I would indicate in my assessment that IDNR terminated the consultation, but, since this is on public notice, I am faxing it to you to put in the file.

If you have any questions or comments, please let me know.

Scott

Illinois EPA - Bureau of Water
1021 North Grand Avenue East
Springfield, Illinois 62702

Water Quality Standards Unit
Phone # 217/558-2012
FAX # 217/782-5549

PLEASE DELIVER THIS FAX TO:

Larry Crislip

Fax #: 618-997-1281

From: Scott Twait

Date: 23 June 2005

Number of Pages (Including Cover Sheet): 2

Message:

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Scott

Illinois EPA - Bureau of Water
1021 North Grand Avenue East
Springfield, Illinois 62702

Water Quality Standards Unit
Phone # 217/558-2012
FAX # 217/782-5549

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

1021 NORTH GRAND AVENUE EAST, P.O. BOX 19276, SPRINGFIELD, ILLINOIS 62794-9276, 217-782-3397
JAMES R. THOMPSON CENTER, 100 WEST RANDOLPH, SUITE 11-300, CHICAGO, IL 60601, 312-814-6026

ROD R. BLAGOJEVICH, GOVERNOR RENEE CIPRIANO, DIRECTOR

Memorandum

Date: 20 May 2005

To: Larry Crislip

From: Scott Twait ST

Subject: Steelhead Development Co. L.L.C. - Pond Creek Mine No. 1
Antidegradation Assessment
NPDES Permit No. IL0077666 (Williamson County)

The subject facility has applied for an NPDES permit for a new underground coal mine. The facility will contain a processing plant, coal stockpiles, refuse disposal areas, railroad loop, and support areas. The new discharges are South of Pond Creek. An unnamed tributary will receive all eight (8) of the proposed effluents. Outfalls 001, 002, 003, 004, and 005 will be classified as alkaline mine drainage. Outfalls 006, 007, and 008 will be classified as acid mine drainage. Pond 006 (outfall 006) will also receive underground pumpage.

Identification and Characterization of the Affected Water Body.

The subject facility discharges to an unnamed tributary of Pond Creek at a point where 0 cfs of flow exists upstream of the outfall during critical 7Q10 low-flow conditions. The outfalls are located between two miles and seven miles from the confluence of the tributary and Pond Creek. The unnamed tributary of Pond Creek is classified as a General Use Water. Neither the unnamed tributary of Pond Creek or Pond Creek itself are rated under the Agency's Biological Stream Characterization (BSC) program. The unnamed tributary of Pond Creek, tributary to Waterbody Segment, NG-02, is not found on the 2004 Illinois 303(d) List. However, Pond Creek itself, Waterbody Segment, NG-02, is found on the 2004 Illinois 303(d) List. The uses impaired for this segment were aquatic life and primary contact (swimming). The potential causes of impairment given for the segment were copper, manganese, pH, sedimentation/siltation, dissolved oxygen, physical habitat alterations (streams), total fecal coliform bacteria, and total suspended solids (TSS). The potential sources associated with the impairment are agriculture, crop related sources, non-irrigated crop production, resource extraction, surface mining, petroleum activities, hydrologic/habitat modification, channelization, and source unknown.

The Illinois Natural History Survey does not list the unnamed tributary of Pond Creek or Pond Creek itself as biologically significant streams according to the 1992 publication *Biologically Significant Illinois Streams*. The IDNR WIRT system indicates that no threatened or endangered species of aquatic life are present.

Identification of Proposed Pollutant Load Increases or Potential Impacts on Uses.

The parameters of concern for alkaline discharges are total suspended solids, iron (total), pH, alkalinity, acidity, sulfates, chlorides, and settleable solids. In addition, the acid mine discharges will have manganese added. The applicant has estimated that effluent water quality will meet water quality standards for all parameters. Suspended solids should settle in the sedimentation pond to a substantial degree before the storm water is released to the receiving stream. The concentration of suspended solids in the effluent should be no greater than runoff from the existing land use of the property. Some iron should settle with the solids. The pH related parameters should not be a problem, however, neutralization of the effluent is available if necessary.

Fate and Effect of Parameters Proposed for Increased Loading.

Whatever suspended solids remain in the effluent after settling in the treatment pond would be expected to behave in a manner similar to the existing soil particles in runoff from the site. The other substances in the discharge will tend to persist in stream water except when taken up by living organisms. Since water quality standards are predicted to be met in the effluent, and will be regulated at the water quality standards in the permit, no adverse impact is expected in the receiving waters.

Manganese is listed in the Illinois 2004 303(d) List as a potential cause of the impairment noted for segment NG-02 of Pond Creek. As no other potential sources of manganese are listed other than surface mining and petroleum activities, it is believed that pre-law mining operations are responsible for occasional violations of the 1 mg/L water quality standard for manganese. Recent manganese data from the NG-02 monitoring station was compared to total suspended solids (TSS) data taken at the same date and time. TSS is an indicator of stream flow, i.e., when flow is high, TSS is generally higher than when the stream flow is lower. It was found that samples exceeding the water quality standard were collected when TSS, and therefore stream flow, was lower than were flows when manganese did not exceed the standard. This corroborates the theory that abandoned mines are the sources of the manganese problem since these unregulated mine discharges occur even during dry periods. The discharge from the new mine will not contain manganese at concentrations above the water quality standard, moreover, the applicant will manage the water level in Pond 006 so that a discharge will only occur during wet weather events when the stream does not have a history of exceeding the standard. The new discharges should not exacerbate the manganese impairment of Pond Creek, as no net loading of manganese will occur during low stream flow conditions.

Purpose and Anticipated Benefits of the Proposed Activity.

The purpose of this project is to allow a new mine to be opened. The benefits of this project are employment in the local community and provision of an energy supply for the state and region.

Assessments of Alternatives for Less Increase in Loading or Minimal Environmental Degradation.

The use of sedimentation ponds is the generally accepted practice to control suspended solids and associated pollutants in runoff.

Very little pumpage is expected in the development of the underground works. The water level in Pond 006 will be managed to prevent a discharge in dry weather.

Summary Comments of the Illinois Department of Natural Resources, Regional Planning Commissions, Zoning Boards or Other Entities

IDNR has received a copy of the application and will also have the opportunity to review the public notice and fact sheet containing this assessment. Any comments by IDNR or other entities received prior to the end of the public notice period will be reviewed after the public notice period and appropriate responses will be made at that time.

Agency Conclusion.

This assessment was conducted pursuant to the Illinois Pollution Control Board regulation for Antidegradation found at 35 Ill. Adm. Code 302.105 (antidegradation standard). We find that the proposed activity will result in the attainment of water quality standards. All existing uses will be fully protected. All technically and economically reasonable measures to avoid or minimize the extent of the proposed increase in pollutant loading have been incorporated into the proposed activity. This activity will benefit the community at large by providing jobs for the community and providing energy for the state and region. The proposed activity is therefore compliant with the Antidegradation standard.

CC: Bob Mosher
Byron Marks
Ron Morse
Chron

R00128

Ave. TSS when Mn < 1000
= 61.6 / 3 = 20.5 exclude 2 highest

Ave. TSS when Mn > 1000
= 200/11 = 18.2

key	MANGANESE	MANGANESE	SOLIDS, F	PctDiff
B00137800	1500	1700	9	12
B00341000	550	570	12	4
B00532300	520	540	13	4
B00758100	1600	1600	21	0
B00848600	NG	02 6,	25	
B00886900	NG	02 6,	22	
B00945000	NG	02 6,	18	
B00990800	NG	02 6,	51	
B00992300	480	550	36	13
B01038100	NG	02 6,	346	
B01064900	NG	02 7,	2	
B01148300	NG	02 7,	9	
B01195400	NG	02 7,	9	
B01215000	NG	02 7,	11	
B01243100	570	600	16	5
B01277900	NG	02 7,	9	
B01486800	820	870	15	6
B01579300	NG	02 9,	28	
B01649200	NG	02 9,	15	
B01649300	NG	02 9,	13	
B01692300	NG	02 9,	35	
B01736400	NG	02 9,	9	
B01829300	640	640	6	0
B02191500	350	370	11	5
B10163200	280	300	17	7
B10345800	240	290	65	17
B10570700	15	100	19	85
B10692500	1100	1100	10	0
B11317200	750	800	22	6
B11649400	850	910	35	7
B11970100	780	800	14	2
B12160800	490	520	4	6
B12338100	240	270	27	11
B20255100	400	420	20	5
B20462200	110	380	293	71
B20791600	350	450	25	22
B21006300	990	1000	14	1
B21462800	1100	1100	17	0
B21808100	2900	3000	17	3
B22055600	500	520	30	4
B22240200	4300	4700	17	9
B30055600	370	360	10	-3
B30310900	200	200	11	0
B30636700	590	620	19	5
B30845100	560	630	37	11
B30938400	93	670	1230	86
B31202700	510	540	18	6
B31884200	3900	4000	33	2
B32027300	94	110	6	15
B40141200	350	380	12	8
B90021200	650	710	21	8
B90165200	300	350	20	14
B90522400	450	520	12	13
B90633200	490	530	26	8
B90978700	1600	1600	24	0
B91412900	700	810	37	14

B91706000	3000	3200 [redacted]	16	6
B91941400	1000	1100 [redacted]	22	9

R00130

Scott Twait - Re: NG-02 Manganese impairment

From: David Muir
To: Shasteen, Scott; Smogor, Roy; Twait, Scott
Date: 5/19/2005 3:16 PM
Subject: Re: NG-02 Manganese impairment

There is not surface mining (old or new) in the watershed of Pond Creek that I'm aware of. There could be some small older underground mines that had some discharges in the wateshed. There is a lot of oil wells in the watershed, but I doubt that this provides much manganese to the creek. Mostly, I think soils in the area are naturally high in manganese, but I can't say what is the source of manganese in the water.

>>> Roy Smogor 05/19/05 2:27 PM >>>
Dave or Scott,

Might you have any insights for Scott T. ? Thanks.

For segment NG-02 in our 2004 305(b) report, Aquatic Life Use is impaired due to manganese and copper (among other causes). Sources listed for these two parameters are: Surface Mining and Petroleum Activities.

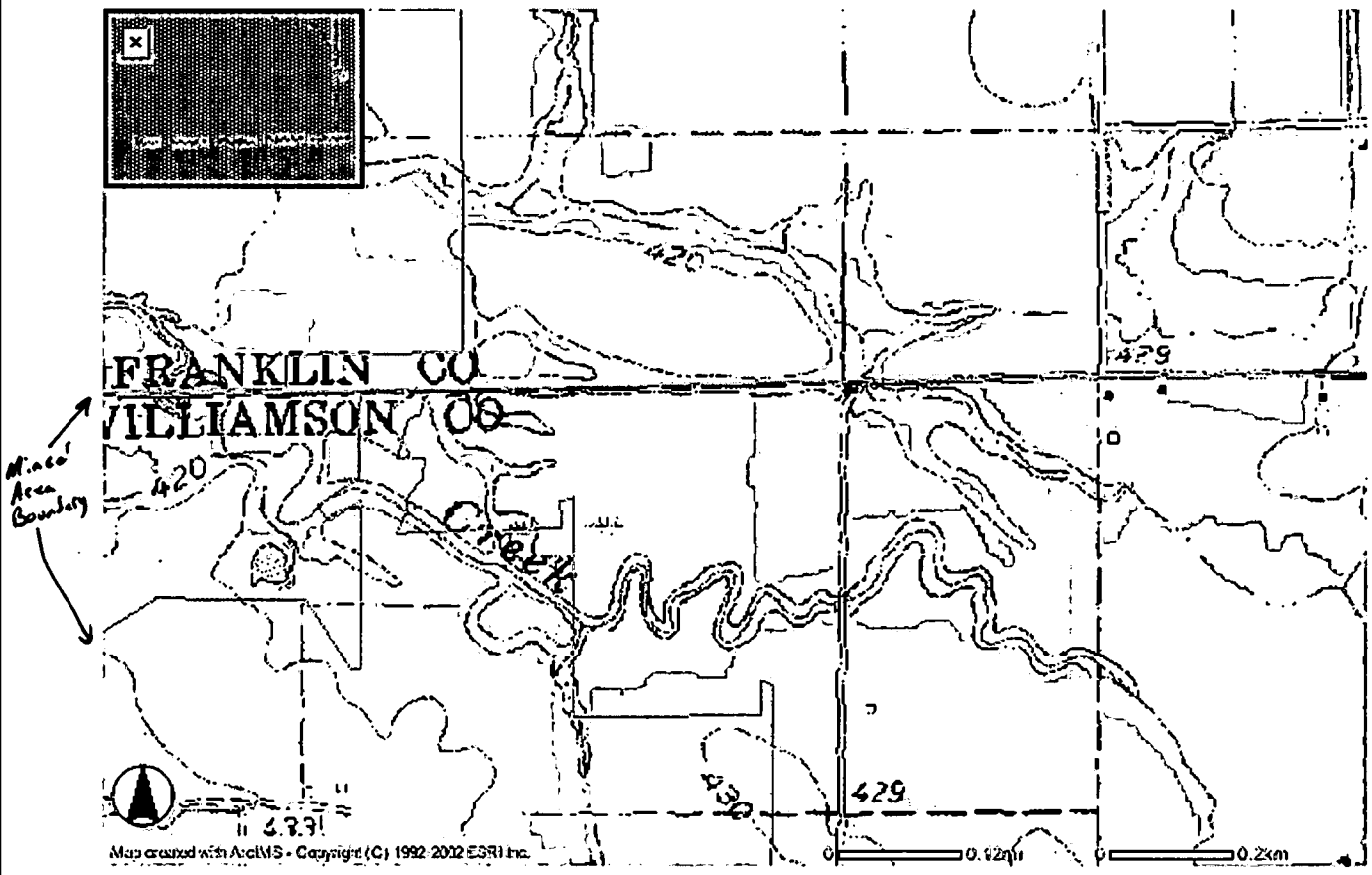
Roy

>>> Scott Twait 05/19/05 2:07 PM >>>
Roy,

Who would I talk to in order to find out the source of the Manganese impairment of Pond Creek (NG-02)? I would like to find out if it is from prior mining (pre-law) or an existing facility.

Thanks,
Scott

I investigated the IDNR mining areas and determined that most of Pond Creek is not influenced by mining. However the [redacted] most downstream areas, including, AWQMN Station NG-02 is within [redacted] mining boundaries.



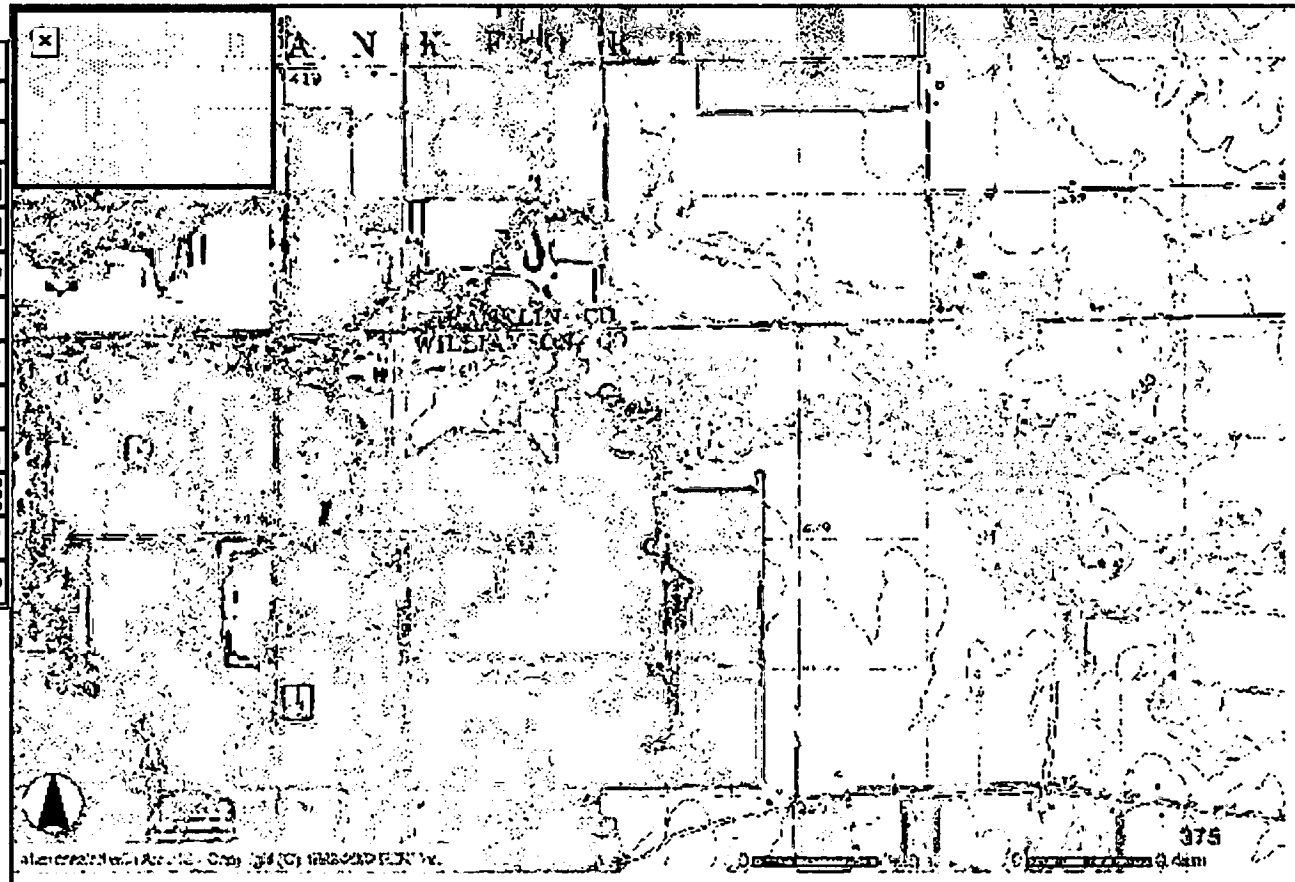
Mined Area Boundary

R001331

Illinois Department of Natural Resources
Office of Mines & Minerals
Land Reclamation Division

ArcIMS Illinois Coal Mine Permit Viewer

Select Permit Number | HELP ? | Zoom Out



Refresh Map

Layers

Visible Active

- [x] (•) Coal Mine Permit Boundaries for the Permanent Program
- [ ] ( ) Ground Water Monitoring Wells
- [x] ( ) SGS Surface Mined Areas - Incomplete
- [x] ( ) SGS Underground Mined Areas circa 2004
- [ ] ( ) Affected Acres
- [ ] ( ) Bond Release Phase 1
- [ ] ( ) Bond Release Phase 2
- [ ] ( ) Bond Release Phase 3
- [ ] ( ) Incremental Bonding
- [ ] ( ) Soil Capability
- [ ] ( ) Post-Mining Land Use
- [ ] ( ) PLSS - Twp, Range, Section
- [x] ( ) County Boundaries
- [ ] ( ) 100 + 500 yr Floodzones for Unincorporated Areas
- [ ] ( ) NWI Wetlands
- RMP Digital Plat

R00132

RECEIVED
Watershed Management Section
BUREAU OF WATER

Memorandum

To: Bob Mosher, Standards Development Unit

From: Larry D. Crislip, Manager, Permit Section, MPCP LDC

Date: April 29, 2005

Re: Anti-Degradation Analysis for New Outfalls
Steelhead Development Company, L.L.C. – Pond Creek Mine No. 1

Analysis Needed:

☐ Ammonia Current Limits (avg./max.): summer: _____ mg/L
winter: _____ mg/L

☐ Reasonable Potential Analysis

☐ Toxicity Recommendations

☒ Anti-degradation Current DAF/DMF: _____ MGD
Proposed DAF/DMF: _____ MGD

☒ 303(d) Listing for Receiving Water ☒ BCS Rating for Receiving Water

NPDES Permit No. IL0077666 County: Williamson

Facility Name: Pond Creek Mine No. 1

NPDES Permit Expiration Date: New NPDES Permit Application

Receiving Water: Unnamed tributaries to Pond Creek

Comments: A new underground mine is proposed where there has been no previous mining. The facility will contain a processing plant, coal stockpiles, refuse disposal areas, railroad loop, and support areas. The effluent from all eight outfalls is estimated to meet water quality standards at all times.

Pond Creek
Nos. 02 listed

A draft NPDES permit is being written for the above mentioned facility. Please evaluate the receiving stream with regards to the biological stream characterization and 303(d) list by completing the following:

Type of Discharge: Sedimentation pond discharge. Discharge Nos. 001, 002, 003, 004 and 005 will be classified alkaline mine drainage. Discharge Nos. 006, 007 and 008 will be classified acid mine drainage. Pond (Outfall) 006 will also receive underground pumpage.

Design Flow: See table.

Outfall No.	**25 yr, 6 hr Discharge cfs**	**10 yr, 24 hr Discharge cfs**
001	54.01	113.01
002	13.46	25.80
003	5.91	8.52
004	8.12	13.95
005	96.73	178.98
006	25.18	35.35
007	109.62	106.68
008	44.51	66.38

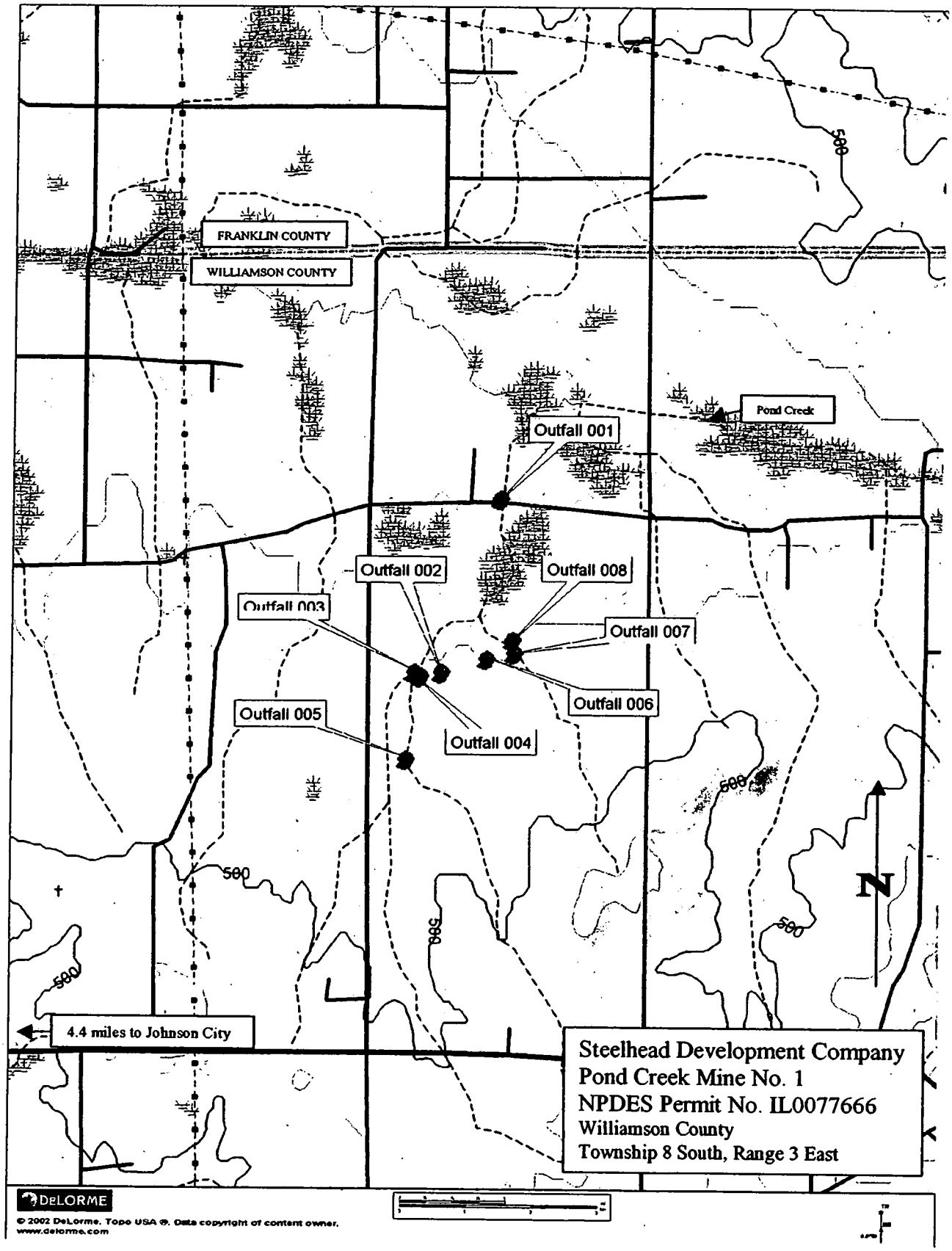
Effluent Parameters: For alkaline discharges: Total Suspended Solids, Iron (total), pH, Alkalinity, Acidity, Sulfates, Chlorides and Settleable Solids. For acid mine discharges, Manganese will be added.

Outfall	Receiving Stream	Latitude	Longitude	Stream Classification	Biological Stream Characterization
001	Unnamed tributaries to Pond Creek	37°50'59.2"	88°49'37.5"		
002	Unnamed tributaries to Pond Creek	37°50'26.0"	88°49'51.5"		
003	Unnamed tributaries to Pond Creek	37°50'26.0"	88°49'58.0"		
004	Unnamed tributaries to Pond Creek	37°50'25.0"	88°49'56.6"		
005	Unnamed tributaries to Pond Creek	37°50'9.1"	88°50'00"		

006	Unnamed tributaries to Pond Creek	37°50'28.4"	88°49'40.6"		
007	Unnamed tributaries to Pond Creek	37°50'29.5"	88°49'34.0"		
008	Unnamed tributaries to Pond Creek	37°50'31.4"	88°49'33.9"		

The stream segment receiving the discharge from outfall(s) _____ is on the 303(d) list of impaired waters.
The stream segment receiving the discharge from outfall(s) _____ is not on the 303(d) list of impaired waters. The following parameters have been identified as the pollutants causing impairment:

POLLUTANT	POTENTIAL CONTRIBUTORS
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____


FRANKLIN COUNTY
WILLIAMSON COUNTY
Pond Creek
Outfall 001
Outfall 002
Outfall 003
Outfall 004
Outfall 005
Outfall 006
Outfall 007
Outfall 008
4.4 miles to Johnson City
N
Steelhead Development Company
Pond Creek Mine No. 1
NPDES Permit No. IL0077666
Williamson County
Township 8 South, Range 3 East
DeLORME
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www.delorme.com

From: Bob Kerr
To: Twait, Scott
Date: 5/12/2005 9:44:43 AM
Subject: Re: Crislip's Phone

Talked to Tim Myers (Steelhead Engineer) this morning concerning 006. Fresh water from West Frankfort Lake will be pumped through a 12" pipe to the Freshwater Lake which is tributary to Pond 006. The water level in 006 will be managed to prevent a discharge in dry weather. The water accumulating in this series of ponds should be of good quality. We (MPCP) have to include manganese in the effluent sampling list, because of the definition of the discharge- acid mine drainage. He thought he could live with 1.0 mg/l manganese without problems. The manganese impairment in Pond Creek is very likely due to previous mining. Manganese is a routine parameter, except when acid water treatment is be conducted, which is not planned here. Most ground water pumpage will be through a discharge yet to be proposed or approved through a facility approximately 3 miles away. This facility will be located where the coal is the lowest for gravity drainage. Very little pumpage is expected in the development of the underground works, but he wanted to be able to pump to 006 just in case.

Need anything else?

>>> Scott Twait 05/12/05 9:10 AM >>>
I am working on Pond Creek Mine No. 1, which will have 8 discharge locations that will discharge to an unnamed tributary to Pond Creek. Pond Creek is on the 303(d) list for Manganese (plus other contaminants). I will have to talk to my boss before we allow more Manganese to Pond Creek. I was wondering if you knew the reason that the stream is listed for Manganese. Is it from old mines? Also, is Manganese expected or is it just a routine parameter?

Finally, they have underground pumpage to outfall 006. Will this outfall discharge continuously or only when it rains? If it will discharge during non-stormwater events, what will be the flowrate?

Scott

>>> Bob Kerr 05/12/05 8:57 AM >>>
You left a message on Crislips's phone on Tuesday. He won't be in much today or tomorrow and asked me to find out what you needed.

CC: epa1409

R00138

US Army Corps of Engineers ®

Information Systems and Technology
a Strategic Research Initiative funded by the Illinois Council on Food and Agricultural Research

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

Wetland Impact Review Tool Report: Preliminary Checks on NWP Conditions

Critical Resource	Inside Parcel	Buffer	Buffer to account for GIS inaccuracy
100 year Floodplain	NO CONFLICT FOUND	NO CONFLICT FOUND	NO CONFLICT FOUND
ADID Wetlands	NO CONFLICT FOUND	NO CONFLICT FOUND	NO CONFLICT FOUND
Aquatic Life Movements	NO CONFLICT FOUND	NO CONFLICT FOUND	NO CONFLICT FOUND
Critical Resource Waters	NO CONFLICT FOUND	NO CONFLICT FOUND	NO CONFLICT FOUND
Downstate Regional Condition #2	NO CONFLICT FOUND	NO CONFLICT FOUND	NO CONFLICT FOUND
High Value Subwatersheds	NO CONFLICT FOUND	NO CONFLICT FOUND	NO CONFLICT FOUND
National Wetlands Inventory (NWI)	Conflict found	Conflict found within 100 feet	Conflict found within 100 feet
Navigation	NO CONFLICT FOUND	NO CONFLICT FOUND	NO CONFLICT FOUND
Nature Preserve LWR & NAI	NO CONFLICT FOUND	NO CONFLICT FOUND	NO CONFLICT FOUND
Public Water Supply Intakes	NO CONFLICT FOUND	NO CONFLICT FOUND	NO CONFLICT FOUND
Spawning Areas	NO CONFLICT FOUND	NO CONFLICT FOUND	NO CONFLICT FOUND
Threatened and Endangered Species	NO CONFLICT FOUND	NO CONFLICT FOUND	NO CONFLICT FOUND
Wild and Scenic Rivers			



County: WILLIAMSON. Section (PLSS): 3 8S 3E12.
Watershed (IEPA 818): ILNG02.

Area: 0.29 square miles = 187.192 acres

Mon May 9 11:58:30 CDT 2005

R0013

RECEIVED
MAY - 2 2005
Watershed Management Section
BUREAU OF WATER

Memorandum

To: Bob Mosher, Standards Development Unit

From: Larry D. Crislip, Manager, Permit Section, MPCP

Date: April 29, 2005

Re: Anti-Degradation Analysis for New Outfalls
Steelhead Development Company, L.L.C. – Pond Creek Mine No. 1

Analysis Needed:

☐ Ammonia Current Limits (avg./max.): summer: _____ mg/L
winter: _____ mg/L

☐ Reasonable Potential Analysis

☐ Toxicity Recommendations

☒ Anti-degradation Current DAF/DMF: _____ MGD
Proposed DAF/DMF: _____ MGD

☒ 303(d) Listing for Receiving Water ☒ BCS Rating for Receiving Water

NPDES Permit No. IL0077666 County: Williamson

Facility Name: Pond Creek Mine No. 1

NPDES Permit Expiration Date: New NPDES Permit Application

Receiving Water: Unnamed tributaries to Pond Creek

Comments: A new underground mine is proposed where there has been no previous mining. The facility will contain a processing plant, coal stockpiles, refuse disposal areas, railroad loop, and support areas. The effluent from all eight outfalls is estimated to meet water quality standards at all times.

Pond Creek
Non-classified

A draft NPDES permit is being written for the above mentioned facility. Please evaluate the receiving stream with regards to the biological stream characterization and 303(d) list by completing the following:

Type of Discharge: Sedimentation pond discharge. Discharge Nos. 001, 002, 003, 004 and 005 will be classified alkaline mine drainage. Discharge Nos. 006, 007 and 008 will be classified acid mine drainage. Pond (Outfall) 006 will also receive underground pumpage.

Design Flow: See table.

Outfall No.	**25 yr, 6 hr Discharge cfs**	**10 yr, 24 hr Discharge cfs**
001	54.01	113.01
002	13.46	25.80
003	5.91	8.52
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008	44.51	66.38

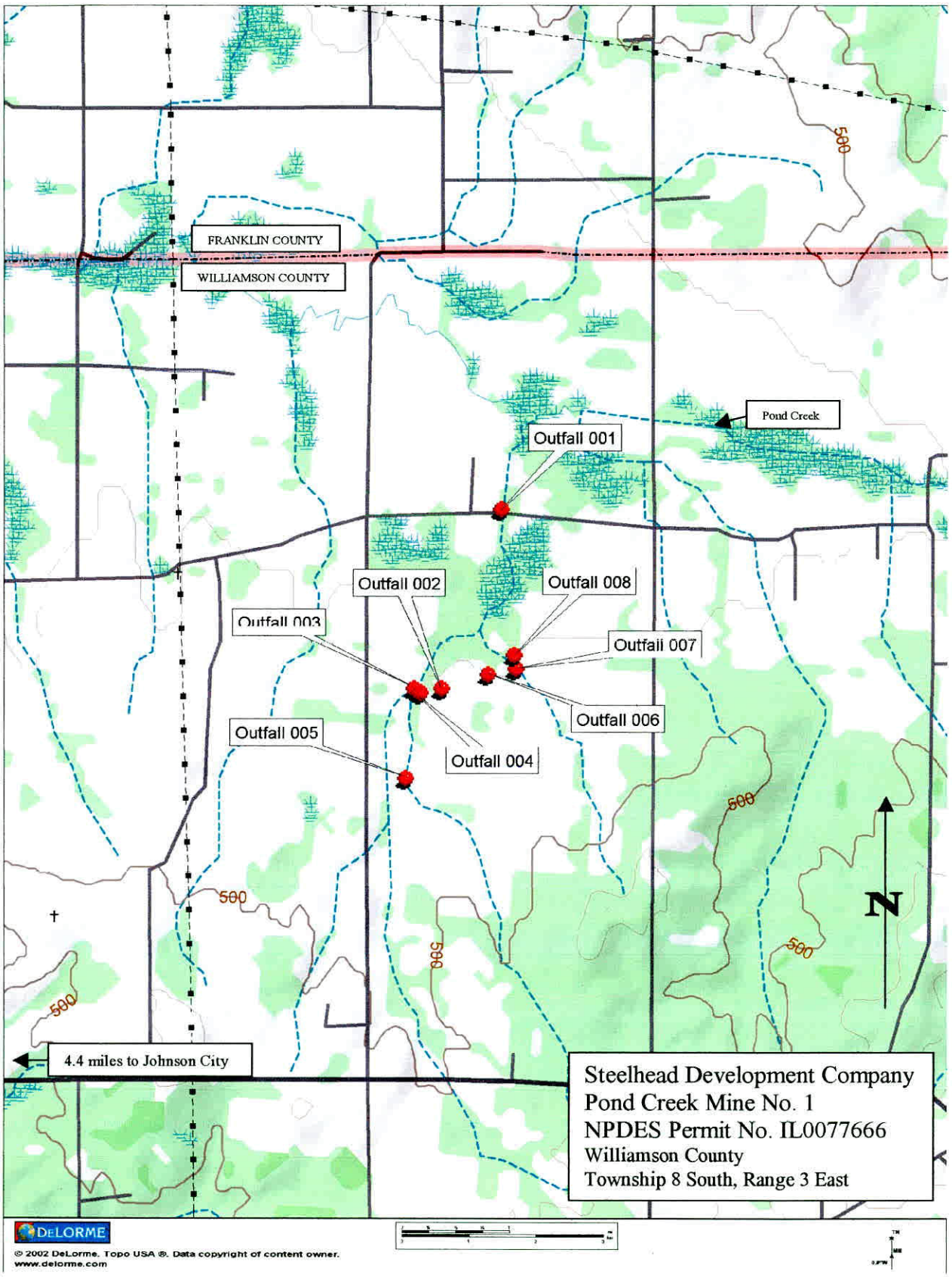
Effluent Parameters: For alkaline discharges: Total Suspended Solids, Iron (total), pH, Alkalinity, Acidity, Sulfates, Chlorides and Settleable Solids. For acid mine discharges, Manganese will be added.

Outfall	Receiving Stream	Latitude	Longitude	Stream Classification	Biological Stream Characterization
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008	Unnamed tributaries to Pond Creek	37°50'31.4"	88°49'33.9"		

The stream segment receiving the discharge from outfall(s) _____ is on the 303(d) list of impaired waters.
The stream segment receiving the discharge from outfall(s) _____ is not on the 303(d) list of impaired waters. The following parameters have been identified as the pollutants causing impairment:

POLLUTANT	POTENTIAL CONTRIBUTORS
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____


FRANKLIN COUNTY
WILLIAMSON COUNTY
Pond Creek
Outfall 001
Outfall 002
Outfall 003
Outfall 004
Outfall 005
Outfall 006
Outfall 007
Outfall 008
500
N
4.4 miles to Johnson City
Steelhead Development Company
Pond Creek Mine No. 1
NPDES Permit No. IL0077666
Williamson County
Township 8 South, Range 3 East
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********** -COMM. JOURNAL- ********** DATE MAY-09-2005 ***** TIME 14:52 **********

MODE = MEMORY TRANSMISSION START=MAY-09 14:50 END=MAY-09 14:52

FILE NO.=133

STN NO.	COMM.	ONE-TOUCH/ ABBR NO.	STATION NAME/TEL NO.	PAGES	DURATION
001	OK	8	95244177	005/005	00:01:19

-IEPA BOW -

********** - ***** - 217 785 1225- **********

PLEASE DELIVER THIS FAX TO:

Mike Branham

Fax #: 524-4177

From: Scott Twait

Date: 9 May 2005

Number of Pages (Including Cover Sheet): 6

Message:

Mike,

Attached is a consultation request for Pond Creek Mine No. 1. This is a new underground coal mine that will have 8 new outfalls. Please see attached. I am also sending you something from WIRT to help you locate the site.

Thanks,
Scott

Illinois EPA - Bureau of Water
1021 North Grand Avenue East
Springfield, Illinois 62702

Water Quality Standards Unit
Phone # 217/558-2012
FAX# 217/782-5549

PLEASE DELIVER THIS FAX TO:

Mike Branham

Fax #: 524-4177

From: Scott Twait

Date: 9 May 2005

Number of Pages (Including Cover Sheet): 6

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Thanks,
Scott

Illinois EPA - Bureau of Water
1021 North Grand Avenue East
Springfield, Illinois 62702

Water Quality Standards Unit
Phone # 217/558-2012
FAX# 217/782-5549

DOCUMENT

5

Illinois Department of
Natural Resources
One Natural Resources Way Springfield, Illinois 62702-1271
www.dnr.illinois.gov

JB Pritzker, Governor
Colleen Callahan, Director

October 22, 2021
Christopher Skelton, Engineer
Williamson Energy, LLC.
P.O. Box 99
Johnston City, IL 62951

RE: Pond Creek Mine, Williamson Energy, Mine Dewatering at Depth
Consultation Program
EcoCAT Review #2001813 (2-Year Renewal)
Williamson and Franklin Counties

Dear Mr. Skelton:

This letter is in reference to your Illinois Environmental Protection Agency (IEPA), National Pollutant Discharge Elimination System (NPDES) permit application No. IL0077666. The purpose of this letter is to satisfy consultation requirements pursuant to the Illinois Endangered Species Protection Act [520 ILCS 10/11], the Illinois Natural Areas Preservation Act [525 ILCS 30/17], and Title 17 Illinois Administrative Code Part 1075. Additionally, the Department may offer advice and recommendations for species covered under the Fish & Aquatic Life Code [515 ILCS 5, et seq.]; the Illinois Wildlife Code [520 ILCS 5, et seq.]; and the Herptiles-Herps Act [510 ILCS 69].

This review is specific to the NPDES permit application as the pipeline installation was previously reviewed in EcoCAT projects 1905659, 1905660, and 1905661 under the jurisdiction of the Department's Office of Mines and Minerals. This review does not include necessary permits for the outfall structure(s) from the Department's Office of Water Resources. A separate consultation will be required for those permits.

Per the NPDES permit narrative: "The applicant proposes additional surface facilities area to an existing underground coal mine (SIC 1222). Mine operations result in the discharge of alkaline and acid mine drainage. Incorporates three (3) new outfalls designated as Outfall Nos. 009, 009ES and 011. Receiving waters are Big Muddy River, Pond Creek, and tributaries to Pond Creek." The permit states that Pond Creek outfalls 009 and 009ES are permitted to discharge under stormwater conditions and are held to specified permit limits. For outfall 011 to the Big Muddy River, water will be conveyed from the mine to the river via a 12.5-mile pipeline with a maximum flow of 5,000 gpm at Outfall 011. Discharge will only be allowed when the Big Muddy River is flowing above 30 cfs. The permit states the applicant will perform real-time monitoring and flow control to achieve compliance with the water quality standards within the maximum distance of 251 feet in length and 25 feet wide, otherwise known as the "mixing zone." The mixing zone for copper is more restrictive at 18.2 feet long by 4 feet wide.

EcoCAT has indicated no records in the vicinity of the proposed outfalls for state-listed species or protected natural areas. However, the Department offers the following general information on the aquatic community in the Big Muddy River:

The Department's routine fish survey efforts indicate 96 species of fish occur in the Big Muddy River. These species include important sportfish and non-game species, as well as 11 species designated in the Illinois Wildlife Action Plan as "Species in Greatest Need of Conservation" (SGNC). The SGNC that occur in the Big Muddy River include the Alligator Gar (*Atractosteus spatula*) Blacktail Shiner (*Cyprinella venusta*), Brown Bullhead (*Ameiurus nebulosus*), Flier (*Centrarchus macropterus*), Mooneye (*Hiodon tergisus*), Paddlefish (*Polyodon spathula*), Pugnose Minnow (*Opsopoeodus emiliae*),

Ribbon Shiner (*Lythrurus fumeus*), River Darter (*Percina shumardi*) Spottail Darter (*Etheostoma squamiceps*), and Stripetail Darter (*Etheostoma kennicotti*). The Department also notes that the Lower Big Muddy River is one of several locations in thestate where Alligator Gar have been released as part of our "Alligator Gar Reintroduction Program." The Lower Big Muddy River received a stocking of 500 Alligator Gar in the year 2017. Additionally, a survey by the Illinois Natural History survey detected 19 extant species of freshwater mussels in the Big Muddy River with one, the Pistolgrip (Tritogonia verrucose) classified as an SGNC (Shasteen et al. 2012).

Given the above-mentioned diversity of species known to occur within the Big Muddy River, the Department recommends strict adherence to all effluent limits and all effluent monitoring requirements in accordance with NPDES Permit IL0077666.

Consultation on the part of the Department is closed unless Williamson Energy or the IEPA desires additional information or advice related to this proposal. Consultation for Part 1075 is valid for two years unless new information becomes available which was not previously considered; the proposed action is modified; or additional species, essential habitat, or Natural Areas are identified in the vicinity. If the action has not been implemented within two years of the date of this letter, or any of the above listed conditions develop, a new consultation is necessary.

This natural resource review reflects the information existing in the Illinois Natural Heritage Database at the time of the project submittal and should not be regarded as a final statement on the project being considered, nor should it be a substitute for detailed site surveys or field surveys required for environmental assessments. If additional protected resources are unexpectedly encountered during the project's implementation, the applicant must comply with the applicable statutes and regulations.

Thank you,

Adam Rawe

Adam Rawe
Office of Realty & Capital Planning
Illinois Dept. of Natural Resources
One Natural Resources Way
Springfield, IL 62702-1271
Adam.Rawe@illinois.gov
(217)785-4991

References

Shasteen, D. K., A. L. Price, S. A. Bales. 2012. Freshwater Mussels of the Big Muddy River. INHS Technical Report 2012(11). Prairie Research Institute, University of Illinois at Urbana Champaign.

cc: Scott Twait, IEPA- Division of Water Pollution Control

DOCUMENT

6

8188 - 20
Due date: 12-3-20
R09149

From: Twait, Scott <Scott.Twait@Illinois.gov>
Sent: Tuesday, October 20, 2020 2:55 PM
To: Ward, Iwona <Iwona.Ward@Illinois.gov>
Subject: Pond Creek

Iwona,

Can you please make sure that the attached gets into the permit record for Pond Creek. Sanjay wanted our thought process on Special Condition 15 to be part of the record.

The 1-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

507 Acres of land results in 40,888,598 gallons falling on site from a 1-year, 24-hour precipitation event.

Discharge Rate of 7.2 MGD would take 5.68 days to discharge everything that fell onto the site.

This would allow the mine to discharge the equivalent of all of the precipitation form a 1-year, 24-hour event and store the equivalent of the mine pumpage.

Special Condition 15 allowing discharge from Outfall 011 when the Big Muddy River is between 30 to 2350 cfs, except after a 1-year, 24-hour precipitation event, Outfall 011 can discharge for 6 consecutive days. The 1-year, 24-hour precipitation event for this area is considered to be 2.97 inches.

DOCUMENT

7

8143 · / 20
Due date: 9-2-20
R00151

Williamson Energy, LLC
PO Box 99
Johnston City, IL 62951
Office: 618-983-3020 Fax: 618-983-3017

July 20, 2020

Mrs. Iwona Ward
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY
2309 West Main Street, Suite 116
Marion, IL 62959

Re: Williamson Energy, LLC – Supplemental information concerning Big Muddy Mussel Survey at the proposed mixing zone.
NPDES Permit IL0077666

Dear Mrs. Ward:

Please find attached one (1) copy of the Supplemental information concerning the Big Muddy Mussel Survey at the proposed mixing zone regarding the NPDES permit IL0077666 for Williamson Energy, LLC's Pond Creek Mine.

One copy of this submittal has also been submitted to the permit manager at the IEPA Office in Marion.

We appreciate your assistance with the matter. If you have any questions or require additional information, please contact me at (618) 435-9464.

Respectfully submitted,

WILLIAMSON ENERGY, LLC

James Plumley

James Plumley, P.E.

RECEIVED
JUL 23 2020
IL Environmental Protection Agency
MARION REGIONAL OFFICE

Unionid survey at a proposed diffuser outfall site, Big Muddy River, Franklin County, Illinois

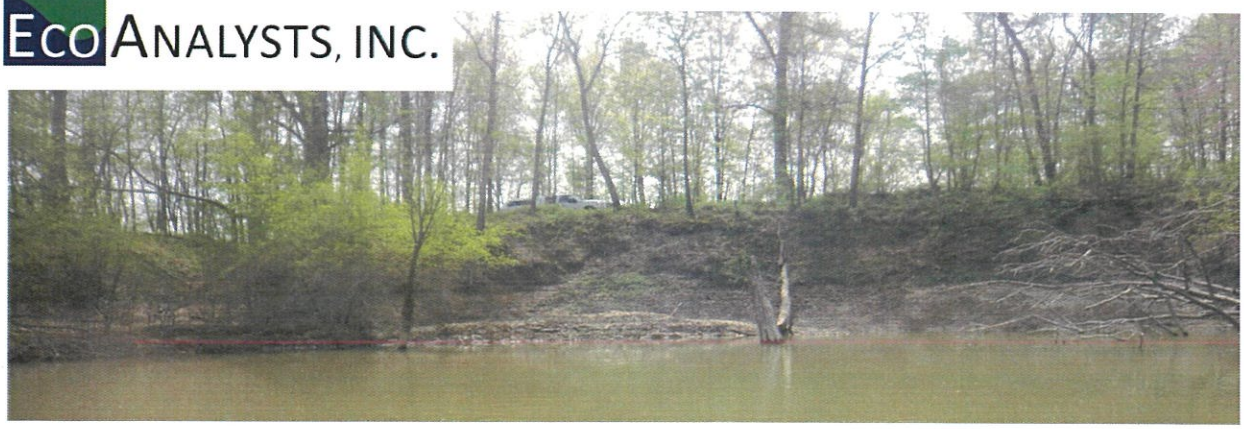
Prepared for:
Alliance Consulting, Inc.

Prepared by:
EcoAnalysts, Inc.

EcoAnalysts Principal Investigator:
Nathan Badgett
Senior Aquatic Ecologist
1417 Hoff Industrial Drive
O'Fallon, MO 63366
636-281-1982
nbadgett@ecoanalysts.com

Final Report
July 2020

EcoAnalysts, Inc.



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ACKNOWLEDGMENTS

Funding for this reconnaissance survey was provided by Alliance Consulting, Inc. of Beaver, West Virginia. Mr. Braden Hoffman coordinated the survey for Alliance Consulting. Mr. Nathan Badgett was the field team leader for EcoAnalysts, Inc. Mr. Kendall Cranney and Mr. Benjamin Dunn of EcoAnalysts assisted with the field effort. Mr. Badgett was the primary author of this report, and Ms. Heidi Dunn (EcoAnalysts) assisted with report preparation.

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1.0 INTRODUCTION

Alliance Consulting, Inc. is in the permitting process for a proposed outfall diffuser in Franklin County, Illinois (Figure 1-1). In-stream construction activity associated with construction of the diffuser has the potential to disrupt the substrate and the unionid (freshwater mussel) assemblage therein. Unionids in the project area may be crushed by equipment, and increased turbidity may inhibit unionid feeding and respiration.

A 2011 survey of the Big Muddy basin accounted for live individuals of 19 species; while not collected in the 2011 survey, historical records exist for an additional 6 species, including the state threatened *Eurynaia dilatata* (Table 1-1). Because the proposed diffuser project may impact mussels, Alliance Consulting commissioned a unionid survey of the project area. The objective of this survey was to determine unionid distribution and species composition in the project area to determine if unionids, particularly state-listed species may be affected by construction.

2.0 METHODS

Fieldwork for this study was conducted April 22-26 and June 5, 2020; stream discharge recorded at the Plumfield, Illinois gage was between 742 and 855 cfs during this time period (USGS, 2020).

The Survey Area encompassed the width of the river from 50 m upstream to 150 m downstream of the proposed diffuser location. The Survey Area was divided into 40 approximately 10 x 10 m cells. Four (4) 5-minute qualitative samples were collected within each cell. Qualitative sampling entailed a diver searching the substrate, collecting all unionids encountered within the time period. Substrate composition (Wentworth scale) and water depth (m) were recorded at the beginning of each sample. Unionids were classified as live, fresh dead (with or without tissue, nacre shiny, valves still intact, periostracum present; likely dead less than one year), weathered dead (no tissue, nacre chalky, valves separate or intact, periostracum present; likely dead more than one year), and weathered dead (entire shell chalky, valves not intact, no periostracum; dead many years to decades). Live individuals were identified to species, aged external annuli count, and measured (length in mm). At least one individual of each live species was photographed, and (if available) a dead shell of each species was retained as a voucher specimen. Live individuals of non-listed species were relocated to a Recipient Area upstream of the project area; reconnaissance dives in the Recipient Area confirmed similar substrate and depth profile as the Survey Area.

3.0 RESULTS AND DISCUSSION

Physical habitat was fairly uniform throughout the Survey Area. The left descending (south) bank, which formed an outside bend through the Survey Area, was steeply sloped with depths increasing rapidly with distance from the bank. The right descending (north) bank was less severely sloped, with thick overhanging vegetation lining much of the bank. Maximum depth observed in Survey Area cells was 3.7 m (Figure 3-1). Substrate was a mix of silt, clay, and woody debris, with varying amounts of gravel, sand, and detritus also present (Figure 3-2). The prevalence of woody debris posed an entanglement hazard for divers, and portions of the Survey Area, particularly those with high current velocities, could not be safely sampled.

A total of 46 live individuals of 11 species were collected from the Survey Area. *Megolonaias nervosa* was the most commonly collected species (n=13), followed by *Leptodea fragilis* (n=11) and *Potamilus alatus* (n=5); remaining species were represented by 4 or fewer live individuals each (Table 3-1). Catch per unit effort (CPUE) ranged from 0.0 to 1.5 and averaged 0.3 individuals/5-minute search (Table 3-1; Figure 3-3). Abundance was low, with 16 of the 37 searched cells yielding no live individuals. Unionids were scattered throughout the Survey Area; however, abundance appeared to be greater towards the downstream end of the site, as 23 of the 46 live individuals were collected in cells 31-40 (see Table 3-1). Anecdotally, divers reported collecting most live individuals along the riverward margins of search cells, near the interface between the bank slope and the thalweg.

The mussel assemblage observed during the reconnaissance survey is consistent with the 2011 basin-wide survey (INHS, 2012). Nine (9) of the 11 species collected in this study were also collected in 2011; *Lampsilis cardium* and *P. alatus* were not collected in the 2011 survey, but are historically known to occur in the Big Muddy River. No state listed species (live individuals or dead shell material) were observed in this study.

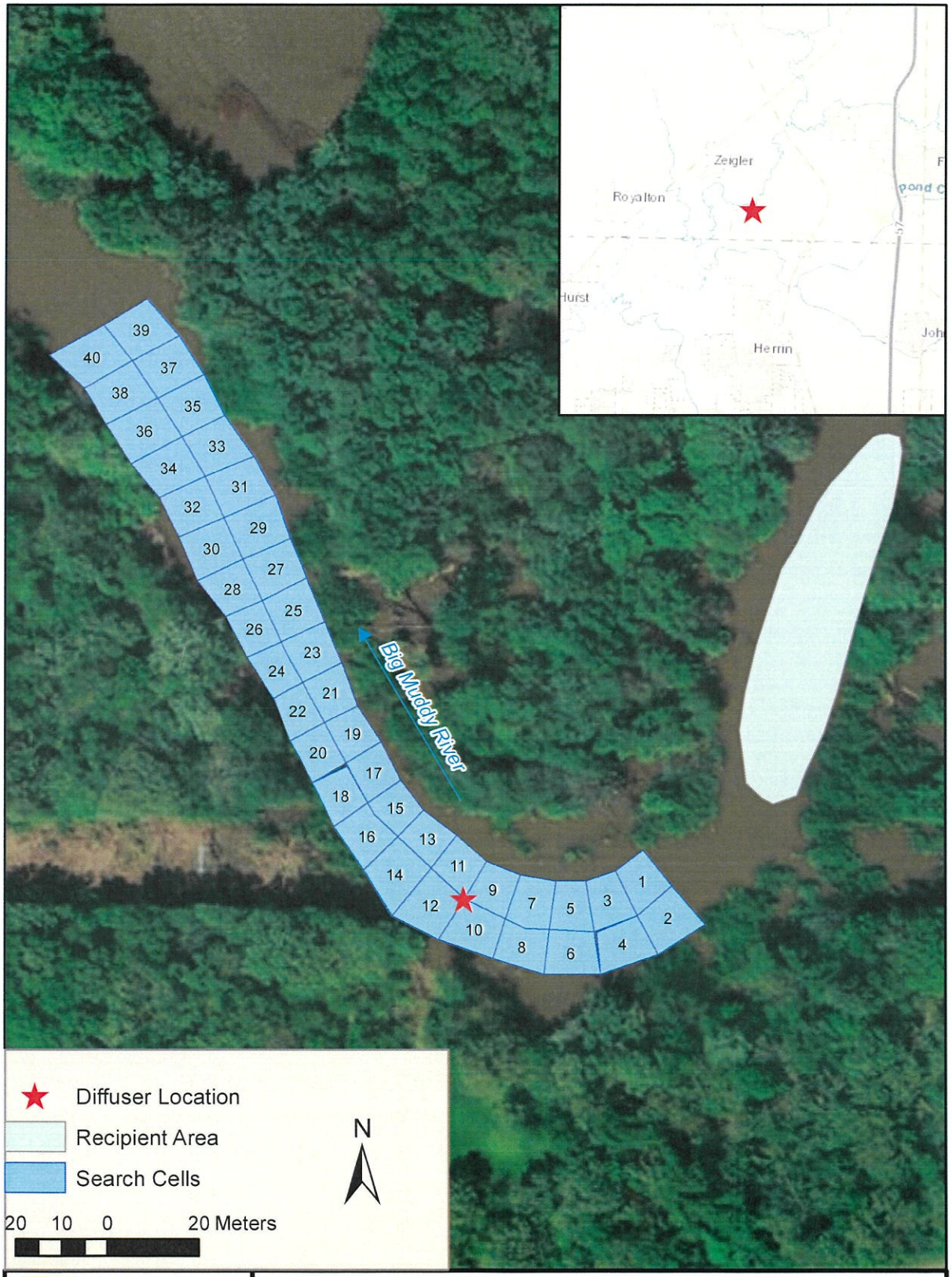
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4.0 LITERATURE CITED

Illinois Department of Natural Resources (IDNR). 2020. Current list of threatened and endangered invertebrates. http://www2.illinois.gov/dnr/conservation/NaturalHeritage/Pages/Invertebrates.aspx

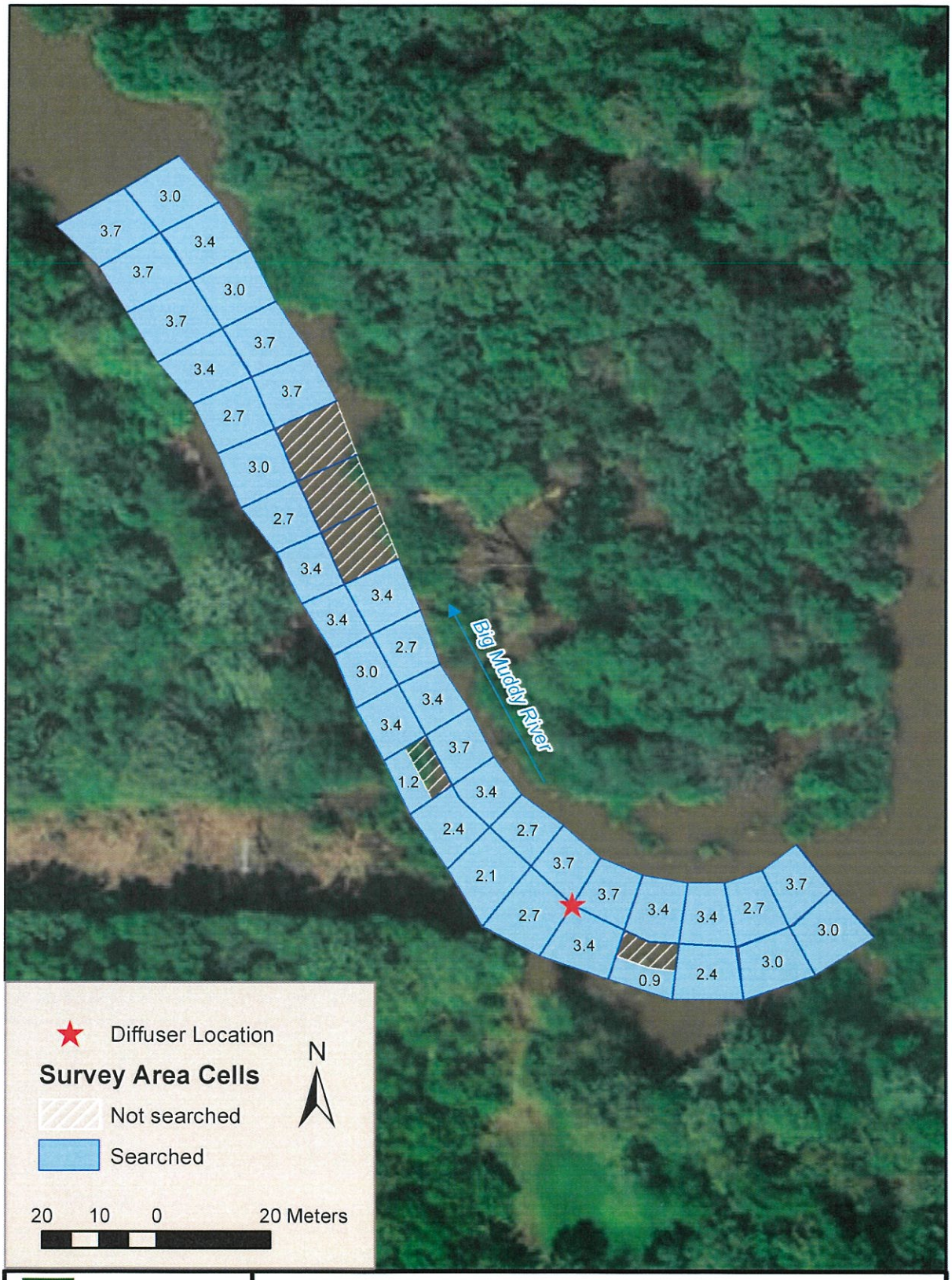
Illinois Natural History Survey (INHS). 2012. Freshwater Mussels of the Big Muddy River – Technical Report. Prepared for Illinois Department of Natural Resources: Office of Resource Conservation. 15 pp.

U.S. Geological Survey (USGS). 2020. Water data for USGS gage 0559700, Big Muddy River at Plumfield, IL http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=0559700



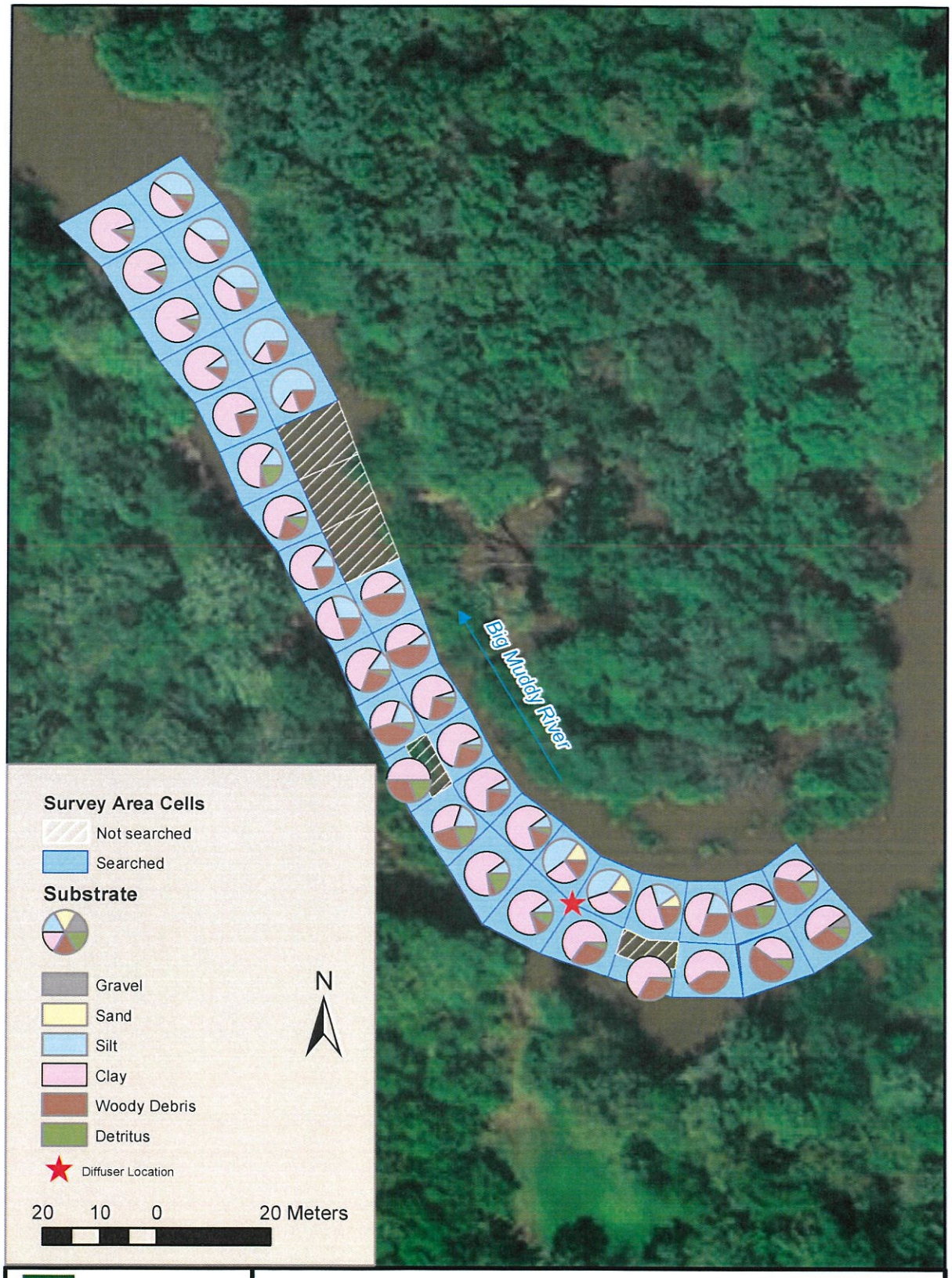
EcoAnalysts, Inc.

Figure 1-1. Survey Area search cells, Recipient Area, and diffuser location, Big Muddy River, Franklin County, Illinois.



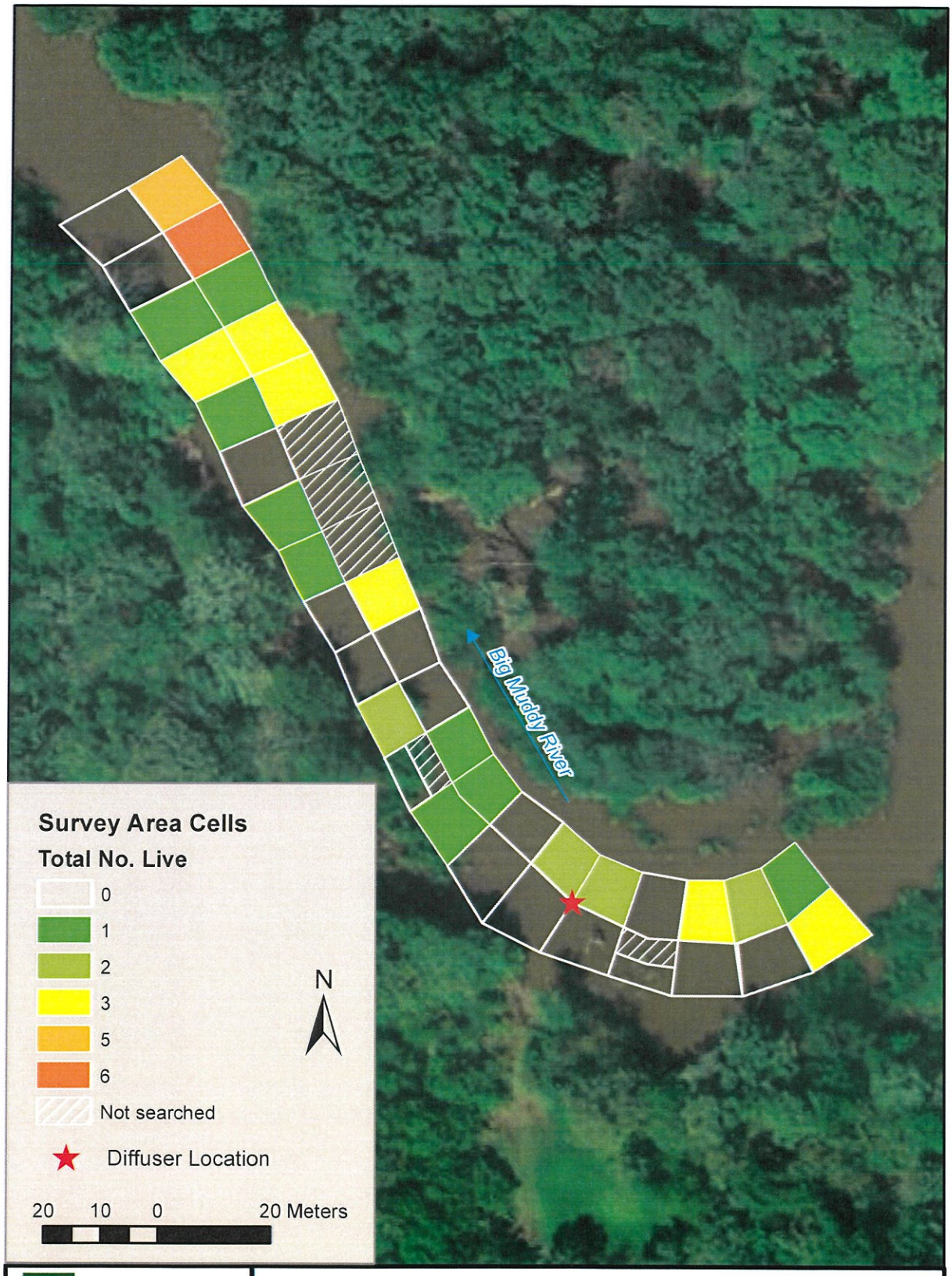
EcoAnalysts, Inc.

Figure 3-1. Maximum depth (m) observed in Survey Area Cells, Big Muddy River, Franklin County, Illinois.



EcoAnalysts, Inc.

Figure 3-2. Substrate observed in Survey Area Cells, Big Muddy River, Franklin County, Illinois.



EcoAnalysts, Inc.

Figure 3-3. Live unionids collected in Search Area Cells, Big Muddy River, Franklin County, Illinois.

Table 1-1. Recent unionid records within Big Muddy Basin.

Tribe	Species	Status[2]	Species accounts[1] Franklin County (includes tribs.)	Species accounts[1] Big Muddy Basin-wide (includes tribs.)
Amblemini	*Amblema plicata*		L	L
Pleurobemini	*Eurynaia dilatata*	IT	-	H
	Fusconaia flava		L	L
Quadrulini	*Cyclonaias pustulosa*		-	H
	Megalonaias nervosa		L	L
	Quadrula quadrula		L	L
	Tritogonia verrucosa		L	L
	Uniomerus tetralasmus		L	L
Lampsilini	*Lampsilis cardium*		-	H
	Lampsilis siliquoidea		-	L
	Lampsilis teres		L	L
	Leptodea fragilis		L	L
	Ligumia subrostrata		-	L
	Potamilus alatus		-	H
	Potamilus ohiensis		L	L
	Toxolasma parvum		-	L
	Toxolasma texasiense		L	L
	Truncilla donaciformis		-	H
	Truncilla truncata		L	L
Anodontini	*Arcidens confragosus*		-	L
	Lasmigona complanata		L	L
	Pyganodon grandis		L	L
	Strophitus undulatus		-	H
	Utterbackia imbecillis		L	L
	Utterbackiana suborbiculata		L	L
	No. Live Species		15	19
	Total No. Species		15	25

[1]INHS, 2012

[2]IT = Illinois Threatened; IDNR, 2020

L = collected live during 2011 basin-wide surveys, H = historical records, not observed in 2011

Table 3-1. Unionids collected by Survey Area Cell, Big Muddy River, Franklin County, Illinois.

Tribe	Species	Survey Area Cell																																					Total No. Live	%
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26	28	30	31	32	33	34	35	36	37	38	39	40		
Pleurobemini	*Fusconaia flava*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	WD	-	-	-	-	-	-	1	2.2
Quadrulini	*Tritogonia verrucosa*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	2	4.3
	Quadrula quadrula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	WD	-	-	-	-	1	2.2
	Megalonaias nervosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-	-	-	5	-	4	-	13	28.3
Lampsilini	*Leptodea fragilis*	FD	1	1	-	-	-	-	-	1	-	1	-	-	-	-	1	1	-	-	1	WD	-	-	-	-	1	-	-	1	-	2	-	-	-	-	-	-	11	23.9
	Lampsilis teres	-	1	1	-	WD	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	8.7
	Potamilus alatus	1	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	5	10.9
	Truncilla truncata	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2.2
	Lampsilis cardium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	2.2
Anodontini	*Pygonodon grandis*	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	6.5
	Lasmigona complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	1	-	1	-	4	8.7
	Total No. Live	**1**	**3**	**2**	**0**	**3**	**0**	**0**	**0**	**2**	**0**	**2**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**2**	**0**	**0**	**3**	**0**	**1**	**1**	**0**	**3**	**1**	**3**	**3**	**1**	**1**	**6**	**0**	**5**	**0**	**46**	
	No. Live Species	1	3	2	0	3	0	0	0	2	0	2	0	0	0	1	1	1	0	0	2	0	0	2	0	1	1	0	2	1	3	2	1	1	2	0	2	0	11	
	Total No. Species	2	3	2	0	4	0	0	0	2	0	2	0	0	0	1	1	1	0	0	2	1	0	2	0	1	1	0	2	1	3	3	1	2	2	0	2	0	11	
	(No. live/5 min)	0.3	0.8	0.5	0.0	0.8	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.5	0.0	0.0	0.8	0.0	0.3	0.3	0.0	0.8	0.3	0.8	0.8	0.3	0.3	1.5	0.0	1.3	0.0	0.3	

FD = fresh dead shell, WD = weathered dead shell

R00164

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8

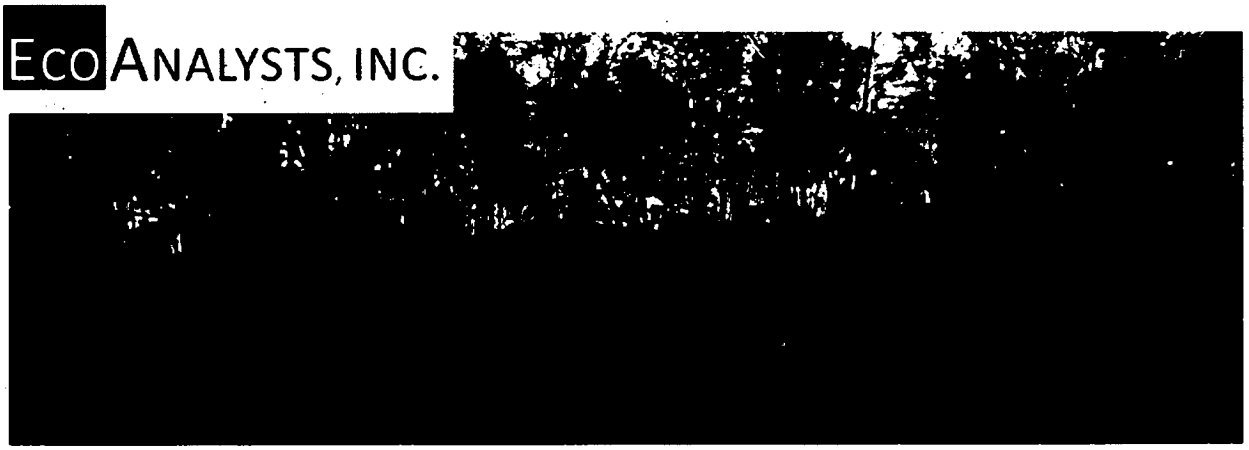
Unionid survey at a proposed diffuser outfall site, Big Muddy River, Franklin County, Illinois

Prepared for:
Alliance Consulting, Inc.

Prepared by:
EcoAnalysts, Inc.

EcoAnalysts Principal Investigator:
Nathan Badgett
Senior Aquatic Ecologist
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Final Report
July 2020



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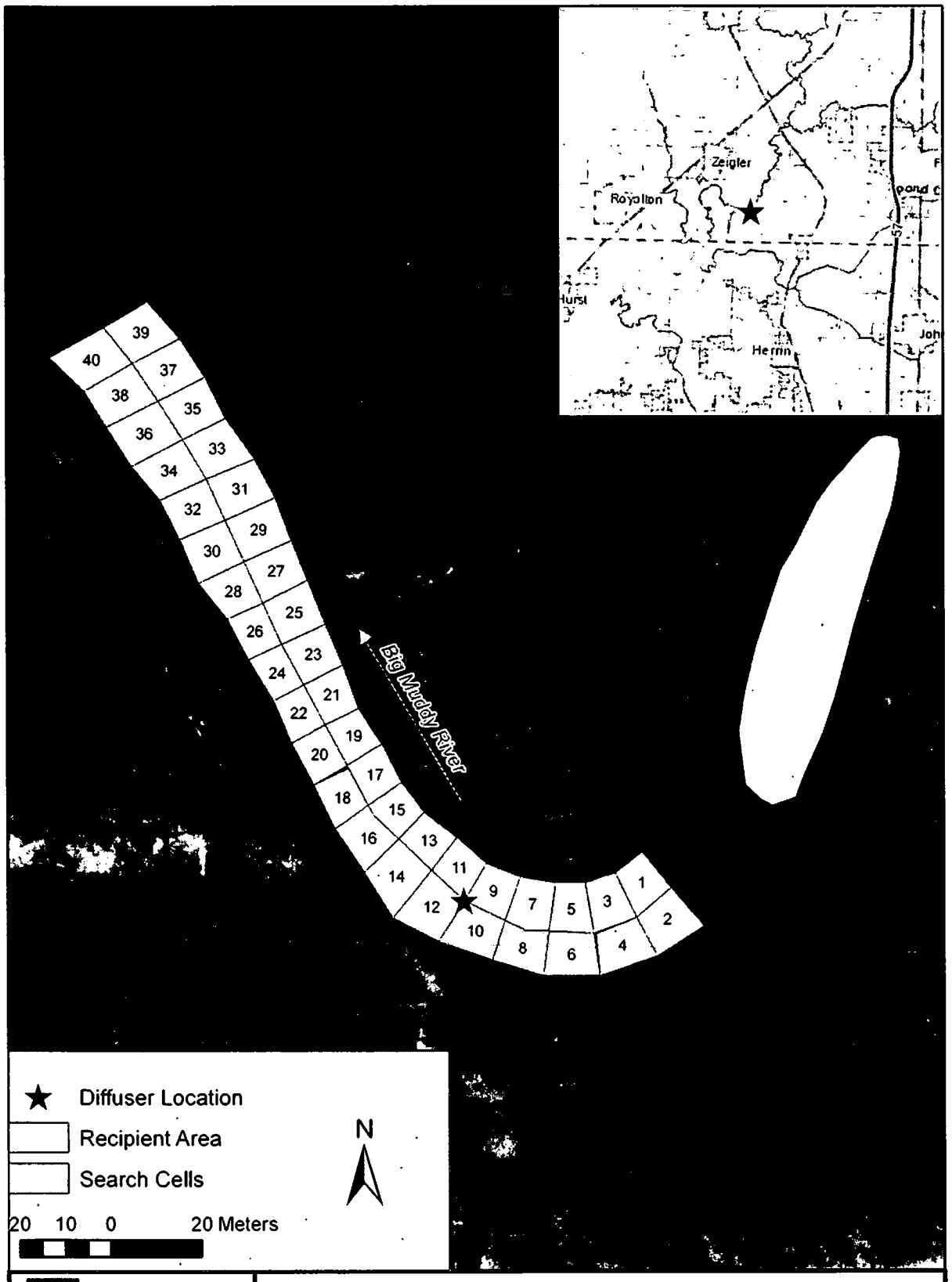
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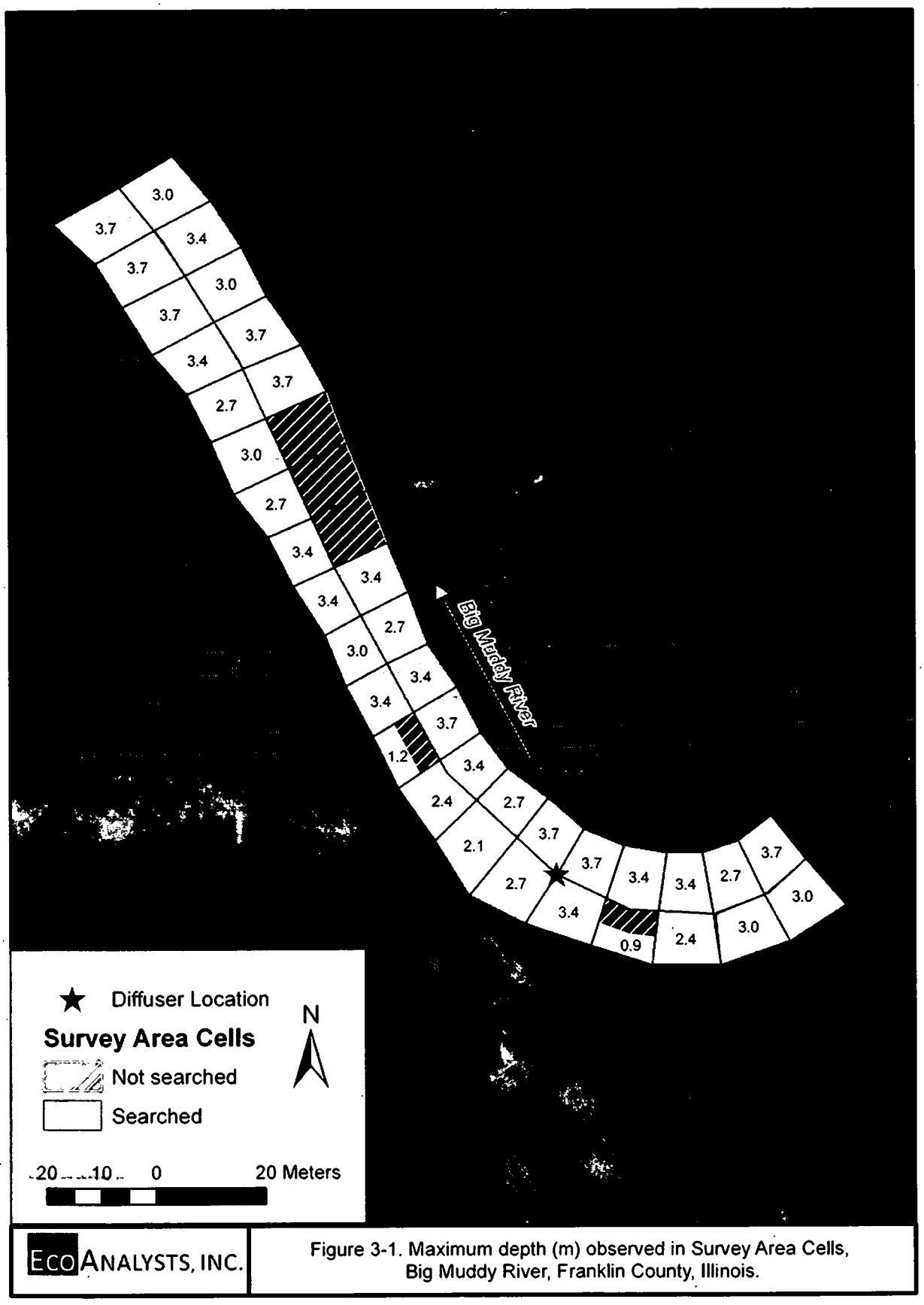
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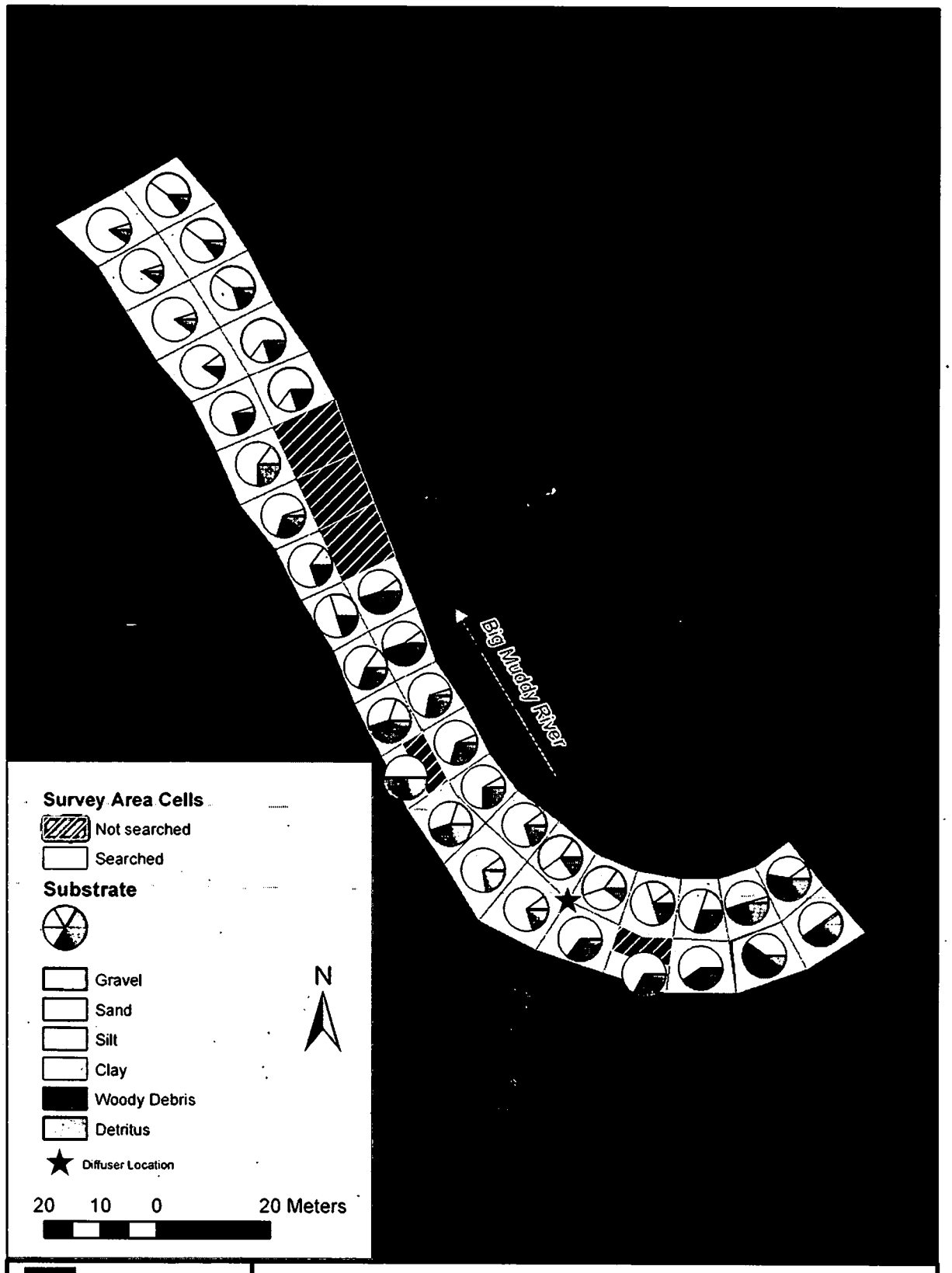
EcoAnalysts, Inc.

Figure 1-1. Survey Area search cells, Recipient Area, and diffuser location, Big Muddy River, Franklin County, Illinois.



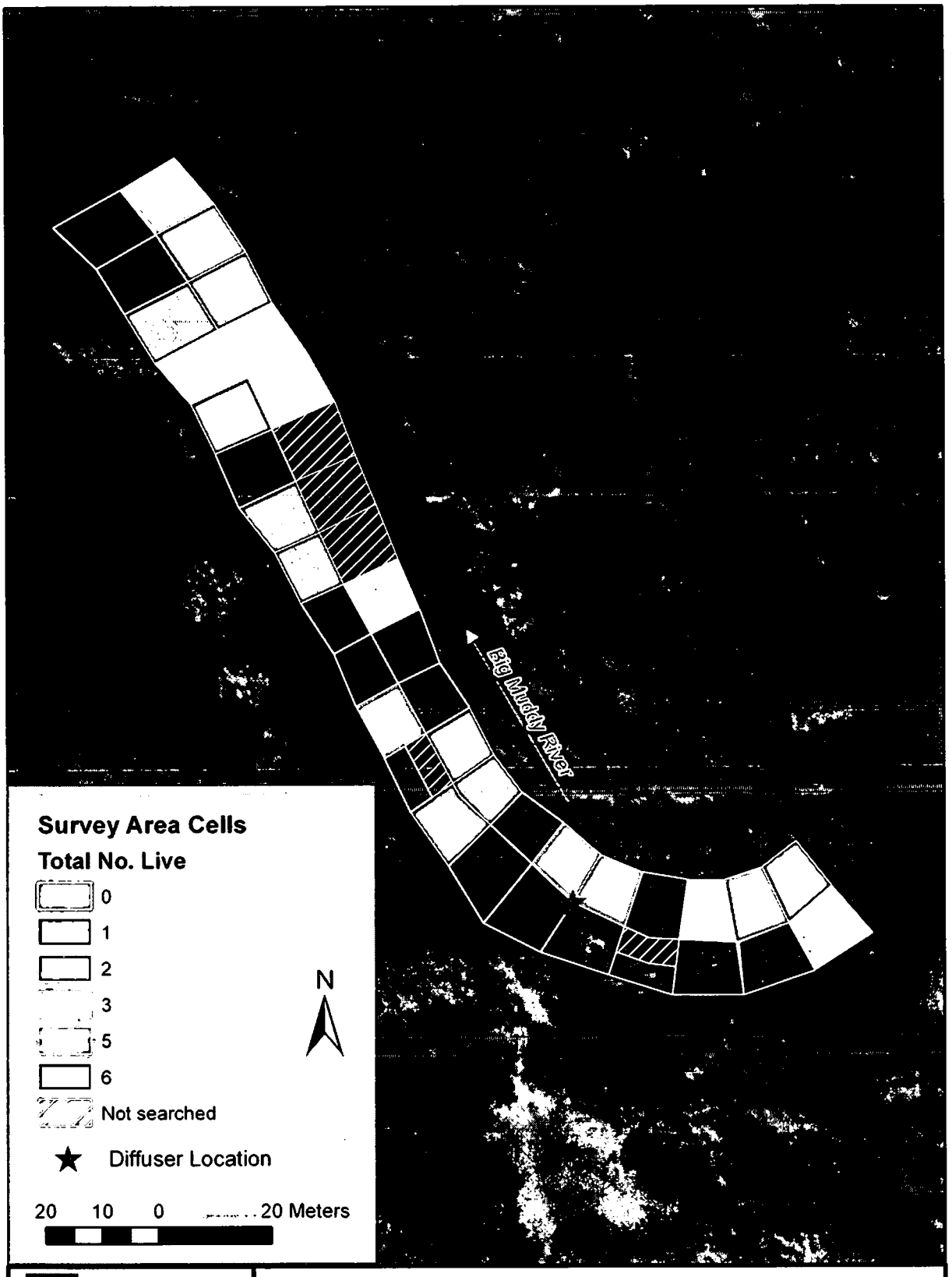
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Figure 3-1. Maximum depth (m) observed in Survey Area Cells, Big Muddy River, Franklin County, Illinois.



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Figure 3-2. Substrate observed in Survey Area Cells, Big Muddy River, Franklin County, Illinois.



EcoAnalysts, Inc.

Figure 3-3. Live unionids collected in Search Area Cells, Big Muddy River, Franklin County, Illinois.

Table 1-1. Recent unionid records within Big Muddy Basin.

Tribe	Species	Status[2]	Species accounts[1]	
			Franklin County (includes tribs.)	Big Muddy Basin-wide (includes tribs.)
Amblemini	*Amblema plicata*		L	L
Pleurobemini	*Eurynaia dilatata*	IT	-	H
	Fusconaia flava		L	L
Quadrulini	*Cyclonaias pustulosa*		-	H
	Megalonaias nervosa		L	L
	Quadrula quadrula		L	L
	Tritogonia verrucosa		L	L
	Uniomerus tetralasmus		L	L
Lampsilini	*Lampsilis cardium*		-	H
	Lampsilis siliquoidea		-	L
	Lampsilis teres		L	L
	Leptodea fragilis		L	L
	Ligumia subrostrata		-	L
	Potamilus alatus		-	H
	Potamilus ohiensis		L	L
	Toxolasma parvum		-	L
	Toxolasma texasiense		L	L
	Truncilla donaciformis		-	H
	Truncilla truncata		L	L
Anodontini	*Arcidens confragosus*		-	L
	Lasmigona complanata		L	L
	Pyganodon grandis		L	L
	Strophitus undulatus		-	H
	Utterbackia imbecillis		L	L
	Utterbackiana suborbiculata		L	L
	No. Live Species		15	19
	Total No. Species		15	25

[1]INHS, 2012

[2]IT = Illinois Threatened; IDNR, 2020

L = collected live during 2011 basin-wide surveys, H = historical records, not observed in 2011

Table 3-1. Unionids collected by Survey Area Cell, Big Muddy River, Franklin County, Illinois.

Tribe	Species	Survey Area Cell																																					Total No. Live	%
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26	28	30	31	32	33	34	35	36	37	38	39	40		
Pleurobemini	*Fusconaia flava*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	WD	-	-	-	-	-	-	1	2.2
Quadrulini	*Tritogonia verrucosa*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	2	4.3
	Quadrula quadrula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	WD	-	-	-	-	1	2.2
	Megalonaias nervosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-	-	-	5	-	4	-	13	28.3
Lampsilini	*Leptodea fragilis*	FD	1	1	-	-	-	-	-	1	-	1	-	-	-	-	1	1	-	-	1	WD	-	-	-	-	1	-	-	1	-	2	-	-	-	-	-	-	11	23.9
	Lampsilis teres	-	1	1	-	WD	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	8.7
	Potamilus alatus	1	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	5	10.9
	Truncilla truncata	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2.2
	Lampsilis cardium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	2.2
Anodontini	*Pyganodon grandis*	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	6.5
	Lasmigona complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	1	-	1	-	4	8.7
	Total No. Live	**1**	**3**	**2**	**0**	**3**	**0**	**0**	**0**	**2**	**0**	**2**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**2**	**0**	**0**	**3**	**0**	**1**	**1**	**0**	**3**	**1**	**3**	**3**	**1**	**1**	**6**	**0**	**5**	**0**	**46**	
	No. Live Species	1	3	2	0	3	0	0	0	2	0	2	0	0	0	1	1	1	0	0	2	0	0	2	0	1	1	0	2	1	3	2	1	1	2	0	2	0	11	
	Total No. Species	2	3	2	0	4	0	0	0	2	0	2	0	0	0	1	1	1	0	0	2	1	0	2	0	1	1	0	2	1	3	3	1	2	2	0	2	0	11	
	(No. live/5 min)	0.3	0.8	0.5	0.0	0.8	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.5	0.0	0.0	0.8	0.0	0.3	0.3	0.0	0.8	0.3	0.8	0.8	0.3	0.3	1.5	0.0	1.3	0.0	0.3	

FD = fresh dead shell, WD = weathered dead shell

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WILLIAMSON ENERGY'S RESPONSES TO IEPA QUESTIONS

Questions	Responses
Question No. 12: How will the unfiltered water discharged into the Big Muddy be filtered? BY whom and how is the discharge monitored? Monitoring needs to occur at all times to assess chemical discharge. (E180)	The water is treated at the site by settling solids out in the holding pond. This is a standard method of treatment for solids for many wastewater treatment systems. The Mine is required to comply with a Total Suspended Solids (TSS) concentration at the compliance point. Filtering has not been required to meet the water quality standards specified by the NPDES Permit. With respect to the monitoring request, a system of continuous monitors was proposed by the Mine and has been incorporated into the NPDES Permit. The treated effluent and the receiving stream upstream from the diffuser will have continuous monitors that will allow the system to maintain compliance with the water quality standards downstream.
Questions No. 18: Several documents have said the pipeline is only for 10 years and then it will be removed. Is this the projected end of date of the coal seam and mine closure? (E259)	IEPA is unaware of any statement from the applicant indicating a 10-year service life of this pipeline.
Question No. 27 What are the long-term impacts of continual water usage and water withdrawal on nearby communities?	There are no known communities nearby that withdraw drinking water from the aquifers impacted by the Pond Creek Mine; therefore, long-term impacts of the water continuously infiltrating and removed from the underground mine is not anticipated.
Question No. 28: What is Foresight's daily Rend Lake usage in initial stages of coal production? What does it pay Adena Resources and the state of Illinois for this use? Explain the water contracts and Foresight's use of TVA's coal.	Currently Sugar Camp, LLC uses Rend Lake water to supplement make-up water for coal processing. There is a provision for Pond Creek Mine to utilize this source of water as coal processing make-up water; however, Pond Creek Mine does not currently use this approved availability. Williamson Energy does not mine, control or have access to TVA coal.

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Questions	Responses
Question No. 35: I would like to know what the depth of the Big Muddy in that area is currently because it surely isn't 30 feet deep for the diffuser to be pouring effluent into the water?	The river depth at the diffuser site is 8-12 feet at baseline flow. This is more than enough depth to accommodate diffuser flow.
Question No. 36: How will the diffuser vents be protected from people continuing to use the location as a dump site?	As part of the NPDES Permit requirements, the Outfall will be marked by signage on the bank to let people on the River know the outfall is present. The diffuser ports will be installed in a way to minimize damage due to strikes from natural objects such as logs. The site is not located on a public road, which will reduce the potential for average member of the public from dumping large objects into the River at this location. The opposite bank is private property, which will also minimize the average member of the public from attempting to vandalize the diffuser. For those determined to do harm to the diffuser, the site will be monitored and access to the River will be limited.

Questions	Responses
Question No. 41: The IEPA should include a fish survey, a mussel survey and a survey of invertebrates pre-construction as well as long term monitoring post-construction would be or should be required.	The mixing zone is sized and designed to provide fish passage and should not affect the fish community in the Big Muddy River. IEPA used a fish survey conducted by the Illinois Department of Natural Resources in assessing any potential fish impacts and found no adverse impacts. Likewise, a benthic macroinvertebrate survey has already been conducted by Alliance Consulting in 2019 and submitted to the administrative record by Williamson. The Survey occurred in the area downstream of the mixing zone. This survey demonstrated that the diffuser will be located in a pool of the river with poor habitat availability for greater than three-quarters of a mile below the diffuser. The benthic macroinvertebrate community in the downstream sample was dominated by tolerant Chironomidae and Ceratopogonidae, typical of fine, unstable substrate. A few mayflies and unionids were collected in this survey which may indicate substrate, not water quality, is the limiting factor in this reach. A mussel survey is also scheduled to be conducted prior to diffuser construction but mussel surveys are limited to a specific sampling season which begins in April. In the unlikely event that a mussel bed is found within the diffuse construction location or mixing zone, this would be addressed with IEPA prior to construction.

Questions	Responses
	this deposited mercury would be expected to migrate downstream within the water column. Without a new source of mercury to the sediments, the mercury concentration that may be present in the sediments could decrease so that the potential for methylmercury production in the sediments would be reduced. If the elevated chloride and TDS concentrations could lead to increased transformation of the mercury in Riverbed sediments and subsequent transport into the water column from the sediments, this would be a short-lived phenomenon, since the potential for the sorption of new inorganic mercury onto sediments and subsequent deposition to the bed sediments would be reduced. In other words, the rate of production of methyl mercury would be expected to decline overall since the source of new mercury to the sediments would be reduced.
Question No. 60(a): My major concern is how will the public and your organization know if the dilution system is effective, especially if the proposed egress of the wastewater is downstream from the gauging station where water is measured and analyzed.	The IEPA will require a continuous real-time monitoring program as a condition in the NPDES Permit. The closest station downstream that can be safely monitored will be chosen to ensure compliance with the water quality standards.
Question 60(b): Has the wastewater been tested before and after diluted measures taken place on a normal day, and week of operation?	Dilution occurs within the mixing zone and is monitored and calibrated to ensure water quality standards are continuously met.

Questions	Responses
Question 60(e): How dangerous will; this water be for the ecosystem?	The water will be well within standards based on our studies and will not be a threat. The main concern for this discharge is the addition of salt (chloride, which is also found in table salt, is the main component of concern). By utilizing the mixing zone, which is very small and meets all limits imposed by the State of Illinois, the Mine will be ensuring that their discharge will not harm the Big Muddy River. Water quality standards are set after a regulatory process the determines whether they are protective of uses of the stream. By meeting water quality standards, the discharge will not be considered a threat to the ecosystem.
Question 60(f): Is it safe for anyone or anything to consume, bath and swim?	The Big Muddy River has not been approved as a source of drinking water. The IEPA does not recommend human consumption of this water. The Big Muddy River has been designated as fully supporting Primary Contact Recreation. The addition of this discharge will not change the ability of this waterbody to meet that existing use, since all water quality criteria related to the constituents discharged by the Mine will be met.
Question 60(g): What is the economic impact as it relates to tourism and the recreation industry?	Because the mine discharge will comply with water quality standards, the existing uses of the Big Muddy River will not change. Thus, the discharge is not expected to impact tourism or recreation. In addition, the physical outfall structure is not expected to physically interfere with human activity on or near the river.
Question 60(h): What is Williamson Energy's safety and health record for its miners?	The safety and health of the workforce is beyond the scope of IEPAs review of this water discharge permit.

Questions	Responses
Question No. 78: How did Williamson Energy LLC dispose of high chloride and sulfate water in the past?	As this became a more significant issue as mining progressed the mine developed a multi-faceted strategy for dealing with the water that included storing water underground, reusing the water in operations, storing water in the impoundments and occasionally discharging water when permit conditions allow. This system has reached capacity for current and potential future volumes of water hence the mixing zone request.
Question No. 87: Mixing is not allowed in waters containing mussel beds an endangered species habitat has this been determined by IEPA and IDNR? How's the current state of the river as well as the Sugar Creek mine discharge pipeline been considered in determining this?	IEPA relied upon a study entitled Freshwater Mussels of the Big Muddy River prepared for Illinois Department of Natural Resources: Office of Resource Conservation that shows no particularly sensitive species of mussel are present in the main stem of the Big Muddy River that would be adversely impacted by this discharge. In addition, the applicant has conducted a Mussel Survey in April 2020 in the immediate vicinity of the mixing zone and determined that no mussel beds are present in the area of mixing. Based on habitat evaluations and surveys conducted to site benthic macroinvertebrate collections, no mussel habitat is believed in the vicinity of the diffuser and mixing zone. The absence of mussels will be confirmed with a mussel survey which is scheduled to be performed prior to construction. The expected discharge from Sugar Camp has been accounted for in both the model analyzing the expected water quality standards and in the permit conditions that prohibit discharge if the background concentration in the Big Muddy River exceeds the water quality standard.
Question No. 91: How will the IEPA verify all these calibrations will work so that the effluent stays within the limits of the regulations? (E246)	IEPA will review the monitoring results via the submission of company data that is required in the permit. The monitoring plan is designed to give real time data that allows for immediate action should a problem be detected by the company or IEPA.

Questions	Responses
Question No. 101: If the mine waste contaminants don't go down stream, will they spread out over fields and forests and how will the applicant monitor the distribution of mine wastes? Will contaminants become more concentrated as flood water recede? What will be the impact of these mine contaminates on farm soils and wildlife? (E385)	The constituents discharged at the diffuser location will be transported downstream by the Big Muddy River. All water quality criteria will be met at the edge of the mixing zone. In the event of flooding conditions within the Big Muddy River, the constituent concentrations will be further reduced by the volume of water present. The distribution of these constituents would not likely be able to be detected. These constituents are dissolved in the water, so as the flood waters recede, the dissolved salts will move with the water. Flood waters tend to leach salts from soils, rather than depositing them. Farm soils and wildlife are not expected to be impacted by the constituents from this discharge. The concentrations present in the Big Muddy River downstream from the mixing zone are not expected to be affect farm soils or wildlife. While too much salt can be a concern for crop production, the predicted concentrations in the water downstream during normal conditions are within ranges that have been found to be manageable for use as irrigation. The additional natural floodwaters that will be present during floods will further reduce the concentrations. At no point in time is a flooding condition expected to concentrate the dispersed discharge.

Questions	Responses
Question No. 105(a): By allowing increased discharge of chloride, sulfate, tss and other pollutants that will adversely affect existing uses of the Big Muddy River and Pond Creek and other creeks in the area. The applicants plan to prevent violations of Illinois water quality standards outside the mixing zone for numerous pollutants is unlikely to be implemented. Among the ways in which existing uses will be impacted will be through chemical and biological process resulting from allowed discharges that will cause increased methyl mercury, increased phosphorus, increased cyanobacteria and decreased dissolved oxygen in the water column. Damage to existing uses may also occur through damage to creeks not receiving discharges from the mine but that they may be affected in quality from reduced stream flow caused by groundwater moving downward to fill areas vacated by groundwater filling the mine. (E389)	The plan to prevent violations of Illinois water quality standards will be implemented as required by the NPDES Permit. For the response regarding methylmercury, refer to the response to Question 47. There is not expected to be an increase in phosphorus concentrations in the Big Muddy River due to this discharge. The citations given imply that this phosphorus will be released from the sediments due to the increased chloride and salt concentrations. This would imply that the sediments represent an infinite source of phosphorus as well. This is simply not true. The discharge is not expected to result in an increase in the phosphorus concentration downstream. Cyanobacteria have a potential competitive advantage over algal species due to the ability of some species to convert nitrogen gas into inorganic forms of nitrogen needed for growth. The claim that there will be an increase in cyanobacteria is based on the claim that there will be an increase in phosphorus. There is not expected to be an increase in phosphorus downstream from the proposed discharge. There is therefore not expected to be an increase in cyanobacteria. The treated discharge is not expected to decrease the dissolved oxygen concentration in the Big Muddy River. The increased turbulence should result in increased reaeration, although it is not expected to be a significant impact to the DO concentration. The mixing zone is not a zone of instant death. There is not expected to be a substantial increase in dead biomass as a result of this treated effluent. There is not enough biomass present in the River or within the mixing zone to cause an impact on the dissolved oxygen if all of the biomass was killed. Historic records of carbonaceous BOD from the Big Muddy River indicated concentrations less than 2.5 mg/L. This

Questions	Responses
Question No. 106: The NPDES permit does not ensure compliance a written with Illinois water quality standard 35 Ill. Adm. Code 302, 304. 105, and 308.143. by increasing the levels of methyl mercury and phosphorus, deceasing DO levels, and causing violations of narrative standards in the Big Muddy. The Big Muddy is already listed as impaired by methyl mercury, low DO and TSS in the receiving segment and numerous downstream segments and as potentially impaired by phosphorus. (E389)	See response to Question 105.
Question No. 106(a) The antidegradation assessment makes no attempt to address impacts to mussels or even assess if mussels are present in the area, despite clear direction that Illinois antidegradation policy calls for the maintenance and protection of existing uses, including the prevention of a shift from pollution-sensitive to more pollution tolerant community and the loss of species diversity.	Total Maximum Daily Load evaluations conducted in the Big Muddy River document the current and historic impairment in the watershed, which is already dominated by pollutant tolerant species. This was further confirmed in the vicinity of the mixing zone and diffuser in recent benthic macroinvertebrate surveys which demonstrated poor habitat and communities dominated by Chironomidae and Ceratopogonidae, both tolerant families. No degradation of existing uses is expected as a result of the mixing zone and discharges. Due to the depth and habitat limitations, no mussels are likely to be present in the vicinity of the discharge. However, a mussel survey is scheduled to be conducted as soon as temperature and flow conditions permit.

Questions	Responses
Question No. 110: The NPDES permit violates 302.102, 302.105(a), 304.105, 309.141(d) and 309.143 because the reasonable potential test on which the public document relies was not properly performed at least with regard to mercury, copper, iron, nickel, and selenium. It appears that cadmium and manganese have also not been tested properly.	The applicant has conducted additional sampling in response to comments previously received at the direction of IEPA and IEPA has used standard reasonably potential analyses to set the limits in the permit.
Question No. 111: The NPDES permit violates 302.102m 302.105(a), 304.105, 309.141(d) and 309.143 because the testing done for mercury was not done with sufficient sensitivity to determine whether there is a reasonable potential for the discharge to cause or contribute to violations of the applicable 12 ng/l water quality standard in 302.208(f).	The applicant has conducted additional sampling for mercury in response to comments previously received at the direction of IEPA. The minimum detection limit in the additional sampling is .5 nanograms per liter (0.000005 mg/L). Based upon the additional at this MDL, the applicant's effluent does not have the reasonable potential to exceed the WQS for mercury.

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WILLIAMSON ENERGY'S RESPONSES TO IEPA QUESTIONS

Questions	Responses
Question No. 12: How will the unfiltered water discharged into the Big Muddy be filtered? BY whom and how is the discharge monitored? Monitoring needs to occur at all times to assess chemical discharge. (E180)	The water is treated at the site by settling solids out in the holding pond. This is a standard method of treatment for solids for many wastewater treatment systems. The Mine is required to comply with a Total Suspended Solids (TSS) concentration at the compliance point. Filtering has not been required to meet the water quality standards specified by the NPDES Permit. With respect to the monitoring request, a system of continuous monitors was proposed by the Mine and has been incorporated into the NPDES Permit. The treated effluent and the receiving stream upstream from the diffuser will have continuous monitors that will allow the system to maintain compliance with the water quality standards downstream.
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Question No. 28: What is Foresight's daily Rend Lake usage in initial stages of coal production? What does it pay Adena Resources and the state of Illinois for this use? Explain the water contracts and Foresight's use of TVA's coal.	Currently Sugar Camp, LLC uses Rend Lake water to supplement make-up water for coal processing. There is a provision for Pond Creek Mine to utilize this source of water as coal processing make-up water; however, Pond Creek Mine does not currently use this approved availability. Williamson Energy does not mine, control or have access to TVA coal.

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Questions	Responses
Question No. 30: In response to the question of why deep injection wells for salty water was not being considered, has Foresight provided numbers to IEPA to justify assertion? If it comes from saline aquifers why not return it to them instead of dumping surface waters contain life?	At Foresight's Sugar Camp operation, two underground injection wells were installed – Well 1 in September 2013 and Well 2 in October 2014. The wells operated until January 2017, at which point the wells ceased operating because they were unable to continue to accept injections. The history of these two wells showed they only accepted, on average 3,750,000 gallons per month, which represents less than 4% of Williamson water disposal needs.
Question No. 31: Williamson Energy was found to have 45 effluent violations between the years 2015 and 2017. Eleven of those violations were sulfate and ten were chloride in Pond Creek. How can you say that we will not have problems with water quality when they have repeated problems with water quality? How can the water be safe if they're repeatedly violated? (T47)	Williamson Energy has had water quality excursions noted on NPDES Discharge Monitoring Reports over the past few years. The number of excursions noted are far exceeded by the number of compliant discharges reported over the same time period and it is important to know that Williamson remediated each excursion. Water management is of great concern to Williamson and with the increase of water in the mine is causing Williamson to seek out more efficient and effective systems to maintain proper water quality. Williamson is working diligently to maintain compliant water quality in Pond Creek and has determined a mixing zone is the safest and most effective system to employ. The mixing zone request is designed to remove most discharges from Pond Creek and put in place via the mixing zone a system that is designed to consistently maintain compliant water quality with real time monitoring to ensure that compliant water quality is being maintained at all times. All this is to reduce the possibility of non-compliant discharges. The real-time monitoring and flow controls included in the permit application are specifically designed to prevent water quality exceedances.

Questions	Responses
Question No. 35: I would like to know what the depth of the Big Muddy in that area is currently because it surely isn't 30 feet deep for the diffuser to be pouring effluent into the water?	The river depth at the diffuser site is 8-12 feet at baseline flow. This is more than enough depth to accommodate diffuser flow.
Question No. 36: How will the diffuser vents be protected from people continuing to use the location as a dump site?	As part of the NPDES Permit requirements, the Outfall will be marked by signage on the bank to let people on the River know the outfall is present. The diffuser ports will be installed in a way to minimize damage due to strikes from natural objects such as logs. The site is not located on a public road, which will reduce the potential for average member of the public from dumping large objects into the River at this location. The opposite bank is private property, which will also minimize the average member of the public from attempting to vandalize the diffuser. For those determined to do harm to the diffuser, the site will be monitored and access to the River will be limited.

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Question No. 37: We analyzed the Data and found that the 90th percentile chloride concentration is actually 108 mgl, so I wanted to ask tonight how did the mine come to use 30 mgl as the 90th percentile?	The design used a background concentration of 151 mg/L for determining the worse-case condition for discharging. By using a background chloride concentration that is greater than the known background concentration, the Mine is ensuring that the water quality criteria will be met. The maximum discharge determined for each flow scenario utilized this elevated background concentration, so that the water quality criteria will be met at the edge of the mixing zone. In any event, even if the model under-reports the background levels, the water quality standard is still protected, because if the background concentration approaches or exceeds the WQS, then Williamson's ability to use the mixing zone will be limited or prevented by the terms and conditions of the permit.
Question No. 40: How will the mine develop that accurate calibration? Does the Agency have to approve the calibration curve derived by the mine? And are the calibrated values also reported on the DMR? Do we have all the information that they're using to do that calibration?	The Mine will utilize a database that correlates the conductivity and chloride concentrations for the River coming to the diffuser and for the treated effluent discharged. The use of the conductivity sensor allows the system to respond in real-time to reduce the discharge as necessary. These data will be provided to IEPA so that the Agency will be able to ensure compliance with the water quality standards and the Permit. The Mine will review these data to ensure the control system stays up to date so that the system will maintain compliance with the water quality standards. IEPA is adding a condition to the permit that requires Williamson to submit, and IEPA to accept, the correlation and underlying data prior to use of the mixing zone. Any information or data submitted to support the calibration will be publicly available.

Questions	Responses
Question No. 41: The IEPA should include a fish survey, a mussel survey and a survey of invertebrates pre-construction as well as long term monitoring post-construction would be or should be required.	The mixing zone is sized and designed to provide fish passage and should not affect the fish community in the Big Muddy River. IEPA used a fish survey conducted by the Illinois Department of Natural Resources in assessing any potential fish impacts and found no adverse impacts. Likewise, a benthic macroinvertebrate survey has already been conducted by Alliance Consulting in 2019 and submitted to the administrative record by Williamson. The Survey occurred in the area downstream of the mixing zone. This survey demonstrated that the diffuser will be located in a pool of the river with poor habitat availability for greater than three-quarters of a mile below the diffuser. The benthic macroinvertebrate community in the downstream sample was dominated by tolerant Chironomidae and Ceratopogonidae, typical of fine, unstable substrate. A few mayflies and unionids were collected in this survey which may indicate substrate, not water quality, is the limiting factor in this reach. A mussel survey is also scheduled to be conducted prior to diffuser construction but mussel surveys are limited to a specific sampling season which begins in April. In the unlikely event that a mussel bed is found within the diffuse construction location or mixing zone, this would be addressed with IEPA prior to construction.

Questions	Responses
Question No. 47: Will the increased chloride and total dissolved solids levels in the Big Muddy River cause higher methyl mercury levels? Will the acid mine drainage allowed in this permit also increase the conversion of mercury to methyl mercury? Can Illinois EPA assure us that it will not? (T111)	The increased chloride and total dissolved solids concentrations in the Big Muddy River are not expected to lead to greater concentrations of methyl mercury. The claim of increased methylmercury releases due to the increased chloride concentrations are unsubstantiated. Methylmercury is formed primarily under anaerobic conditions. These conditions are not expected in the Big Muddy River. These conditions are expected in sediments not in direct contact with aerated water. Meaning the deeper sediments that are not directly impacted by the overlying water column are expected to be anaerobic or anoxic. While the literature sources cited indicate a potential for the increase in the release of methylmercury upon increased chloride concentrations, this does not mean that there is an infinite source of available mercury to convert. Effluent present in the mixing zone, where the greatest concentrations of chlorides are expected is not anticipated to interact with the bottom sediments. Therefore, there is minimal risk of increased release of methylmercury within the mixing zone area. Moving downstream, the concentration of chloride will continue to decrease, further reducing the theoretical risk of mercury release. There is much discussion in the public comments that atmospheric deposition of mercury is the primary source of mercury in the Big Muddy River. The presence of elevated chloride concentrations has been shown to prevent inorganic mercury from sorbing to sediments (Randall, March 2013, Environmental Research). Therefore, the presence of this chloride is expected to reduce the potential deposition of mercury to the sediment beds. By reducing the potential sorption of mercury onto sediments, more of

Questions	Responses
	this deposited mercury would be expected to migrate downstream within the water column. Without a new source of mercury to the sediments, the mercury concentration that may be present in the sediments could decrease so that the potential for methylmercury production in the sediments would be reduced. If the elevated chloride and TDS concentrations could lead to increased transformation of the mercury in Riverbed sediments and subsequent transport into the water column from the sediments, this would be a short-lived phenomenon, since the potential for the sorption of new inorganic mercury onto sediments and subsequent deposition to the bed sediments would be reduced. In other words, the rate of production of methyl mercury would be expected to decline overall since the source of new mercury to the sediments would be reduced.
Question No. 60(a): My major concern is how will the public and your organization know if the dilution system is effective, especially if the proposed egress of the wastewater is downstream from the gauging station where water is measured and analyzed.	The IEPA will require a continuous real-time monitoring program as a condition in the NPDES Permit. The closest station downstream that can be safely monitored will be chosen to ensure compliance with the water quality standards.
Question 60(b): Has the wastewater been tested before and after diluted measures taken place on a normal day, and week of operation?	Dilution occurs within the mixing zone and is monitored and calibrated to ensure water quality standards are continuously met.

Questions	Responses
Question 60(c): What exactly does diluted measures mean?	The holding pond from where the treated effluent will be discharged has been monitored in preparation for this permit and will continue to be monitored as part of the NPDES Permit compliance. The effluent is expected to vary with the addition of rainwater as part of natural conditions. This is the only natural dilution that will occur prior to discharge. With respect to the outfall configuration, the effluent will be discharged in a manner to maintain the water quality criteria downstream. The NPDES sets discharge limits for the discharge to the Big Muddy River. The Mine will not be allowed to exceed these limits. If the Big Muddy River flow is very high, the maximum discharge that can occur is 5,000 gallons per minute. During the majority of the time based on the historical flow record, the Mine's discharge will be limited by the actual flowrate, the background concentration, and the effluent concentration. Each of these three parameters will be monitored to achieve the water quality criteria at the edge of the mixing zone.
Question 60(d): How effective and how much of the heavy metals are recovered in the process on a daily, weekly, and monthly period?	Based on testing performed as part of the permit application, heavy metals are not at concentrations that have the reasonable potential to exceed the water quality criteria. The effect of the mixing zone will be to further reduce the concentration, so that there is less of a chance of exceeding the water quality criteria in the Big Muddy River due to this discharge. The Mine does not actively attempt to recover heavy metals as part of its business model. However, as part of the water treatment on-site, the capture of solids within the pond systems does serve to reduce the potential concentration of metals that would be discharged. This is due to most metals preference to be attached to solids under the conditions found in the Holding Pond.

Questions	Responses
Question 60(e): How dangerous will; this water be for the ecosystem?	The water will be well within standards based on our studies and will not be a threat. The main concern for this discharge is the addition of salt (chloride, which is also found in table salt, is the main component of concern). By utilizing the mixing zone, which is very small and meets all limits imposed by the State of Illinois, the Mine will be ensuring that their discharge will not harm the Big Muddy River. Water quality standards are set after a regulatory process the determines whether they are protective of uses of the stream. By meeting water quality standards, the discharge will not be considered a threat to the ecosystem.
Question 60(f): Is it safe for anyone or anything to consume, bath and swim?	The Big Muddy River has not been approved as a source of drinking water. The IEPA does not recommend human consumption of this water. The Big Muddy River has been designated as fully supporting Primary Contact Recreation. The addition of this discharge will not change the ability of this waterbody to meet that existing use, since all water quality criteria related to the constituents discharged by the Mine will be met.
Question 60(g): What is the economic impact as it relates to tourism and the recreation industry?	Because the mine discharge will comply with water quality standards, the existing uses of the Big Muddy River will not change. Thus, the discharge is not expected to impact tourism or recreation. In addition, the physical outfall structure is not expected to physically interfere with human activity on or near the river.
Question 60(h): What is Williamson Energy's safety and health record for its miners?	The safety and health of the workforce is beyond the scope of IEPAs review of this water discharge permit.

Questions	Responses
Question 60(i): How have other mines dealt with this similar situation?	Several mines in IL have employed mixing zones previously and currently. While this saltwater aquifer is not unique, it is also not common. Other mines are able to discharge through stormwater discharges while still meeting the water quality criteria. This has become impossible due to the inclusion of the saltwater aquifer into our water supply.
Question No. 65: Why would the permittee determine the effluent limitation for chloride and the maximum effluent flow? How would this be monitored? Given the violations related to this company concerning its outfall sites, why would you trust that regulations will be followed? (E158)	The maximum flow at which compliant water quality could be maintained had to be determined for permitting purposes so that the monitoring system could be properly calibrated so that flow can be automatically adjusted to ensure water quality is always maintained. The monitoring design and protocol can be found in the response to request. Diligent monitoring and IEPA reporting requirements and oversight will ensure water quality is properly maintained. The law imposes the requirement to monitor and report water quality of effluent on every discharger in the state of Illinois. The State does not conduct the required bi-monthly monitoring of any permitee's effluent.
Question No. 74: Are there any locations downstream that have mussel populations?	IEPA relied upon a study entitled Freshwater Mussels of the Big Muddy River prepared for Illinois Department of Natural Resources: Office of Resource Conservation that shows no particularly sensitive species of mussel are present in the main stem of the Big Muddy River that would be adversely impacted by this discharge. In addition, the applicant has conducted a Mussel Survey in April 2020 in the immediate vicinity of the mixing zone and determined that no mussel beds are present in the area of mixing.

Questions	Responses
Question No. 78: How did Williamson Energy LLC dispose of high chloride and sulfate water in the past?	As this became a more significant issue as mining progressed the mine developed a multi-faceted strategy for dealing with the water that included storing water underground, reusing the water in operations, storing water in the impoundments and occasionally discharging water when permit conditions allow. This system has reached capacity for current and potential future volumes of water hence the mixing zone request.
Question No. 87: Mixing is not allowed in waters containing mussel beds an endangered species habitat has this been determined by IEPA and IDNR? How's the current state of the river as well as the Sugar Creek mine discharge pipeline been considered in determining this?	IEPA relied upon a study entitled Freshwater Mussels of the Big Muddy River prepared for Illinois Department of Natural Resources: Office of Resource Conservation that shows no particularly sensitive species of mussel are present in the main stem of the Big Muddy River that would be adversely impacted by this discharge. In addition, the applicant has conducted a Mussel Survey in April 2020 in the immediate vicinity of the mixing zone and determined that no mussel beds are present in the area of mixing. Based on habitat evaluations and surveys conducted to site benthic macroinvertebrate collections, no mussel habitat is believed in the vicinity of the diffuser and mixing zone. The absence of mussels will be confirmed with a mussel survey which is scheduled to be performed prior to construction. The expected discharge from Sugar Camp has been accounted for in both the model analyzing the expected water quality standards and in the permit conditions that prohibit discharge if the background concentration in the Big Muddy River exceeds the water quality standard.
Question No. 91: How will the IEPA verify all these calibrations will work so that the effluent stays within the limits of the regulations? (E246)	IEPA will review the monitoring results via the submission of company data that is required in the permit. The monitoring plan is designed to give real time data that allows for immediate action should a problem be detected by the company or IEPA.

Questions	Responses
Question No. 95: Can Williamson Energy be responsible for restoring the fish population	We do not expect or anticipate fish kills directly related to the mixing zone discharges because the water leaving the mixing zone boundaries will meet all relevant water standards. Within the mixing zone itself it is required to leave a safe passage for fish and you cannot use more the ¼ of the stream width for the mixing zone by regulation. Should there be an unanticipated fish kill directly related to the mixing zone the State of Illinois will investigate and take appropriate actions under existing laws.
Question No. 97: What happens to the wildlife that lives in these backflow areas? Why do corporations get with dumping the true costs of their for-profit operations,? Who's going to pay to clean up our waterways or deal with the cancer that will surely develop from this pollution? (E371)	The effluent is discharged into the Big Muddy River, not into a backwater area. During a flood in which water from the Big Muddy River could be pushed upstream into the tributaries, the additional dilution from the flood waters would result in even lower concentrations. Therefore, there would not be any expected impacts to backflow areas of the tributaries. Mixing zones are specifically sized and shaped to protect wildlife by providing passage around the mixing zone and achieving protective water quality criteria at the edge of the mixing zone. Compliance with water quality standards is designed to be protective of aquatic life and human health.
Question No. 100: Will the applicant be allowed to pump contaminants into the Big Muddy during periods when it is flowing backwards? How will the applicant monitor dilution of mine wastes in the water column during periods of backwards flow and stagnation? (E385)	Upon reviewing the data for the gage at Murphysboro, which has recorded gage height since 1995, the elevations recorded during times of flow reversal range from 339.36 ft NGVD29 to 366.45 ft NGVD29. The proposed diffuser location has a minimum water surface elevation of 357.21 ft NGVD29. It is therefore not likely that any flow reversal will occur within the mixing zone.

Questions	Responses
Question No. 101: If the mine waste contaminants don't go down stream, will they spread out over fields and forests and how will the applicant monitor the distribution of mine wastes? Will contaminants become more concentrated as flood water recede? What will be the impact of these mine contaminates on farm soils and wildlife? (E385)	The constituents discharged at the diffuser location will be transported downstream by the Big Muddy River. All water quality criteria will be met at the edge of the mixing zone. In the event of flooding conditions within the Big Muddy River, the constituent concentrations will be further reduced by the volume of water present. The distribution of these constituents would not likely be able to be detected. These constituents are dissolved in the water, so as the flood waters recede, the dissolved salts will move with the water. Flood waters tend to leach salts from soils, rather than depositing them. Farm soils and wildlife are not expected to be impacted by the constituents from this discharge. The concentrations present in the Big Muddy River downstream from the mixing zone are not expected to be affect farm soils or wildlife. While too much salt can be a concern for crop production, the predicted concentrations in the water downstream during normal conditions are within ranges that have been found to be manageable for use as irrigation. The additional natural floodwaters that will be present during floods will further reduce the concentrations. At no point in time is a flooding condition expected to concentrate the dispersed discharge.

Questions	Responses
Question No. 102: What are the impacts to the La Rue Swamp if polluted mine water seeps under the Big Muddy Levy? (E385)	There are not expected to be any impacts to the LaRue Swamp. The LaRue Swamp is located approximately within 6 miles from the confluence with the Mississippi River. At this point, the water discharged by the Mine at the diffuser location will be dispersed within the River. There will not be a separate layer of water. The ability for any water to seep into the LaRue swamp through the levy system is dependent upon the difference in elevation (head) of the waters on each side of the levy. During normal flow conditions on the Big Muddy River, we do not anticipate a head pressure significant enough to push water from the River to the other side of the swamp. During times of higher flow including flooding conditions, the amount of additional water present in the River will further decrease the concentrations that are discharged. Any water that would seep through the levy system would not be expected to contain concentrations of constituents discharged by the mine that would impact the LaRue Swamp.
Question No. 103: What is the total and exact chemical composition, as well as the safety and inspection proposed by this pipeline?	The discharge pipe will be constructed using PVC material of appropriate gauge and will be inspected according to good engineering practices, permit and agency requirements.
Question No. 105: The NPDES permit does not ensure compliance as written with Illinois water quality standard 35 Ill. Adm. Code 302.	We assert that the NPDES permit does meet standards and it is the IEPA obligation throughout the permitting and approval process to place standards and conditions in the permit to assure compliance.

Questions	Responses
Question No. 105(a): By allowing increased discharge of chloride, sulfate, tss and other pollutants that will adversely affect existing uses of the Big Muddy River and Pond Creek and other creeks in the area. The applicants plan to prevent violations of Illinois water quality standards outside the mixing zone for numerous pollutants is unlikely to be implemented. Among the ways in which existing uses will be impacted will be through chemical and biological process resulting from allowed discharges that will cause increased methyl mercury, increased phosphorus, increased cyanobacteria and decreased dissolved oxygen in the water column. Damage to existing uses may also occur through damage to creeks not receiving discharges from the mine but that they may be affected in quality from reduced stream flow caused by groundwater moving downward to fill areas vacated by groundwater filling the mine. (E389)	The plan to prevent violations of Illinois water quality standards will be implemented as required by the NPDES Permit. For the response regarding methylmercury, refer to the response to Question 47. There is not expected to be an increase in phosphorus concentrations in the Big Muddy River due to this discharge. The citations given imply that this phosphorus will be released from the sediments due to the increased chloride and salt concentrations. This would imply that the sediments represent an infinite source of phosphorus as well. This is simply not true. The discharge is not expected to result in an increase in the phosphorus concentration downstream. Cyanobacteria have a potential competitive advantage over algal species due to the ability of some species to convert nitrogen gas into inorganic forms of nitrogen needed for growth. The claim that there will be an increase in cyanobacteria is based on the claim that there will be an increase in phosphorus. There is not expected to be an increase in phosphorus downstream from the proposed discharge. There is therefore not expected to be an increase in cyanobacteria. The treated discharge is not expected to decrease the dissolved oxygen concentration in the Big Muddy River. The increased turbulence should result in increased reaeration, although it is not expected to be a significant impact to the DO concentration. The mixing zone is not a zone of instant death. There is not expected to be a substantial increase in dead biomass as a result of this treated effluent. There is not enough biomass present in the River or within the mixing zone to cause an impact on the dissolved oxygen if all of the biomass was killed. Historic records of carbonaceous BOD from the Big Muddy River indicated concentrations less than 2.5 mg/L. This

Questions	Responses
	indicates that there is not a significant concentration of biomass present in the Big Muddy River. The saltwater aquifer that is the source of this chloride water is not likely connected to the freshwater systems feeding the surface drainage. Furthermore, no connection between surface drainage features and the mining operations is known. The claim that creeks will be affected by a loss of water due to groundwater migrating to fill the saltwater aquifer as it is migrating into the mine is unfounded.
Question No. 105(a)(2): Nickel has not been properly considered and the cumulative effect of the increased concentrations of these pollutants together have been ignored. The limits of the testing and the sensitivity of testing methods is such that increased loading of a number of other pollutants is probable. (E389)	Nickel is not a constituent of concern for site surface pond operations. While nickel can be found in coal, the source of the salt water is from an aquifer in the sandstone layer above the operating unit of the mine and is not expected to have a nickel concentration that is above water quality criteria. The water being discharged will be a mix of the saltwater aquifer and from surface water collected on-site. Nickel can be found in coal. However, this nickel is not expected to leach from the coal under the operating conditions found at the mine site. Further, it is expected that the control of solids discharged from the final holding pond will limit the amount of coal and therefore, metals that may be found in coal, that could be discharged. As part of the permitting process, the mine sampled its expected effluent for total nickel and dissolved nickel, each with a minimum detection limit of .005 mg/L. The results from this sampling and analysis indicate that the mine effluent does not have the reasonable potential to exceed the water quality standard for nickel.

Questions	Responses
Question No. 106: The NPDES permit does not ensure compliance a written with Illinois water quality standard 35 Ill. Adm. Code 302, 304. 105, and 308.143. by increasing the levels of methyl mercury and phosphorus, deceasing DO levels, and causing violations of narrative standards in the Big Muddy. The Big Muddy is already listed as impaired by methyl mercury, low DO and TSS in the receiving segment and numerous downstream segments and as potentially impaired by phosphorus. (E389)	See response to Question 105.
Question No. 106(a) The antidegradation assessment makes no attempt to address impacts to mussels or even assess if mussels are present in the area, despite clear direction that Illinois antidegradation policy calls for the maintenance and protection of existing uses, including the prevention of a shift from pollution-sensitive to more pollution tolerant community and the loss of species diversity.	Total Maximum Daily Load evaluations conducted in the Big Muddy River document the current and historic impairment in the watershed, which is already dominated by pollutant tolerant species. This was further confirmed in the vicinity of the mixing zone and diffuser in recent benthic macroinvertebrate surveys which demonstrated poor habitat and communities dominated by Chironomidae and Ceratopogonidae, both tolerant families. No degradation of existing uses is expected as a result of the mixing zone and discharges. Due to the depth and habitat limitations, no mussels are likely to be present in the vicinity of the discharge. However, a mussel survey is scheduled to be conducted as soon as temperature and flow conditions permit.

Questions	Responses
Question No. 107: The NPDES permit violates 302.105(c) by allowing new discharges to the Big Muddy River and Pond Creek that are not necessary to accommodate important social and economic development but, on the contrary, will harm social and economic development by further wedding the local economy to an industry without a long term future and a company likely to leave the community with a large environmental hazard that will have to be cleaned up with public funds. Neighbors of the mine will continue to be harmed by the mining operations. Further, the mining of coal , to the extent it occurs, and the coal is burned in China or elsewhere, will harm the local economy by increasing the emission of greenhouse gases.	The applicant indicates that the discharge will support a mining operation that employs over 235 direct, highly paid employees and supports an additional 705 indirect jobs, using industry-standard metrics for measuring indirect impacts of coal mining. The mine supports an additional 100 jobs directly through use of contractors. The discharge is not anticipated to have the harm stated in the question as it will comply with water quality standards. The effect of coal burn in China or elsewhere is beyond the scope of IEPA's review of this water discharge permit.
Question No. 108: The NPDES permit violates 302.105 and 309.141(d), 309.143, and 309.146 by allowing a mixing zone that (the misrepresentations made in the record by the applicant notwithstanding) will in fact result is violations of applicable water quality standards outside the mixing zone by allowing increased discharges subject to implementation of a complex dilution and monitoring formula by an applicant that has proven itself utterly incapable of complying with limits and reporting requirements of its current relatively simple permit and by allowing a mixing zone in Pond Creek with no dilution is available.	The applicant has removed the mixing zone on Pond Creek from its renewal application in response to this comment. However, the Big Muddy mixing zone remains. The operation of the discharge will be controlled by programmable logic controls using real-time and continuous data. Thus, the software systems will control the flow.
Question No. 109: The NPDES permit violates Code 146 by failing to require monitoring adequate to determine compliance with the complex dilution scheme contemplated by the permit.	Most NPDES permits issued require limited sampling. This Permit will require continuous monitoring. This includes real-time sensors that track the Big Muddy River coming to the proposed diffuser location as well as the effluent being discharged. This scheme will ensure that the effluent is not being discharged at a rate or at a concentration that will cause an exceedance of the water quality criteria.

Questions	Responses
Question No. 110: The NPDES permit violates 302.102, 302.105(a), 304.105, 309.141(d) and 309.143 because the reasonable potential test on which the public document relies was not properly performed at least with regard to mercury, copper, iron, nickel, and selenium. It appears that cadmium and manganese have also not been tested properly.	The applicant has conducted additional sampling in response to comments previously received at the direction of IEPA and IEPA has used standard reasonably potential analyses to set the limits in the permit.
Question No. 111: The NPDES permit violates 302.102m 302.105(a), 304.105, 309.141(d) and 309.143 because the testing done for mercury was not done with sufficient sensitivity to determine whether there is a reasonable potential for the discharge to cause or contribute to violations of the applicable 12 ng/l water quality standard in 302.208(f).	The applicant has conducted additional sampling for mercury in response to comments previously received at the direction of IEPA. The minimum detection limit in the additional sampling is .5 nanograms per liter (0.000005 mg/L). Based upon the additional at this MDL, the applicant's effluent does not have the reasonable potential to exceed the WQS for mercury.

DOCUMENT

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ILLINOIS ENVIRONMENTAL PROTECTION AGENCY
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JB PRITZKER, GOVERNOR JOHN J. KIM, DIRECTOR

S. Twait
R00211

Memorandum

DATE: 15 April 2020

TO: Iwona Ward

FROM: Scott Twait ST

SUBJECT: WQBELs
Williamson Energy, LLC – Pond Creek Mine
NPDES Permit No. IL007766 (Williamson County)

The subject facility discharges to the unnamed tributaries of Pond Creek through Outfalls 001 – 008 at a point where 0 cfs of flow exists upstream of the outfalls during critical 7Q10 low-flow conditions. The unnamed tributaries of Pond Creek are classified as a General Use Water. The unnamed tributaries of Pond Creek are not listed as a biologically significant streams in the 2008 Illinois Department of Natural Resources Publication *Integrating Multiple Taxa in a Biological Stream Rating System*, nor are they given an integrity rating in that document. The unnamed tributaries of Pond Creek, tributary to Waterbody Segment, NG-02, is not listed on the draft 2016 Illinois Integrated Water Quality Report and Section 303(d) List since they have not been assessed. The unnamed tributaries of Pond Creek are not subject to enhanced dissolved oxygen standards.

Outfalls 001 through 005 are alkaline mine drainage and outfalls 006 - 008 are acid mine drainage. The NPDES application did not indicate any watershed sizes or flow expected for mixing and therefore, no mixing is allowed.

Chloride should be regulated as a daily maximum at the water quality standard of 500 mg/L for all of the outfalls.

The Sulfate limit is determined according to the water quality standards at 302.208(h)(2). The chloride and hardness data is from AWQMN station NG-02, Pond Creek, South edge of West Frankfort, downstream of the Williamson Energy, LLC – Pond Creek Mine No. 1 property, so this limit should be used for all outfalls. Flow data was not provided, so calculation of mixing was not completed. No mixing was used in the derivation of the effluent limit. The following table shows the results of downstream chloride and hardness.

Outfalls	Average Receiving Stream Chloride (mg/L)	Receiving Stream Critical Hardness (mg/L)	Sulfate Water Quality Standard (mg/L)
001-009	21.5	141	1250

The sulfate values in the far-right column are applied as daily maximum permit limits.

Where appropriate, Manganese should be regulated as a daily maximum at the water quality standard of 1.0 mg/L.

Monitoring for chloride, sulfate and hardness should be periodically required at a downstream location from each outfall, or downstream of the mine property, during the course of the permit. This data will be used to recalculate sulfate limits for the next renewed or modified permit.

Cadmium, Chromium (Trivalent), Copper, Fluoride, Lead, Manganese, Nickel, and Zinc standards are based on hardness data collected at AWQMN station NJ-07, Casey Fork, S of Mount Vernon, with a critical hardness value of 141 mg/L as $CaCO_3$. Water quality standards identified in the table are expressed in units of mg/L except where noted. Dissolved metals standards have been converted to total metal except where noted. All data was provided

by the discharger.

Outfall 001

Substance	Max. Eff. Conc.	No. of Samples	Multiply by	95% Potential	Acute Standard	302.208(g) standard	Further Analysis?
Arsenic	0.002	7	2.0	0.004	0.3600	-	No RP*
Cadmium	0.018	7	2.0	0.036	0.0144	-	Yes
Chromium (Total)	0.004	7	2.0	0.008	2.3009	-	No RP*
Copper	0.004	7	2.0	0.008	0.0245	-	No RP*
Iron (Dissolved)	0.386	17	1.4	0.5404	-	1.0	No RP*
Lead	< 0.0075	7	2.0	0.015	0.1482	-	No RP*
Manganese	0.52	6	2.1	1.092	5.51		No RP*
Mercury (ng/L) **	14.7	10	1.7	24.99	-	12.0	Yes
Nickel	0.067	7	2.0	0.134	0.1104	-	Yes
Phenols	< 0.01	7	2.0	0.02	-	0.1	No RP*
Silver	< 0.005	7	2.0	0.01	-	0.005	Yes
Zinc	0.025	7	2.0	0.05	0.1635	-	No RP*
Selenium	0.011	7	2.0	0.022	-	1.0	No RP*

* No RP = no reasonable potential to exceed water quality standards.
** all results in ng/L. Human Health standard given

Further Analysis:

There is a reasonable potential to exceed the acute water quality standard for Cadmium. Cadmium should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

The average of the Mercury samples times the multiplier (12. ng/L x 1.7 = 20.4 ng/L) was greater than the human health water quality standard. My conclusion is that a Mercury limit should be incorporated into the NPDES permit at the human health water quality standard.

The Williamson Energy – Pond Creek Mine #1 facility STP had no detections reported for Silver. My conclusion is that no regulation of Silver is necessary and that no monitoring beyond the routine requirements is needed.

The Nickel value (0.067 mg/L) reported in the application has been determined to be an outlier according to the procedure found in the 18th edition of Standard Methods. The next highest Nickel value times the multiplier (0.003 mg/L x 2.1 = 0.0063 mg/L), therefore, there is no reasonable potential to exceed the acute water quality standard for Nickel. My conclusion is that no regulation of Nickel is necessary and that no monitoring beyond the routine requirements is needed.

Outfall 002

Substance	Max. Eff. Conc.	No. of Samples	Multiply by	95% Potential	Acute Standard	302.208(g) standard	Further Analysis?
Arsenic	0.002	7	2.0	0.004	0.3600	-	No RP*

Cadmium	0.031	7	2.0	0.062	0.0144	-	Yes
Chromium (Total)	0.004	7	2.0	0.008	2.3009	-	No RP*
Copper	0.013	7	2.0	0.026	0.0245	-	Yes
Iron (Dissolved)	0.63	17	1.4	0.882	-	1.0	No RP*
Lead	< 0.0075	7	2.0	0.015	0.1482	-	No RP*
Manganese	1.185	6	2.1	2.4885	5.51	-	No RP*
Mercury (ng/L) **	3.67	10	1.7	6.239	-	12.0	No RP*
Nickel	0.074	7	2.0	0.148	0.1104	-	Yes
Phenols	< 0.01	7	2.0	0.02	-	0.1	No RP*
Silver	< 0.002	7	2.0	0.004	-	0.005	No RP*
Zinc	0.059	7	2.0	0.118	0.1635	-	No RP*
Selenium	0.016	7	2.0	0.032	-	1.0	No RP*

* No RP = no reasonable potential to exceed water quality standards.
** all results in ng/L. Human Health standard given.

Further Analysis:

There is a reasonable potential to exceed the acute water quality standard for Cadmium. Cadmium should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

There is a reasonable potential to exceed the acute water quality standard for Copper. Copper should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

There is a reasonable potential to exceed the acute water quality standard for Nickel. Nickel should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

Outfall 003

Substance	Max. Eff. Conc.	No. of Samples	Multiply by	95% Potential	Acute Standard	302.208(g) standard	Further Analysis?
Arsenic	0.003	7	2.0	0.006	0.3600	-	No RP*
Cadmium	0.024	7	2.0	0.048	0.0144	-	Yes
Chromium (Total)	0.004	7	2.0	0.008	2.3009	-	No RP*
Copper	0.003	7	2.0	0.006	0.0245	-	No RP*
Iron (Dissolved)	0.73	17	1.4	1.022	-	1.0	Yes
Lead	< 0.0075	7	2.0	0.015	0.1482	-	No RP*
Manganese	0.625	7	2.0	1.25	5.51	-	No RP*
Mercury (ng/L) **	10	9	1.8	18	-	12.0	Yes
Nickel	0.003	7	2.0	0.006	0.1104	-	No RP*
Phenols	< 0.01	7	2.0	0.02	-	0.1	No RP*
Silver	< 0.005	7	2.0	0.01	-	0.005	Yes
Zinc	< 0.05	7	2.0	0.1	0.1635	-	No RP*

Selenium	0.009	7	2.0	0.018	-	1.0	No RP*

* No RP = no reasonable potential to exceed water quality standards.
** all results in ng/L. Human Health standard given.

Further Analysis:

There is a reasonable potential to exceed the acute water quality standard for Cadmium. Cadmium should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

There is a reasonable potential to exceed the 302.208(g) water quality standard for Iron (dissolved). Iron (dissolved) should be regulated as a daily maximum in the NPDES permit at the 302.208(g) water quality standard.

The average of the Mercury samples times the multiplier (7.36 ng/L x 1.4 = 10.3 ng/L) was less than the human health water quality standard. My conclusion is that no regulation of Mercury is necessary and that no monitoring beyond the routine requirements is needed.

The Williamson Energy – Pond Creek Mine #1 facility STP had no detections reported for Silver. My conclusion is that no regulation of Silver is necessary and that no monitoring beyond the routine requirements is needed.

Outfall 004

Substance	Max. Eff. Conc.	No. of Samples	Multiply by	95% Potential	Acute Standard	302.208(g) standard	Further Analysis?
Arsenic	0.002	7	2.0	0.004	0.3600	-	No RP*
Cadmium	0.024	7	2.0	0.048	0.0144	-	Yes
Chromium (Total)	0.002	7	2.0	0.004	2.3009	-	No RP*
Copper	0.019	7	2.0	0.038	0.0245	-	Yes
Iron (Dissolved)	0.42	17	1.4	0.588	-	1.0	No RP*
Lead	< 0.0075	7	2.0	0.015	0.1482	-	No RP*
Manganese	0.75	6	2.1	1.575	5.51	-	No RP*
Mercury (ng/L) **	3.4	10	1.7	5.78	-	12.0	No RP*
Nickel	0.005	7	2.0	0.01	0.1104	-	No RP*
Phenols	< 0.01	7	2.0	0.02	-	0.1	No RP*
Silver	< 0.005	7	2.0	0.01	-	0.005	Yes
Zinc	0.0203	7	2.0	0.0406	0.1635	-	No RP*
Selenium	0.008	6	2.1	0.0168	-	1.0	No RP*

* No RP = no reasonable potential to exceed water quality standards.
** all results in ng/L. Human Health standard given.

Further Analysis:

There is a reasonable potential to exceed the acute water quality standard for Cadmium. Cadmium should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

There is a reasonable potential to exceed the acute water quality standard for Copper. Copper should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

The Williamson Energy – Pond Creek Mine #1 facility STP had no detections reported for Silver. My conclusion is that no regulation of Silver is necessary and that no monitoring beyond the routine requirements is needed.

Outfall 005

Substance	Max. Eff. Conc.	No. of Samples	Multiply by	95% Potential	Acute Standard	302.208(g) standard	Further Analysis?
Arsenic	0.002	7	2.0	0.004	0.3600	-	No RP*
Cadmium	0.043	7	2.0	0.086	0.0144	-	Yes
Chromium (Total)	0.003	7	2.0	0.006	2.3009	-	No RP*
Copper	0.003	7	2.0	0.006	0.0245	-	No RP*
Iron (Dissolved)	0.37	17	1.4	0.518	-	1.0	No RP*
Lead	< 0.0075	7	2.0	0.015	0.1482	-	No RP*
Manganese	0.736	6	2.1	1.5456	5.51	-	No RP*
Mercury (ng/L) **	8.22	10	1.7	13.974	-	12.0	Yes
Nickel	0.0052	7	2.0	0.0104	0.1104	-	No RP*
Phenols	< 0.01	7	2.0	0.02	-	0.1	No RP*
Silver	< 0.005	7	2.0	0.01	-	0.005	Yes
Zinc	0.0255	8	1.9	0.0485	0.1635	-	No RP*
Selenium	0.007	6	2.1	0.0147	-	1.0	No RP*

* No RP = no reasonable potential to exceed water quality standards.
** all results in ng/L. Human Health standard given.

Further Analysis:

There is a reasonable potential to exceed the acute water quality standard for Cadmium. Cadmium should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

The average of the Mercury samples times the multiplier (5.64 ng/L x 1.7 = 9.59 ng/L) was less than the human health water quality standard. My conclusion is that no regulation of Mercury is necessary and that no monitoring beyond the routine requirements is needed.

The Williamson Energy – Pond Creek Mine #1 facility STP had no detections reported for Silver. My conclusion is that no regulation of Silver is necessary and that no monitoring beyond the routine requirements is needed.

Outfall 006

Substance	Max. Eff. Conc.	No. of Samples	Multiply by	95% Potential	Acute Standard	302.208(g) standard	Further Analysis?
Arsenic	0.002	7	2.0	0.004	0.3600	-	No RP*
Cadmium	0.03	7	2.0	0.06	0.0144	-	Yes
Chromium (Total)	0.012	7	2.0	0.024	2.3009	-	No RP*

Copper	0.012	7	2.0	0.024	0.0245	-	No RP*
Iron (Dissolved)	0.24	17	1.4	0.336	-	1.0	No RP*
Lead	< 0.0075	7	2.0	0.015	0.1482	-	No RP*
Mercury (ng/L) **	5.81	10	1.7	9.877	-	12.0	No RP*
Nickel	0.106	7	2.0	0.212	0.1104	-	Yes
Phenols	< 0.01	7	2.0	0.02	-	0.1	No RP*
Silver	< 0.005	7	2.0	0.01	-	0.005	Yes
Zinc	0.095	7	2.0	0.19	0.1635	-	Yes
Selenium	0.022	6	2.1	0.0462	-	1.0	No RP*

* No RP = no reasonable potential to exceed water quality standards.
** all results in ng/L. Human Health standard given.

Further Analysis:

There is a reasonable potential to exceed the acute water quality standard for Cadmium. Cadmium should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

There is a reasonable potential to exceed the acute water quality standard for Nickel. Nickel should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

The Williamson Energy – Pond Creek Mine #1 facility STP had no detections reported for Silver. My conclusion is that no regulation of Silver is necessary and that no monitoring beyond the routine requirements is needed.

The Zinc value (0.095 mg/L) samples on December 6, 2019 has been determined to be an outlier according to the procedure found in the 18th edition of Standard Methods. The next highest Zinc value times the multiplier (0.0217 mg/L x 2.1 = 0.0456 mg/L), therefore, there is no reasonable potential to exceed the acute water quality standard for Zinc. My conclusion is that no regulation of Zinc is necessary and that no monitoring beyond the routine requirements is needed.

Outfall 007

Substance	Max. Eff. Conc.	No. of Samples	Multiply by	95% Potential	Acute Standard	302.208(g) standard	Further Analysis?
Arsenic	0.003	7	2.0	0.006	0.3600	-	No RP*
Cadmium	0.044	7	2.0	0.088	0.0144	-	Yes
Chromium (Total)	0.021	7	2.0	0.042	2.3009	-	No RP*
Copper	0.012	7	2.0	0.024	0.0245	-	No RP*
Iron (Dissolved)	0.943	17	1.4	1.3202	-	1.0	Yes
Lead	< 0.0075	7	2.0	0.015	0.1482	-	No RP*
Mercury (ng/L) **	16.3	10	1.7	27.71	-	12.0	Yes
Nickel	0.14	7	2.0	0.28	0.1104	-	Yes
Phenols	< 0.01	7	2.0	0.02	-	0.1	No RP*
Silver	< 0.005	7	2.0	0.01	-	0.005	Yes
Zinc	0.227	7	2.0	0.454	0.1635	-	Yes

Selenium	0.018	6	2.1	0.0378	-	1.0	No RP*

* No RP = no reasonable potential to exceed water quality standards.
** all results in ng/L. Human Health standard given.

Further Analysis:

There is a reasonable potential to exceed the acute water quality standard for Cadmium. Cadmium should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

There is a reasonable potential to exceed the 302.208(g) water quality standard for Iron (dissolved). Iron (dissolved) should be regulated as a daily maximum in the NPDES permit at the 302.208(g) water quality standard.

The average of the Mercury samples times the multiplier (12. ng/L x 1.7 = 5.76 ng/L) was less than the human health water quality standard. My conclusion is that no regulation of Mercury is necessary and that no monitoring beyond the routine requirements is needed.

There is a reasonable potential to exceed the acute water quality standard for Nickel. Nickel should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

The Williamson Energy – Pond Creek Mine #1 facility STP had no detections reported for Silver. My conclusion is that no regulation of Silver is necessary and that no monitoring beyond the routine requirements is needed.

There is a reasonable potential to exceed the acute water quality standard for Zinc. Zinc should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

Outfall 008

Substance	Max. Eff. Conc.	No. of Samples	Multiply by	95% Potential	Acute Standard	302.208(g) standard	Further Analysis?
Arsenic	0.004	7	2.0	0.008	0.3600	-	No RP*
Cadmium	0.0114	7	2.0	0.0228	0.0144	-	Yes
Chromium (Total)	0.015	7	2.0	0.03	2.3009	-	No RP*
Copper	0.505	7	2.0	1.01	0.0245	-	Yes
Iron (Dissolved)	0.366	17	1.4	0.5124	-	1.0	No RP*
Lead	< 0.0075	7	2.0	0.015	0.1482	-	No RP*
Mercury (ng/L) **	12.1	10	1.7	20.57	-	12.0	Yes
Nickel	0.222	7	2.0	0.444	0.1104	-	Yes
Phenols	< 0.01	7	2.0	0.02	-	0.1	No RP*
Silver	< 0.005	7	2.0	0.01	-	0.005	Yes
Zinc	0.288	7	2.0	0.576	0.1635	-	Yes
Selenium	0.024	6	2.1	0.0504	-	1.0	No RP*

* No RP = no reasonable potential to exceed water quality standards.
** all results in ng/L. Human Health standard given.

Further Analysis:

There is a reasonable potential to exceed the acute water quality standard for Cadmium. Cadmium should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

There is a reasonable potential to exceed the acute water quality standard for Copper. Copper should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

The average of the Mercury samples times the multiplier (2.35 ng/L x 1.7 = 4.0 ng/L) was less than the human health water quality standard. My conclusion is that no regulation of Mercury is necessary and that no monitoring beyond the routine requirements is needed.

There is a reasonable potential to exceed the acute water quality standard for Nickel. Nickel should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

The Williamson Energy – Pond Creek Mine #1 facility STP had no detections reported for Silver. My conclusion is that no regulation of Silver is necessary and that no monitoring beyond the routine requirements is needed.

There is a reasonable potential to exceed the acute water quality standard for Zinc. Zinc should be regulated as a daily maximum in the NPDES permit at the acute water quality standard using the default metals translator.

Recommendations:

My evaluation of the metals and other substances given for Outfall 001 finds that water quality-based permit limits are necessary for Cadmium and Mercury at the limits below. Permit limits identified in the table are expressed in units of mg/L except where otherwise noted.

Substance	Daily Maximum	12-month rolling average
Cadmium	0.0144	
Mercury (ng/L)		12 ng/L

My evaluation of the metals and other substances given for Outfall 002 finds that water quality-based permit limits are necessary for Cadmium, Copper, and Nickel at the limits below. Permit limits identified in the table are expressed in units of mg/L except where otherwise noted.

Substance	Daily Maximum
Cadmium	0.0144
Copper	0.0245
Nickel	0.1104

My evaluation of the metals and other substances given for Outfall 003 finds that water quality-based permit limits are necessary for Cadmium and Iron (dissolved) at the limits below. Permit limits identified in the table are expressed in units of mg/L except where otherwise noted.

Substance	Daily Maximum
Cadmium	0.0144

Iron (dissolved)	1.0

My evaluation of the metals and other substances given for Outfall 004 finds that water quality-based permit limits are necessary for Cadmium and Copper at the limits below. Permit limits identified in the table are expressed in units of mg/L except where otherwise noted.

Substance	Daily Maximum
Cadmium	0.0144
Copper	0.0245

My evaluation of the metals and other substances given for Outfall 005 finds that water quality-based permit limits are necessary for Cadmium at the limits below. Permit limits identified in the table are expressed in units of mg/L except where otherwise noted.

Substance	Daily Maximum
Cadmium	0.0144

My evaluation of the metals and other substances given for Outfall 006 finds that water quality-based permit limits are necessary for Cadmium and Nickel at the limits below. Permit limits identified in the table are expressed in units of mg/L except where otherwise noted.

Substance	Daily Maximum
Cadmium	0.0144
Nickel	0.1104

My evaluation of the metals and other substances given for Outfall 007 finds that water quality-based permit limits are necessary for Cadmium, Iron (dissolved), Nickel, and Zinc at the limits below. Permit limits identified in the table are expressed in units of mg/L except where otherwise noted.

Substance	Daily Maximum
Cadmium	0.0144
Iron (dissolved)	1.0
Nickel	0.1104
Zinc	0.1635

My evaluation of the metals and other substances given for Outfall 008 finds that water quality-based permit limits are necessary for Cadmium, Copper, Manganese, Nickel, and Zinc at the limits below. Permit limits identified in the table are expressed in units of mg/L except where otherwise noted.

Substance	Daily Maximum
Cadmium	0.0144

Copper	0.0245
Nickel	0.1104
Zinc	0.1635

These recommendations reflect a water quality standards perspective only and should not be construed as being inclusive of all factors that must be taken into consideration by the permit writer.

cc: Carol Selinger
Chron

Cell 417

Substance	lax. Eff. Co	of Sam	Multiply b	% Potenc	ute Standa	onic Stanc	208(g) stan	her Analysis?		Date Sampled	Application	
Arsenic	0.004	7	2.0	0.008	0.3600	0.1900	-	No RP*		Arsenic	< 0.002	1
Barium			0.0	0	-	-	5.0	No Data		Barium		
Cadmium	0.008	7	2.0	0.016	0.0144	0.0015	-	**Yes**		Cadmium	0.008	1
Chromium (Hex)			0.0	0	0.0160	0.0110	-	No Data		Chromium (Hex)		
Chromium (Total)	0.015	7	2.0	0.03	2.3009	0.2742	-	No RP*		Chromium (Total)	< 0.006	1
Cyanide (available)	< 0.02	6	2.1	0.042	0.0220	0.0052	-	Yes		Cyanide (available)		
Copper	0.505	7	2.0	1.01	0.0245	0.0159	-	**Yes**		Copper	0.003	1
Fluoride			0.0	0	12.10	4.00	-	No Data	6.0867	Fluoride		
Iron (Dissolved)	0.366	15	1.5	0.549	-	-	1.0	No RP*		Iron (Dissolved)		
Lead	< 0.0075	7	2.0	0.015	0.1482	0.0311	-	No RP*		Lead	< 0.0075	1
Manganese	0.145	7	2.0	0.29	5.51	2.34	-	No RP*		Manganese	0.011	1
Mercury (ng/L) **	5.08	10	1.7	8.636	-	-	12.0	No RP*		Mercury		
Nickel	0.1	7	2.0	0.2	0.1104	0.0067	-	**Yes**		Nickel	< 0.01	1
Phenols	< 0.01	7	2.0	0.02	-	-	0.1	No RP*		Phenols	0.005	1
Silver	< 0.005	7	2.0	0.01	-	-	0.005	Yes		Silver	< 0.002	1
Zinc	< 0.05	7	2.0	0.1	0.1635	0.0424	-	Yes		Zinc	< 0.001	1
Selenium	0.024	6	2.1	0.0504	-	-	1.0	No RP*		Selenium	< 0.002	1
Boron			0.0	0	40.1	7.6	-	No Data		Boron		
Sulfate	2000	7	2.0	4000	-	-	1287.0	**Yes**		Sulfate	1100	1
Chloride	1969	6	2.1	4134.9	-	-	500.0	**Yes**		Chloride		
Benzene			0.0	0	4.2	0.86	-	No Data		Benzene		
Ethylbenzene			0.0	0	0.15	0.014	-	No Data		Ethylbenzene		
Toluene			0.0	0	2	0.6	-	No Data		Toluene		
Xylene			0.0	0	0.92	0.36	-	No Data		Xylene		
Mercury			0.0	0	**0.0026**	**0.0013**	-	No Data		Mercury	< 0.002	1

* No RP = no reasonable potential to exceed water quality standards.

** derived water quality criteria.

** all results in ng/L. Human Health standard given.

**** COV was calculated for Zinc.

10/25/2019		11/1/2019		11/7/2019		11/13/2019		11/20/2019		12/6/2019		1/6/2020		12/20/2019		12/23/2019	
< 0.01	1	0.004	1	0.003	1	0.002	1	0.004	1	0.004	1						
< 0.002	1	< 0.0002	1	< 0.0002	1	< 0.0002	1	0.0003	1	0.004	1						
< 0.005	1	0.011	1	0.009	1	0.014	1	0.011	1	0.013	1						
< 0.02	1	< 0.02	1	< 0.02	1	< 0.02	1	< 0.02	1	< 0.02	1						
< 0.005	1	0.012	1	0.003	1	0.025	1	< 0.001	1	< 0.001	1						
0.3	1	< 0.05	1	< 0.05	1	< 0.05	1	< 0.05	1	0.072	1			< 0.05	1	< 0.05	1
< 0.006	1	< 0.002	1	< 0.002	1	< 0.002	1	< 0.002	1	< 0.002	1						
0.059	1	0.054	1	0.037	1	< 0.2	1	0.076	1	0.145	1						
												1.86	1				
0.0278	1	0.015	1	0.008	1	< 0.001	1	0.016	1	0.014	1						
0.01	1	< 0.01	1	< 0.01	1	< 0.01	1	< 0.01	1	< 0.01	1						
< 0.005	1	< 0.001	1	< 0.001	1	< 0.001	1	< 0.001	1	< 0.001	1						
< 0.02	1	< 0.05	1	< 0.05	1	< 0.05	1	< 0.05	1	< 0.05	1						
0.0128		0.019	1	0.022	1	0.019	1	0.023	1	0.027	1						
1220	1	1633	1	1367	1	1567	1	1833	1	1280	1						
1250	1	1300	1	1350	1	1799	1	1570	1	1250	1						
< 0.002	1	< 0.002	1	< 0.002	1	< 0.002	1	< 0.002	1	< 0.002	1						

1/2/2020		1/3/2020		1/6/2020		1/8/2020		Total		Cell 417 Date Sampled	1/10/2020		1/13/2020		1/15/2020
									7	Arsenic					
									0	Barium					
									7	Cadmium					
									0	Chromium (Hex)					
									7	Chromium (Total)					
									6	Cyanide (available)					
									7	Copper					
									0	Fluoride					
< 0.05	1	< 0.05	1	< 0.05	1	< 0.05	1		12	Iron (Dissolved)	0.104	1	0.058	1	< 0.05
									7	Lead					
									7	Manganese					
						0.57	1		2	Mercury	5.08	1	1.09	1	1.32
									7	Nickel					
									7	Phenols					
									7	Silver					
									7	Zinc					
									6	Selenium					
									0	Boron					
									7	Sulfate					
									6	Chloride					
									0	Benzene					
									0	Ethylbenzene					
									0	Toluene					
									0	Xylene					
									7	Mercury					

	1/17/2020		1/20/2020		1/22/2020		1/27/2020		1/29/2020			
1											0.104	3
1	1.65	1	0.673	1	2.8	1	0.588	1	0.846	1	5.08	8

DOCUMENT

11

3117-115-B
Due date: 5-15-20
R00226

Williamson Energy, LLC
PO Box 99
Johnston City, IL 62951
Office: 618-983-3020 Fax: 618-983-3017

Supplemental Information to Permit Renewal IL 0077666

April 1, 2020

Williamson Energy, LLC
PO Box 99
Johnston City, IL 62951
Office: 618-983-3020 Fax: 618-983-3017

April 1, 2020

Mrs. Iwona Ward
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY
2309 West Main Street, Suite 116
Marion, IL 62959

Re: Williamson Energy, LLC – Supplemental information concerning the Anti-Degradation Document for Pond Creek Mine, Big Muddy Flood Analysis, and Modeling of Big Muddy River Chloride dispersion downstream of the proposed mixing zone.
NPDES Permit IL0077666

Dear Mrs. Ward:

Please find attached one (1) copies of the Supplemental information concerning the NPDES Renewal of Permit IL 0077666.

- Additional Water Samples for RP Analysis
- Additional Water Samples for Low-Level Mercury Analysis
- Additional Water Samples for Dissolved Iron Analysis.

Two copies of this submittal have also been submitted to Mr. Lecrone at the IEPA Office in Springfield.

We appreciate your assistance with the matter. If you have any questions or require additional information, please contact me.

Respectfully submitted,

WILLIAMSON ENERGY, LLC

James Plumley

James Plumley, P.E.

RECEIVED
APR 01 2020
IL Environmental Protection Agency
MARION REGIONAL OFFICE

SUMMIT ENVIRONMENTAL SERVICES, INC.
CHEMICAL ANALYSTS & CONSULTANTS

17650 Route 37
West Frankfort, Illinois 62896
Phone (618) 983-8280
Fax (618) 983-8208
Website: www.summitenviro.com

CLIENT: Mach Mining
PDL: 21407-1
SAMPLE ID: Pond 1
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.9	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	144	mg/L	10	2320 B	10/31/19 OG
Sulfate	113	mg/L	5	4500 E	10/29/19 KR
Chloride	80	mg/L	10	4500 B	10/29/19 KR
Hardness	244	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	< 5	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.372	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.195	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21407-2
SAMPLE ID: Pond 2
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT: DRY
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	*	Unit	1 - 14	4500 B	*
Acidity	*	mg/L	10	2310 B	*
Alkalinity	*	mg/L	10	2320 B	*
Sulfate	*	mg/L	5	4500 E	*
Chloride	*	mg/L	10	4500 B	*
Hardness	*	mg/L	10	2340 C	*
Total Suspended Solids	*	mg/L	5	2540 D	*
Settleable Solids	*	mL/L	0.25	2540 F	*
Cyanide	*	mg/L	0.02	335.4	*
Phenols, Total Recoverable	*	mg/L	0.01	420.4	*
Antimony	*	mg/L	0.0100	200.7	*
Arsenic	*	mg/L	0.0100	200.7	*
Beryllium	*	mg/L	0.0010	200.7	*
Cadmium, Total	*	mg/L	0.0020	200.7	*
Cadmium, Dissolved	*	mg/L	0.0020	200.7	*
Chromium	*	mg/L	0.0050	200.7	*
Copper	*	mg/L	0.0050	200.7	*
Iron, Total	*	mg/L	0.100	200.7	*
Iron, Dissolved	*	mg/L	0.100	200.7	*
Lead	*	mg/L	0.0060	200.7	*
Manganese, Total	*	mg/L	0.0100	200.7	*
Manganese, Dissolved	*	mg/L	0.0100	200.7	*
Mercury	*	mg/L	0.002	245.1	*
Nickel, Total	*	mg/L	0.0050	200.7	*
Nickel, Dissolved	*	mg/L	0.0050	200.7	*
Selenium	*	mg/L	0.0100	200.7	*
Silver	*	mg/L	0.0050	200.7	*
Thallium	*	mg/L	0.0200	200.7	*
Zinc	*	mg/L	0.0200	200.7	*

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CLIENT: Mach Mining
PDL: 21407-3
SAMPLE ID: Pond 3
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	10.7	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	176	mg/L	10	2320 B	10/31/19 OG
Sulfate	40	mg/L	5	4500 E	10/29/19 KR
Chloride	15	mg/L	10	4500 B	10/29/19 KR
Hardness	180	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	48	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	1.72	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.625	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21407-4
SAMPLE ID: Pond 4
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.3	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	136	mg/L	10	2320 B	10/31/19 OG
Sulfate	93	mg/L	5	4500 E	10/29/19 KR
Chloride	30	mg/L	10	4500 B	10/29/19 KR
Hardness	300	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	11	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.593	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.368	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.0203	mg/L	0.0200	200.7	11/15/19 WA

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21407-5
SAMPLE ID: Pond 5
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.3	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	160	mg/L	10	2320 B	10/31/19 OG
Sulfate	60	mg/L	5	4500 E	10/29/19 KR
Chloride	18	mg/L	10	4500 B	10/29/19 KR
Hardness	276	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	39	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	2.48	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.736	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.0052	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.0255	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21407-6
SAMPLE ID: Pond 6
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.4	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	640	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,320	mg/L	5	4500 E	10/29/19 KR
Chloride	1,490	mg/L	10	4500 B	10/29/19 KR
Hardness	340	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	15	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.651	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.0772	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.0245	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	0.0168	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.0217	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21407-7
SAMPLE ID: Pond 7
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.5	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	412	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,220	mg/L	5	4500 E	10/29/19 KR
Chloride	1,350	mg/L	10	4500 B	10/29/19 KR
Hardness	580	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	12	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	0.0089	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	0.0072	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	0.0123	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.801	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	2.05	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	1.82	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.140	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	0.113	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.227	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21407-8
SAMPLE ID: Pond 8
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	6.9	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	26	mg/L	10	2310 B	10/31/19 OG
Alkalinity	312	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,633	mg/L	5	4500 E	10/29/19 KR
Chloride	1,590	mg/L	10	4500 B	10/29/19 KR
Hardness	980	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	91	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	1.50	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	0.0114	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	0.0031	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	0.0155	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	60.3	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	4.19	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	3.61	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.222	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	0.100	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.288	mg/L	0.0200	200.7	11/15/19 WA

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21407-9
SAMPLE ID: Pond 9
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	484	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,600	mg/L	5	4500 E	10/29/19 KR
Chloride	1,380	mg/L	10	4500 B	10/29/19 KR
Hardness	400	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	22	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.647	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.239	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.0488	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	0.0341	mg/L	0.0050	200.7	11/15/19 WA
Selenium	0.0172	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21426-1
SAMPLE ID: Pond 1
DATE SAMPLED: 10/30/19

REPORT DATE: 11/26/19
COMMENT: Grab W2
SAMPLED BY: Client-BM
DATE RECEIVED: 10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.6	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	116	mg/L	10	2320 B	10/31/19 OG
Sulfate	100	mg/L	5	4500 E	11/1/19 KR
Chloride	56	mg/L	10	4500 B	11/1/19 OG
Hardness	240	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	9	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.003	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.680	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.063	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.052	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-2	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.2	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	112	mg/L	10	2320 B	10/31/19 OG
Sulfate	350	mg/L	5	4500 E	11/1/19 KR
Chloride	52	mg/L	10	4500 B	11/1/19 OG
Hardness	304	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	7	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0009	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	0.0008	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.195	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.376	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.323	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.023	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.019	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.004	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21426-3
SAMPLE ID: Pond 3
DATE SAMPLED: 10/30/19

REPORT DATE: 11/26/19
COMMENT: Grab W2
SAMPLED BY: Client-BM
DATE RECEIVED: 10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.0	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	148	mg/L	10	2320 B	10/31/19 OG
Sulfate	46	mg/L	5	4500 E	11/1/19 KR
Chloride	< 10	mg/L	10	4500 B	11/1/19 OG
Hardness	184	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	5	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.001	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.003	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.634	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.106	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.250	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.025	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21426-4
SAMPLE ID: Pond 4
DATE SAMPLED: 10/30/19

REPORT DATE: 11/26/19
COMMENT: Grab W2
SAMPLED BY: Client-BM
DATE RECEIVED: 10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.9	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	12	mg/L	10	2310 B	10/31/19 OG
Alkalinity	156	mg/L	10	2320 B	10/31/19 OG
Sulfate	86	mg/L	5	4500 E	11/1/19 KR
Chloride	14	mg/L	10	4500 B	11/1/19 OG
Hardness	232	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	24	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.499	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.067	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.085	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.005	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.003	mg/L	0.001	3125 B	11/25/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21426-5
SAMPLE ID: Pond 5
DATE SAMPLED: 10/30/19

REPORT DATE: 11/26/19
COMMENT: Grab W2
SAMPLED BY: Client-BM
DATE RECEIVED: 10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.8	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	108	mg/L	10	2320 B	10/31/19 OG
Sulfate	180	mg/L	5	4500 E	11/1/19 KR
Chloride	32	mg/L	10	4500 B	11/1/19 OG
Hardness	284	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	43	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.002	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	1.575	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.321	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.296	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.135	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.004	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.003	mg/L	0.001	3125 B	11/25/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21426-6
REPORT DATE: 11/26/19
COMMENT: Precip/ Grab W2

SAMPLE ID: Pond 6
DATE SAMPLED: 10/28/19
SAMPLED BY: Client-BM
DATE RECEIVED: 10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.2	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	16	mg/L	10	2310 B	10/31/19 OG
Alkalinity	272	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,567	mg/L	5	4500 E	11/1/19 KR
Chloride	880	mg/L	10	4500 B	11/1/19 OG
Hardness	632	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	31	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0073	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	0.0073	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.012	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.704	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.147	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	1.749	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	1.749	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.096	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.094	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.019	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21426-7
SAMPLE ID: Pond 7
DATE SAMPLED: 10/30/19

REPORT DATE: 11/26/19
COMMENT: Grab W2
SAMPLED BY: Client-BM
DATE RECEIVED: 10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.1	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	16	mg/L	10	2310 B	10/31/19 OG
Alkalinity	392	mg/L	10	2320 B	10/31/19 OG
Sulfate	967	mg/L	5	4500 E	11/1/19 KR
Chloride	776	mg/L	10	4500 B	11/1/19 OG
Hardness	628	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	26	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.006	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.290	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.062	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.320	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.128	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.021	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.021	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.006	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-8	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.2	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	340	mg/L	10	2320 B	10/31/19 OG
Sulfate	967	mg/L	5	4500 E	11/1/19 KR
Chloride	1,516	mg/L	10	4500 B	11/1/19 OG
Hardness	672	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	25	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.007	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.391	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.103	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.417	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.197	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.023	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.021	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.009	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-9	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.3	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	320	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,333	mg/L	5	4500 E	11/1/19 KR
Chloride	834	mg/L	10	4500 B	11/1/19 OG
Hardness	524	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	27	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0005	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.009	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.001	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.267	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.351	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.224	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.033	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.026	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.022	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	0.0005	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21449-1	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/5/19	**DATE RECEIVED:**	11/5/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.7	Unit	1 - 14	4500 B	11/5/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	36	mg/L	10	2320 B	11/11/19 OG
Sulfate	540	mg/L	5	4500 E	11/11/19 KR
Chloride	26	mg/L	10	4500 B	11/6/19 KR
Hardness	610	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	39	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/5/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.354	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.063	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.037	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.006	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.005	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.015	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-1	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.6	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	116	mg/L	10	2320 B	11/11/19 OG
Sulfate	120	mg/L	5	4500 E	11/11/19 KR
Chloride	52	mg/L	10	4500 B	11/12/19 OG
Hardness	220	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.359	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.077	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.044	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.002	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.001	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.011	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-2	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	108	mg/L	10	2320 B	11/11/19 OG
Sulfate	60	mg/L	5	4500 E	11/11/19 KR
Chloride	< 10	mg/L	10	4500 B	11/12/19 OG
Hardness	108	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.003	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.275	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.073	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.054	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.002	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.009	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-3	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.2	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	100	mg/L	10	2320 B	11/11/19 OG
Sulfate	100	mg/L	5	4500 E	11/11/19 KR
Chloride	36	mg/L	10	4500 B	11/12/19 OG
Hardness	180	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.002	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.249	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.059	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.004	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.008	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21451-4
SAMPLE ID: Pond 5
DATE SAMPLED: 11/6/19

REPORT DATE: 11/27/19
COMMENT: Grab W3
SAMPLED BY: Client-BM
DATE RECEIVED: 11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.1	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	104	mg/L	10	2320 B	11/11/19 OG
Sulfate	145	mg/L	5	4500 E	11/11/19 KR
Chloride	34	mg/L	10	4500 B	11/12/19 OG
Hardness	188	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	35	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.002	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	1.233	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.245	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.213	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.126	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.007	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-5	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.6	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	12	mg/L	10	2310 B	11/11/19 OG
Alkalinity	176	mg/L	10	2320 B	11/11/19 OG
Sulfate	560	mg/L	5	4500 E	11/11/19 KR
Chloride	248	mg/L	10	4500 B	11/12/19 OG
Hardness	480	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	13	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0014	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	0.0014	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.004	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.002	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.520	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.112	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.438	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.390	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.025	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.024	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.009	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-6	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	32	mg/L	10	2310 B	11/11/19 OG
Alkalinity	720	mg/L	10	2320 B	11/11/19 OG
Sulfate	1,800	mg/L	5	4500 E	11/11/19 KR
Chloride	1,600	mg/L	10	4500 B	11/12/19 OG
Hardness	980	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0003	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.010	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.463	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.112	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.404	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.394	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.011	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.010	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.020	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-7	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	24	mg/L	10	2310 B	11/11/19 OG
Alkalinity	668	mg/L	10	2320 B	11/11/19 OG
Sulfate	1,867	mg/L	5	4500 E	11/11/19 KR
Chloride	1,799	mg/L	10	4500 B	11/12/19 OG
Hardness	780	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0003	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.010	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.399	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.374	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.356	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.011	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.010	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.020	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-8	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	432	mg/L	10	2320 B	11/11/19 OG
Sulfate	1,467	mg/L	5	4500 E	11/11/19 KR
Chloride	1,200	mg/L	10	4500 B	11/12/19 OG
Hardness	460	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	46	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.008	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.210	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.057	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.013	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.013	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.021	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-1	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.1	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	80	mg/L	10	2320 B	11/19/19 KR
Sulfate	115	mg/L	5	4500 E	11/15/19 KR
Chloride	54	mg/L	10	4500 B	11/18/19 OG
Hardness	108	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	7	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.260	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.085	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-2	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.3	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	100	mg/L	10	2320 B	11/19/19 KR
Sulfate	660	mg/L	5	4500 E	11/15/19 KR
Chloride	156	mg/L	10	4500 B	11/18/19 OG
Hardness	460	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	17	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	0.0008	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	0.0008	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.164	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.068	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.511	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	0.511	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.003	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-3	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.5	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	64	mg/L	10	2320 B	11/19/19 KR
Sulfate	63	mg/L	5	4500 E	11/15/19 KR
Chloride	12	mg/L	10	4500 B	11/18/19 OG
Hardness	104	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	5	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.473	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.209	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-4	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.9	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	88	mg/L	10	2320 B	11/19/19 KR
Sulfate	107	mg/L	5	4500 E	11/15/19 KR
Chloride	22	mg/L	10	4500 B	11/18/19 OG
Hardness	168	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	19	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.019	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.127	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.058	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-5	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.4	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	72	mg/L	10	2320 B	11/19/19 KR
Sulfate	130	mg/L	5	4500 E	11/15/19 KR
Chloride	38	mg/L	10	4500 B	11/18/19 OG
Hardness	176	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	19	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.384	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.147	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.139	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-6	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.1	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	172	mg/L	10	2320 B	11/19/19 KR
Sulfate	760	mg/L	5	4500 E	11/15/19 KR
Chloride	526	mg/L	10	4500 B	11/18/19 OG
Hardness	420	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	10	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	0.0007	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	0.0007	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.007	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.155	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.088	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.508	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	0.508	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.009	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-7	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	16	mg/L	10	2310 B	11/19/19 KR
Alkalinity	740	mg/L	10	2320 B	11/19/19 KR
Sulfate	1,933	mg/L	5	4500 E	11/15/19 KR
Chloride	1,849	mg/L	10	4500 B	11/18/19 OG
Hardness	1,200	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	14	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.021	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.045	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	1.156	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.943	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.597	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	0.597	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.020	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-8	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.0	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	630	mg/L	10	2320 B	11/19/19 KR
Sulfate	1,700	mg/L	5	4500 E	11/15/19 KR
Chloride	1,500	mg/L	10	4500 B	11/18/19 OG
Hardness	760	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	14	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.014	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.072	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.149	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.416	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	0.416	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.016	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-9	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	440	mg/L	10	2320 B	11/19/19 KR
Sulfate	1,500	mg/L	5	4500 E	11/15/19 KR
Chloride	1,250	mg/L	10	4500 B	11/18/19 OG
Hardness	360	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	16	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.010	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.008	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	< 0.050	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.016	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-1	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.9	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	68	mg/L	10	2320 B	11/22/19 KR
Sulfate	120	mg/L	5	4500 E	11/25/19 KR
Chloride	60	mg/L	10	4500 B	11/21/19 KR
Hardness	120	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	8	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.002	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.808	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.197	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.121	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.057	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.003	mg/L	0.001	3125 B	12/2/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-2	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.7	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	100	mg/L	10	2320 B	11/22/19 KR
Sulfate	590	mg/L	5	4500 E	11/25/19 KR
Chloride	172	mg/L	10	4500 B	11/21/19 KR
Hardness	550	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	5	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	0.0013	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	0.0013	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.002	mg/L	0.001	3125 B	12/2/19 AK
Copper	0.005	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.218	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.104	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.641	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.641	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.029	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.029	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.006	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-3	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	44	mg/L	10	2320 B	11/22/19 KR
Sulfate	68	mg/L	5	4500 E	11/25/19 KR
Chloride	16	mg/L	10	4500 B	11/21/19 KR
Hardness	104	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.548	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.262	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.185	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.146	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	12/2/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-4	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.3	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	68	mg/L	10	2320 B	11/22/19 KR
Sulfate	117	mg/L	5	4500 E	11/25/19 KR
Chloride	24	mg/L	10	4500 B	11/21/19 KR
Hardness	176	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	11	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.327	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.118	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.101	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.040	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.005	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.005	mg/L	0.001	3125 B	12/2/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-5	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.7	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	68	mg/L	10	2320 B	11/22/19 KR
Sulfate	135	mg/L	5	4500 E	11/25/19 KR
Chloride	38	mg/L	10	4500 B	11/21/19 KR
Hardness	172	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	20	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.001	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.754	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.241	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.226	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.131	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.003	mg/L	0.001	3125 B	12/2/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-6	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.2	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	132	mg/L	10	2320 B	11/22/19 KR
Sulfate	933	mg/L	5	4500 E	11/25/19 KR
Chloride	605	mg/L	10	4500 B	11/21/19 KR
Hardness	372	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	8	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	0.0010	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	0.0009	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.006	mg/L	0.001	3125 B	12/2/19 AK
Copper	0.012	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.302	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.071	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.675	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.629	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.032	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.028	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.016	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-7	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.7	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	556	mg/L	10	2320 B	11/22/19 KR
Sulfate	1,800	mg/L	5	4500 E	11/25/19 KR
Chloride	1,719	mg/L	10	4500 B	11/21/19 KR
Hardness	740	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	12	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.012	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.750	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.223	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.558	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.558	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.017	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.016	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.018	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-8	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	18	mg/L	10	2310 B	11/22/19 KR
Alkalinity	640	mg/L	10	2320 B	11/22/19 KR
Sulfate	2,000	mg/L	5	4500 E	11/25/19 KR
Chloride	1,969	mg/L	10	4500 B	11/21/19 KR
Hardness	800	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	14	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.004	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.015	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	1.919	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.366	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.569	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.566	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.014	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.012	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.024	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-9	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	480	mg/L	10	2320 B	11/22/19 KR
Sulfate	1,733	mg/L	5	4500 E	11/25/19 KR
Chloride	1,530	mg/L	10	4500 B	11/21/19 KR
Hardness	310	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	18	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	0.003	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.004	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.013	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.385	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.166	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.091	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.048	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.022	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.020	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.027	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/11/19
PDL:	21533-1	**COMMENT:**	W1 makeup
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client-JP
DATE SAMPLED:	11/26/19	**DATE RECEIVED:**	11/26/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.6	Unit	1 - 14	4500 B	11/26/19 OG
Acidity	< 10	mg/L	10	2310 B	12/2/19 OG
Alkalinity	120	mg/L	10	2320 B	12/2/19 OG
Sulfate	867	mg/L	5	4500 E	11/26/19 KR
Chloride	250	mg/L	10	4500 B	12/3/19 KR
Hardness	800	mg/L	10	2340 C	12/2/19 OG
Total Suspended Solids	8	mg/L	5	2540 D	12/3/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/26/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	12/10/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/5/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/5/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/5/19 AK
Cadmium, Total	0.0022	mg/L	0.0002	3125 B	12/5/19 AK
Cadmium, Dissolved	0.0017	mg/L	0.0002	3125 B	12/5/19 AK
Chromium	0.005	mg/L	0.001	3125 B	12/5/19 AK
Copper	0.013	mg/L	0.001	3125 B	12/5/19 AK
Iron, Total	0.063	mg/L	0.050	3125 B	12/5/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/5/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/5/19 AK
Manganese, Total	0.711	mg/L	0.020	3125 B	12/5/19 AK
Manganese, Dissolved	0.219	mg/L	0.020	3125 B	12/5/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.048	mg/L	0.001	3125 B	12/5/19 AK
Nickel, Dissolved	0.031	mg/L	0.001	3125 B	12/5/19 AK
Selenium	0.008	mg/L	0.002	3125 B	12/5/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/5/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/5/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/5/19 AK

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CLIENT: Mach Mining
PDL: 21550-1
SAMPLE ID: Pond 1
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	10	mg/L	10	2310 B	12/9/19 OG
Alkalinity	92	mg/L	10	2320 B	12/9/19 OG
Sulfate	82	mg/L	5	4500 E	12/9/19 OG
Chloride	34	mg/L	10	4500 B	12/6/19 KR
Hardness	100	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	29	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.004	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	1.897	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.253	mg/L	0.050	3125 B	12/10/19 AK
Lead	0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.121	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.074	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.002	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT: Mach Mining
PDL: 21550-2
SAMPLE ID: Pond 2
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.3	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	14	mg/L	10	2310 B	12/9/19 OG
Alkalinity	72	mg/L	10	2320 B	12/9/19 OG
Sulfate	640	mg/L	5	4500 E	12/9/19 OG
Chloride	175	mg/L	10	4500 B	12/6/19 KR
Hardness	608	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	9	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0039	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0038	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.004	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.421	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.149	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	1.185	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	1.185	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.074	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.074	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.016	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	0.059	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT: Mach Mining
PDL: 21550-3
SAMPLE ID: Pond 3
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.3	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	< 10	mg/L	10	2310 B	12/9/19 OG
Alkalinity	52	mg/L	10	2320 B	12/9/19 OG
Sulfate	41	mg/L	5	4500 E	12/9/19 OG
Chloride	< 10	mg/L	10	4500 B	12/6/19 KR
Hardness	64	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	23	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.004	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	2.247	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.324	mg/L	0.050	3125 B	12/10/19 AK
Lead	0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.123	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.103	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT: Mach Mining
PDL: 21550-4
SAMPLE ID: Pond 4
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.5	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	14	mg/L	10	2310 B	12/9/19 OG
Alkalinity	128	mg/L	10	2320 B	12/9/19 OG
Sulfate	95	mg/L	5	4500 E	12/9/19 OG
Chloride	18	mg/L	10	4500 B	12/6/19 KR
Hardness	236	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	15	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.002	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.612	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.151	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.750	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.736	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT: Mach Mining
PDL: 21550-5
SAMPLE ID: Pond 5
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.8	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	12	mg/L	10	2310 B	12/9/19 OG
Alkalinity	80	mg/L	10	2320 B	12/9/19 OG
Sulfate	90	mg/L	5	4500 E	12/9/19 OG
Chloride	20	mg/L	10	4500 B	12/6/19 KR
Hardness	148	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	30	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.003	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	1.666	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.349	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.174	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.149	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT: Mach Mining
PDL: 21550-6
SAMPLE ID: Pond 6
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.8	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	14	mg/L	10	2310 B	12/9/19 OG
Alkalinity	120	mg/L	10	2320 B	12/9/19 OG
Sulfate	780	mg/L	5	4500 E	12/9/19 OG
Chloride	610	mg/L	10	4500 B	12/6/19 KR
Hardness	550	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0065	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0060	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.006	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.364	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.128	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	1.734	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	1.603	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.106	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.103	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.022	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	0.095	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT: Mach Mining
PDL: 21550-7
SAMPLE ID: Pond 7
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.8	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	20	mg/L	10	2310 B	12/9/19 OG
Alkalinity	472	mg/L	10	2320 B	12/9/19 OG
Sulfate	1,220	mg/L	5	4500 E	12/9/19 OG
Chloride	1,150	mg/L	10	4500 B	12/6/19 KR
Hardness	680	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	12	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0009	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0009	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.014	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.909	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.538	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.776	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.776	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.023	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.021	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.020	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	0.217	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/16/19
PDL:	21550-8	**COMMENT:**	Grab W6
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/6/19	**DATE RECEIVED:**	12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.0	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	18	mg/L	10	2310 B	12/9/19 OG
Alkalinity	428	mg/L	10	2320 B	12/9/19 OG
Sulfate	940	mg/L	5	4500 E	12/9/19 OG
Chloride	1,000	mg/L	10	4500 B	12/6/19 KR
Hardness	610	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	14	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0010	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0010	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.012	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.505	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.311	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.694	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.694	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.024	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.024	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.016	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	0.185	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT: Mach Mining
PDL: 21550-9
SAMPLE ID: Pond 9
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	< 10	mg/L	10	2310 B	12/9/19 OG
Alkalinity	352	mg/L	10	2320 B	12/9/19 OG
Sulfate	1,000	mg/L	5	4500 E	12/9/19 OG
Chloride	1,000	mg/L	10	4500 B	12/6/19 KR
Hardness	450	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	29	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0019	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0019	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.010	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.513	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.103	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.661	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.661	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.048	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.048	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.027	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21579-1	**COMMENT:**	
SAMPLE ID:	Mach	**SAMPLED BY:**	Client-CS
DATE SAMPLED:	12/16/19	**DATE RECEIVED:**	12/16/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/23/19 AK

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CLIENT: Mach Mining
PDL: 21589-1
SAMPLE ID: Mach 2
DATE SAMPLED: 12/18/19

REPORT DATE: 12/30/19
COMMENT:
SAMPLED BY: Client-CS
DATE RECEIVED: 12/19/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21589-2	**COMMENT:**	
SAMPLE ID:	Mach 3	**SAMPLED BY:**	Client-CS
DATE SAMPLED:	12/19/19	**DATE RECEIVED:**	12/19/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT: Mach Mining
PDL: 21603-1
SAMPLE ID: Pond 1
DATE SAMPLED: 12/20/19

REPORT DATE: 12/30/19
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.109	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

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Website: www.summitenviro.com

CLIENT: Mach Mining
PDL: 21603-3
SAMPLE ID: Pond 3
DATE SAMPLED: 12/20/19

REPORT DATE: 12/30/19
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.222	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT: Mach Mining
PDL: 21603-5
SAMPLE ID: Pond 5
DATE SAMPLED: 12/20/19

REPORT DATE: 12/30/19
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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Website: www.summitenviro.com

CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.082	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.174	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21603-9
SAMPLE ID: Pond 9
DATE SAMPLED: 12/20/19

REPORT DATE: 12/30/19
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-10	**COMMENT:**	
SAMPLE ID:	Mach 4 (417)	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.139	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.250	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.123	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.107	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-10	**COMMENT:**	
SAMPLE ID:	Mach 4 (417)	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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3117-15-B
Part 2 of 3

R00305

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-10	**COMMENT:**	
SAMPLE ID:	Mach 6 (417)	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.362	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.573	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.126	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.179	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.200	mg/L	0.050	3125 B	1/10/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-10	**COMMENT:**	
SAMPLE ID:	Mach 7 (417)	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.400	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.085	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.730	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.280	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.299	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.247	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.595	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.118	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.265	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21658-10
SAMPLE ID: Cell 417
DATE SAMPLED: 1/8/20

REPORT DATE: 1/17/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/24/20
PDL:	21666-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.222	mg/L	0.050	3125 B	1/23/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/24/20
PDL:	21666-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.307	mg/L	0.050	3125 B	1/23/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/24/20
PDL:	21666-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.351	mg/L	0.050	3125 B	1/23/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/24/20
PDL:	21666-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.420	mg/L	0.050	3125 B	1/23/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/24/20
PDL:	21666-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.198	mg/L	0.050	3125 B	1/23/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/24/20
PDL:	21666-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.240	mg/L	0.050	3125 B	1/23/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/24/20
PDL:	21666-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.337	mg/L	0.050	3125 B	1/23/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/24/20
PDL:	21666-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.219	mg/L	0.050	3125 B	1/23/20 AK

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Fax (618) 983-8208
Website: www.summitenviro.com

ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/24/20
PDL:	21666-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.235	mg/L	0.050	3125 B	1/23/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/24/20
PDL:	21666-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.104	mg/L	0.050	3125 B	1/23/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/22/20
PDL:	21669-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.379	mg/L	0.050	3125 B	1/21/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21669-2
SAMPLE ID: Pond 2
DATE SAMPLED: 1/13/20

REPORT DATE: 1/22/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.630	mg/L	0.050	3125 B	1/21/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/22/20
PDL:	21669-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.478	mg/L	0.050	3125 B	1/21/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/22/20
PDL:	21669-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.245	mg/L	0.050	3125 B	1/21/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/22/20
PDL:	21669-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.370	mg/L	0.050	3125 B	1/21/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/22/20
PDL:	21669-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.077	mg/L	0.050	3125 B	1/21/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/22/20
PDL:	21669-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.244	mg/L	0.050	3125 B	1/21/20 AK

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21669-8
SAMPLE ID: Pond 8
DATE SAMPLED: 1/13/20

REPORT DATE: 1/22/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.253	mg/L	0.050	3125 B	1/21/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/22/20
PDL:	21669-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.107	mg/L	0.050	3125 B	1/21/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/22/20
PDL:	21669-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.058	mg/L	0.050	3125 B	1/21/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21685-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.112	mg/L	0.050	3125 B	1/27/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21685-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21685-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.217	mg/L	0.050	3125 B	1/27/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21685-4
SAMPLE ID: Pond 4
DATE SAMPLED: 1/15/20

REPORT DATE: 1/28/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21685-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.135	mg/L	0.050	3125 B	1/27/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21685-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21685-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21685-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21685-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21685-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21691-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.087	mg/L	0.050	3125 B	1/27/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21691-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21691-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.218	mg/L	0.050	3125 B	1/27/20 AK

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21691-4
SAMPLE ID: Pond 4
DATE SAMPLED: 1/17/20

REPORT DATE: 1/28/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21691-5
SAMPLE ID: Pond 5
DATE SAMPLED: 1/17/20

REPORT DATE: 1/28/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.073	mg/L	0.050	3125 B	1/27/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21691-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

Reviewed and Authorized By: Amber Wright
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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21691-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21691-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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Fax (618) 983-8208
Website: www.summitenviro.com

ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21691-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/27/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/30/20
PDL:	21697-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.386	mg/L	0.050	3125 B	1/29/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/30/20
PDL:	21697-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/29/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/30/20
PDL:	21697-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.488	mg/L	0.050	3125 B	1/29/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/30/20
PDL:	21697-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.074	mg/L	0.050	3125 B	1/29/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/30/20
PDL:	21697-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.200	mg/L	0.050	3125 B	1/29/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/30/20
PDL:	21697-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.051	mg/L	0.050	3125 B	1/29/20 AK

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21697-7
SAMPLE ID: Pond 7
DATE SAMPLED: 1/20/20

REPORT DATE: 1/30/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.113	mg/L	0.050	3125 B	1/29/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/30/20
PDL:	21697-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.097	mg/L	0.050	3125 B	1/29/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/30/20
PDL:	21697-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.125	mg/L	0.050	3125 B	1/29/20 AK

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3117-15-B
Part 3 of 3

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	4.44	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.783	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	3.65	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.963	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	3.57	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21634-7
SAMPLE ID: Pond 7
DATE SAMPLED: 1/6/20
REPORT DATE: 1/14/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.09	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.974	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.29	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.86	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-11	**COMMENT:**	
SAMPLE ID:	Field Blank	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21657-1
SAMPLE ID: Pond 1
DATE SAMPLED: 1/8/20
REPORT DATE: 1/21/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	4.54	ηg/L	0.500	1631 E	1/20/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/21/20
PDL:	21657-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.514	ηg/L	0.500	1631 E	1/20/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/21/20
PDL:	21657-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	3.72	ηg/L	0.500	1631 E	1/20/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/21/20
PDL:	21657-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.831	ηg/L	0.500	1631 E	1/20/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/21/20
PDL:	21657-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	3.36	ηg/L	0.500	1631 E	1/20/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/21/20
PDL:	21657-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.564	ηg/L	0.500	1631 E	1/20/20 WA

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21657-7
SAMPLE ID: Pond 7
DATE SAMPLED: 1/8/20
REPORT DATE: 1/21/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.02	ηg/L	0.500	1631 E	1/20/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/21/20
PDL:	21657-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.949	ηg/L	0.500	1631 E	1/20/20 WA

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Website: www.summitenviro.com

ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21657-9
SAMPLE ID: Pond 9
DATE SAMPLED: 1/8/20
REPORT DATE: 1/21/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.28	ηg/L	0.500	1631 E	1/20/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/21/20
PDL:	21657-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.570	ηg/L	0.500	1631 E	1/20/20 WA

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/21/20
PDL:	21657-11	**COMMENT:**	
SAMPLE ID:	Field Blank	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/20/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21668-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	9.53	ηg/L	0.500	1631 E	1/22/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21668-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	3.32	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21668-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	10.0	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21668-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	3.41	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21668-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	6.62	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21668-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	5.81	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21668-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	16.3	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21668-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	12.1	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21668-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	7.11	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21668-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	5.08	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21668-11	**COMMENT:**	
SAMPLE ID:	Field Blank	**SAMPLED BY:**	Client
DATE SAMPLED:	1/10/20	**DATE RECEIVED:**	1/10/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21671-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	14.7	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21671-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	3.67	ηg/L	0.500	1631 E	1/22/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21671-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	9.83	ηg/L	0.500	1631 E	1/22/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21671-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.94	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21671-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	8.22	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21671-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.932	ηg/L	0.500	1631 E	1/22/20 WA

Reviewed and Authorized By: Amber Wright
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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21671-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.36	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21671-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.22	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21671-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.44	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21671-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.09	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/23/20
PDL:	21671-11	**COMMENT:**	
SAMPLE ID:	Field Blank	**SAMPLED BY:**	Client
DATE SAMPLED:	1/13/20	**DATE RECEIVED:**	1/13/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/27/20
PDL:	21687-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	13.6	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/27/20
PDL:	21687-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.743	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/27/20
PDL:	21687-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	8.53	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/27/20
PDL:	21687-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.21	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/27/20
PDL:	21687-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	7.10	ηg/L	0.500	1631 E	1/22/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/27/20
PDL:	21687-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.34	ηg/L	0.500	1631 E	1/22/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/27/20
PDL:	21687-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.27	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/27/20
PDL:	21687-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.47	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/27/20
PDL:	21687-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.38	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/27/20
PDL:	21687-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.32	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/27/20
PDL:	21687-11	**COMMENT:**	
SAMPLE ID:	Field Blank	**SAMPLED BY:**	Client
DATE SAMPLED:	1/15/20	**DATE RECEIVED:**	1/15/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/22/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21693-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	12.6	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21693-2
SAMPLE ID: Pond 2
DATE SAMPLED: 1/17/20
REPORT DATE: 1/28/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.657	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21693-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	7.15	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21693-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.924	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21693-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	6.28	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21693-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.859	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21693-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.698	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21693-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.817	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21693-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	2.20	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21693-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.65	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21693-11	**COMMENT:**	
SAMPLE ID:	Field Blank	**SAMPLED BY:**	Client
DATE SAMPLED:	1/17/20	**DATE RECEIVED:**	1/17/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21698-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	12.7	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21698-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21698-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	6.99	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21698-4
SAMPLE ID: Pond 4
DATE SAMPLED: 1/20/20

REPORT DATE: 1/28/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.08	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21698-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	5.89	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21698-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.36	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21698-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.15	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21698-8
SAMPLE ID: Pond 8
DATE SAMPLED: 1/20/20
REPORT DATE: 1/28/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.27	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21698-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.18	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21698-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.673	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/28/20
PDL:	21698-11	**COMMENT:**	
SAMPLE ID:	Field Blank	**SAMPLED BY:**	Client
DATE SAMPLED:	1/20/20	**DATE RECEIVED:**	1/20/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/27/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/31/20
PDL:	21708-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/22/20	**DATE RECEIVED:**	1/22/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	12.6	ηg/L	0.500	1631 E	1/30/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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Fax (618) 983-8208
Website: www.summitenviro.com

ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/31/20
PDL:	21708-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/22/20	**DATE RECEIVED:**	1/22/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/30/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/31/20
PDL:	21708-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/22/20	**DATE RECEIVED:**	1/22/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	7.30	ηg/L	0.500	1631 E	1/30/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/31/20
PDL:	21708-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/22/20	**DATE RECEIVED:**	1/22/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.593	ηg/L	0.500	1631 E	1/30/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/31/20
PDL:	21708-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/22/20	**DATE RECEIVED:**	1/22/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	5.38	ηg/L	0.500	1631 E	1/30/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/31/20
PDL:	21708-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/22/20	**DATE RECEIVED:**	1/22/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	5.37	ηg/L	0.500	1631 E	1/30/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/31/20
PDL:	21708-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/22/20	**DATE RECEIVED:**	1/22/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	8.24	ηg/L	0.500	1631 E	1/30/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/31/20
PDL:	21708-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/22/20	**DATE RECEIVED:**	1/22/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.84	ηg/L	0.500	1631 E	1/30/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/31/20
PDL:	21708-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/22/20	**DATE RECEIVED:**	1/22/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.930	ηg/L	0.500	1631 E	1/30/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/31/20
PDL:	21708-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/22/20	**DATE RECEIVED:**	1/22/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	2.80	ηg/L	0.500	1631 E	1/30/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/31/20
PDL:	21708-11	**COMMENT:**	
SAMPLE ID:	Field Blank	**SAMPLED BY:**	Client
DATE SAMPLED:	1/22/20	**DATE RECEIVED:**	1/22/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/29/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21726-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/27/20	**DATE RECEIVED:**	1/27/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	12.7	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21726-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/27/20	**DATE RECEIVED:**	1/27/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.542	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21726-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/27/20	**DATE RECEIVED:**	1/27/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	6.36	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21726-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/27/20	**DATE RECEIVED:**	1/27/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.834	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21726-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/27/20	**DATE RECEIVED:**	1/27/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	5.03	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21726-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/27/20	**DATE RECEIVED:**	1/27/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.569	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21726-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/27/20	**DATE RECEIVED:**	1/27/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.40	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21726-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/27/20	**DATE RECEIVED:**	1/27/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.15	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21726-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/27/20	**DATE RECEIVED:**	1/27/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.887	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21726-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/27/20	**DATE RECEIVED:**	1/27/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.588	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21726-11	**COMMENT:**	
SAMPLE ID:	Field Blank	**SAMPLED BY:**	Client
DATE SAMPLED:	1/27/20	**DATE RECEIVED:**	1/27/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21739-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/29/20	**DATE RECEIVED:**	1/29/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	12.5	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21739-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/29/20	**DATE RECEIVED:**	1/29/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.761	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21739-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/29/20	**DATE RECEIVED:**	1/29/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	6.43	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21739-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/29/20	**DATE RECEIVED:**	1/29/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.794	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21739-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/29/20	**DATE RECEIVED:**	1/29/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	4.90	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21739-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/29/20	**DATE RECEIVED:**	1/29/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.775	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21739-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/29/20	**DATE RECEIVED:**	1/29/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.36	ηg/L	0.500	1631 E	2/6/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21739-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/29/20	**DATE RECEIVED:**	1/29/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.75	ηg/L	0.500	1631 E	2/6/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

*These results relate only to the samples as received.
*This report shall not be reproduced except in full without the approval of SES.

SUMMIT ENVIRONMENTAL SERVICES, INC.
CHEMICAL ANALYSTS & CONSULTANTS
17650 Route 37
West Frankfort, Illinois 62896
Phone (618) 983-8280
Fax (618) 983-8208
Website: www.summitenviro.com

ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21739-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/29/20	**DATE RECEIVED:**	1/29/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.19	ηg/L	0.500	1631 E	2/6/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21739-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/29/20	**DATE RECEIVED:**	1/29/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.846	ηg/L	0.500	1631 E	2/6/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	2/7/20
PDL:	21739-11	**COMMENT:**	
SAMPLE ID:	Field Blank	**SAMPLED BY:**	Client
DATE SAMPLED:	1/29/20	**DATE RECEIVED:**	1/29/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	2/6/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

*These results relate only to the samples as received.
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DOCUMENT

12

2445-116-B
Rec date: 2-2-2020
R00503

Williamson Energy, LLC
PO Box 99
Johnston City, IL 62951
Office: 618-983-3020 Fax: 618-983-3017

January 17, 2020

Mrs. Iwona Ward
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY
2309 West Main Street, Suite 116
Marion, IL 62959

Re: Williamson Energy, LLC – Supplemental information concerning the Anti-Degradation Document for Pond Creek Mine, Big Muddy Flood Analysis, and Modeling of Big Muddy River Chloride dispersion downstream of the proposed mixing zone.
NPDES Permit IL0077666

Dear Mrs. Ward:

Please find attached one (1) copies of the Supplemental information concerning the NPDES Renewal of Permit IL 0077666.

- Alliance Consulting, Inc – Benthic Macroinvertebrate Community Survey of the Big Muddy River
- Illinois Natural History Survey – Fresh Water Mussels of the Big Muddy River
- Aquaeter – Update Cormix Model Results
- Potesta - Opinion of the Ecological Effects of Williamson Energy's Renewal of NPDES Permit IL0077666
- Big Muddy River TMDL Report 2004
- Stage 3 TMDL Report Upper Big Muddy Watershed 2018
- IDNR, Division of Fisheries Resources - Big Muddy Fish Data
- Supplemental Water Data from Williaamson Energy, LLC

Two copies of this submittal have also been submitted to Mr. Lecrone at the IEPA Office in Springfield.

We appreciate your assistance with the matter. If you have any questions or require additional information, please contact me at (618) 969-8259.

Respectfully submitted,

WILLIAMSON ENERGY, LLC

James Plumley

James Plumley, P.E.

RECEIVED
JAN 17 2020
IL Environmental Protection Agency
MARION REGIONAL OFFICE

R00504

Williamson Energy, LLC
PO Box 99
Johnston City, IL 62951
Office: 618-983-3020 Fax: 618-983-3017

January 17, 2020

Mr. Darin LeCrone
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY
1021 North Grand Avenue East
Springfield, IL 62794-9276

Re: Williamson Energy, LLC – Supplemental information concerning the Anti-Degradation Document for Pond Creek Mine, Big Muddy Flood Analysis, and Modeling of Big Muddy River Chloride dispersion downstream of the proposed mixing zone.
NPDES Permit IL0077666

Dear Mr. LeCrone:

Please find attached two (2) copies of the Supplemental information concerning the NPDES Renewal for Permit IL 0077666 . One copy of this submittal has also been submitted to the permit manager at the IEPA Office in Marion.

- Alliance Consulting, Inc – Benthic Macroinvertebrate Community Survey of the Big Muddy River
- Illinois Natural History Survey – Fresh Water Mussels of the Big Muddy River
- Aquaeter – Update Cormix Model Results
- Potesta - Opinion of the Ecological Effects of Williamson Energy's Renewal of NPDES Permit IL0077666
- Big Muddy River TMDL Report 2004
- Stage 3 TMDL Report Upper Big Muddy Watershed 2018
- IDNR, Division of Fisheries Resources - Big Muddy Fish Data
- Supplemental Water Data from Williaamson Energy, LLC

We appreciate your assistance with the matter. If you have any questions or require additional information, please contact me at (618) 969-8259.

Respectfully submitted,

WILLIAMSON ENERGY, LLC

James Plumley

James Plumley, P.E.

RECEIVED
JAN 17 2020
IL Environmental Protection Agency
MARION REGIONAL OFFICE

2445-16-B
R00505

OPINIONS ON THE ECOLOGICAL EFFECTS OF WILLIAMSON ENERGY'S RENEWAL OF NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM PERMIT IL0077666

Prepared for:

Mr. Nick Johnson
Bailey and Glasser, LLP
209 Capitol Street
Charleston, West Virginia 25301

Prepared by:

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Email: potesta@potesta.com

Project No. 0101-19-0375

January 17, 2020

POTESTA

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OPINIONS OF THE ECOLOGICAL EFFECTS OF WILLIAMSON ENERGY'S RENEWAL OF NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM PERMIT IL0077666

1.0 INTRODUCTION

This report summarizes the opinions of Dr. Mindy Yeager-Armstead on the Williamson Energy Renewal of National Pollutant Discharge Elimination System (NPDES) Permit IL0077666 being issued for the Pond Creek Mine discharging into the Muddy River in Franklin County, Illinois. Formation of the opinions herein relied on documents provided to me (listed below), review of the draft permit and comments on the permit, review of relevant literature, and my experience. My educational background is described in my Curriculum Vita. My experience includes 15 years of consulting experience with the mining industry, specifically mining permitting and compliance, and 8 years of teaching and research experience at Marshall University. Since joining the faculty at Marshall University in August of 2011 as an assistant professor, I have established a productive research group, obtained tenure and full professorship, and now serve as Chair of the Department of Natural Resources and the Environment. My review is divided into 3 sections which include: review of the permitting procedures employed in permit issuance; consideration of the potential for biological effects from the permit in Muddy Branch; and a response to issues raised by commenters on the draft permit.

2.0 ITEMS REVIEWED

- Draft NPDES Permit No. IL0077666, Notice No 7516c Williamson Energy, LLC Pond Creek Mine Draft Renewed Permit and Fact Sheet.
- Williamson Energy's Antidegradation Document for NPDES Permit No. IL0077666, Notice No. 7516c Williamson Energy, LLC, Pond Creek Mine.
- Comments provided to Illinois Environmental Protection Agency (IEPA) Bureau of Water, Water Pollution Control Permit Section (August 12, 2019) by Sierra Club, Illinois Chapter.
- IEPA Memorandum to Iwona Ward from Scott Twait, December 13, 2016, pertaining to Water Quality Based Effluent Limitations for Williamson Energy, LLC – Pond Creek Mine NPDES Permit No. Il007766.
- Additional data collected in response to comments on the draft permit.

- Memorandum to James Plumley from John Michael Corn, P.E. and Pam Hoover, P.E., AquAeTer, Inc. on April 26, 2019 regarding 2019 Mach Mine Pond 009 Effluent Results.
- Illinois Department of Natural Resources Endangered Species Act (and others) Consultation Review Letter dated September 26, 2019 EcoCAT Review # 2001813.
- Water Quality Data from sites in the Big Muddy River watershed obtained from IEPA by Freedom of Information Act.
- Freshwater Mussels of the Big Muddy River, INHS Technical Report, 2012.
- Benthic Macroinvertebrate Community Survey in the Big Muddy River, conducted by Alliance Consulting, December 2019.
- Big Muddy River Total Maximum Daily Load (TMDL) Report, IEPA 2004.
- Stage 3 TMDL Report, Upper Big Muddy River Watershed, LimnoTech 2018.
- Figures prepared for the public meeting on December 18, 2019 and general information on the mixing/dilution studies prepared by consultants.
- Historic documents and other information on the watershed obtained by internet searching.

3.0 PERMITTING PROCEDURES

A review of the draft permit and associated information indicates the permit was developed using appropriate methods consistent with the industry standards and protective of in-stream water quality criteria. The permit development included an exceptional and thorough anti-degradation review containing alternatives analysis, endangered species consultation, appropriate presentation of mixing zone and diffuser design considerations, and a real-time water quality management strategy. The real-time water quality management strategy has been sparsely used in permitting historically, but advances in remote sensing technology make this strategy feasible. The location of an United States Geological Survey (USGS) gaging station in the permit area and the ability to hold discharges when necessary optimize conditions to employ this permitting strategy.

Use of a mixing zone is acceptable to achieve permit compliance, which is widely used and consistent with federal and state regulations. Mixing zones are particularly desirable when pollutants are not persistent or bio-accumulative, such as with salts that are decidedly not toxic in lower levels. Additionally, salt discharges are well suited for mixing or dilution because treatment or removal has inherent environmental costs such as the high-energy demands of reverse osmosis, evaporation, and crystallization. Additionally, the consistent relationship between individual salts and specific conductivity, once established, will allow for real-time monitoring of stream and

discharge constituent concentrations. Generally, the relative mineral concentrations of water from the same source are consistent allowing specific conductivity, a surrogate measurement, to represent chloride in permit evaluations. This consistency is demonstrated with 7 samples collected from the holding basin location (417) on sampling dates from October 25, 2019 to January 13, 2020. Major ion concentrations (alkalinity, sulfate, chloride, and hardness) were summed to estimate total dissolved solids that was not determined. The relative contribution of chloride to the total ions ranged from 34.1% to 37.9% in these 7 samples with this minimal variability suggesting high confidence in the ability to develop a predictive relationship between chloride and specific conductivity, which can be measured in real-time. Utilization of this advanced sensor technology is required in the permit; it will support monitoring of real-time stream conditions, demonstrate consistent compliance with permit conditions, and notify operators of deviations from compliance continuously. The state-of-the-art monitoring discussed in detail below will reliably protect the stream from chloride excursions. It should be noted that my review of the mixing zone and diffuser design does not constitute an engineering review, only that the information is presented and was apparently found to be consistent with regulatory expectations by the agency for permit development.

The extensive and thorough anti-degradation analysis and supporting documents provided by the permittee were reviewed by IEPA for permit development. IEPA conducted a review based on Illinois Pollution Control Board (IPCB) Antidegradation regulations (35 Ill. Adm. Code 302.105) and concluded that the discharge would attain water quality standards and maintain existing uses of the stream based on the information provided and pursuant to additional information provided in comments. I concur with their findings and have seen nothing presented in the public comments reviewed that undermines the agency conclusions.

Consultation with the Illinois Department of Natural Resources (IDNR) was undertaken to ensure protection of threatened and endangered (T&E) species in the permit area. The consultation indicated no T&E aquatic species present in the discharge location (letter dated September 26, 2019), but indicates adherence to the permit conditions is requested to protect fish and mussel populations in the area. No concern was expressed by IDNR regarding aquatic community impairment under the permit conditions. The IEPA permit writer also indicates the web-based database was consulted and confirms no T&E species. This information appears to have been appropriately considered in permit development.

4.0 BIOLOGICAL EFFECTS

A benthic macroinvertebrate survey was conducted in the vicinity of the diffuser on November 20, 2019 by Alliance Consulting. Sampling was conducted by dredge due to river depth and accessibility. Sample results are qualitative due to deviation from optimal sampling timeframes, sample collection methods and habitat necessitated by study objectives, and river condition. However, consideration of the type and diversity of macroinvertebrates collected, with knowledge of their life histories and tolerance values, still provides information on the stream conditions. Land use in the diffuser and mixing zone location is dominated by agriculture.

Riparian zones are forested, wide to narrow, and contribute to fair woody debris that appears to be the only stable substrate in the stream. Steep undercut banks in the area downstream of the diffuser indicate historic instability and heavy erosion. Sediment bar formation is substantial, as is deposition. Substrate in the area is dominated by silty, sandy bottoms with hard packed clay also found. Stream morphology is pool with no riffle/run or gravel/cobble substrate noted in the 0.77 mile surveyed. Stream macroinvertebrate community is considered in the context of the sampling limitations. The benthic macroinvertebrate community is dominated by tolerant taxa generally of the gatherer/collector or filter/collector trophic groups. This community is indicative of the slow moving pool conditions. The community does not appear robust or healthy with limitations potentially resulting from habitat degradation as evidenced by the presence of several less tolerant taxa.

A mussel survey reported in 2012 by the Illinois Natural History survey offers an excellent description of the current (2009/2010) and historical condition of the Big Muddy River. It confirms the aforementioned dominance of silt/clay or "mud" stream bottoms, dominance of woody debris as the primary stable substrate, and the dominance of agriculture with lesser-forested land use in the watershed.

The potential for biological effects resulting from discharge mixing in the Big Muddy River is low due to poor habitat conditions, heavy sedimentation, and historic and ongoing anthropogenic impacts in the watershed. While no unique or highly valued mussel populations were found on the main stem of Big Muddy River, the sampling location most representative of the stream in the discharge area was ranked as moderate. Thirteen taxa were found at this specific site in the main stem of the Big Muddy, with 19 of 25 historically collected taxa also collected in the survey. Restricted or limited mussel communities were found at 75% of the locations sampled. Gravel/cobble/boulder substrate were found to be non-existent in the basin, as reported recently in the aforementioned benthic macroinvertebrate survey. Sediment/siltation may influence the lack of mussel species (INH 2012). These factors were also listed as impairing aquatic life at many locations in the Big Muddy River in the 2010 IEPA Water Quality Report and 303(d) list indicated in the mussel survey and specifically in the reach where the diffuser will be located in the 2018 TMDL Report prepared by LimnoTech for the Big Muddy River. Given these geologic and biologic factors, it is not likely that mussel communities will be adversely impacted by this discharge.

Generally, fish are less sensitive to increases in salinity than other taxa evaluated and are well protected by the 500 mg/l single threshold standard. Fish communities in the Big Muddy River demonstrate moderate abundance and richness indicative of anthropogenically influenced watersheds. Historical record indicates the Big Muddy River has traditionally displayed lowland characteristics with muddy banks, predominantly silt substrate, and sluggish flow. The naturally limited habitat and environmental damage already prevalent in the watershed likely contribute to the limited fish community and to selection for tolerant taxa.

The potential for biological effects resulting from discharge mixing in the Big Muddy River is low due to current/historical poor habitat conditions from heavy sedimentation/siltation which have already limited biological communities in the vicinity of the discharge. The moderately healthy fish and mussel communities are comprised of taxa tolerant of the current conditions and are likely to continue to persist if water with the proposed discharge in compliance with the permitting conditions. The historic and ongoing anthropogenic impacts in the watershed, mainly agricultural, are not likely to abate any time in the future. Although better management practices may improve loading, the substrate in the Big Muddy River is likely to remain unfavorable for establishing optimal habitat conditions necessary to support exceptional aquatic populations.

5.0 RESPONSE TO COMMENTS

Comment: The facility has current and recent violations of their NPDES permit that have yet to be resolved.

Response: The mixing zone and updated real-time discharge limits contained in the draft permit represent a long-term solution to previous permit exceedances. Pond Creek Mine has worked with IEPA to develop acceptable regulatory methods to achieve compliance in the river.

Comment: In view of the frequent violations and the danger of discharges of chemicals that are toxic to aquatic life, the monitoring is inadequate.

Response: The permit limits calculate real-time discharge limits to ensure the constituents of the discharge are not in concentrations toxic to aquatic life and is computer controlled such that the system will shut down to prevent permit exceedances. As indicated above, preliminary evaluations show a substantial relationship between chloride concentration and estimated total dissolved solids; the chloride concentration is relatively stable with respect to the other major ions and should be predictable from the specific conductivity measurements. This relationship will be confirmed with additional measurements and a predictive equation developed. When the discharge is initiated, the continuous, real-time monitoring of Outfall 011 in-stream will further ensure compliance with permit conditions and protect aquatic life from toxicity.

Comment: The chloride acute limit is too weak and the permit lacks a chronic chloride limit and thus fails to protect aquatic life and violates 35 Ill. Adm. Code 302.105(a), 302.210, 304.105. and 309.143.

Response: The hardness values in the mixing zone will be influenced by the discharge which has an average hardness of 610 mg/l $CaCO_3$. The permit derivations are in compliance with the mixing zone regulations, water quality standards, and effluent limitations referenced in the comments. The single-standard approach for

chlorides is consistent with low acute to chronic ratios in salt toxicity and the "pass-through" exposure scenario of organisms moving through the mixing zone. The in-place chloride standard is deemed acceptable by the IEPA and the United States Environmental Protection Agency (USEPA). Changes to the in-place water quality criteria are beyond the purview of this permit which puts in place mechanisms to ensure compliance with the currently approved water quality standards which are developed to be protective of daily and long term biological exposures. Chlorides are not "accumulative".
If the standard was to be changed, the permit conditions would be reevaluated; however, the 500 mg/l chloride standard is not substantially different than that calculated using Soucek's equations. The current single-value standard has been acceptable to USEPA in recent considerations of the IEPA for chloride standard revisions in parts of Illinois where road salt application has resulted in exceedances of the standard (PCB 18-32).

Mixing zone concentrations are calculated as "worst case" with highest discharge concentrations and flow volumes mixed under low stream flow conditions to ensure compliance with the water quality criteria. Water quality standards are also determined as worst case; designed to protect for the most sensitive taxa and with a built in margin of safety. Permit conditions limit discharge volumes and concentrations to be protective under both low-flow and high-flow conditions again utilizing "worst case" conditions for each. For these reasons, the biota in Big Muddy River will be protected from adverse conditions continuously when the diffuser is discharging.

Comment: The Reasonable Potential Analysis is improper because the IEPA did not use the multipliers recommended by USEPA to assure measured reasonable potential or require an adequate amount of testing. See Des Plaines Watershed Alliance v. Illinois EPA, 2007 Ill. Env. Lexis 149 *138 (IPCB 2007).

Response: *Reasonable potential analysis is used to predict upper contaminant concentrations in discharges using the variability in the discharge for ensuring stream protection in the previously mentioned "worst case" discharge scenario. The upper contaminant concentration in Outfall 011 is determined in the permit to be 12,000 mg/l chloride and will be measured in real-time using the relationship between chloride and conductivity, an easily monitored indicator. Estimating this upper limit using reasonable potential calculations is not necessary.*

Comment: The potential effect of the increased discharges has not been determined as to flooding, groundwater use and other factors.

Response: *The permit discusses the increased flow to the stream which may occur under high-flow scenarios and states the maximum pumped volume would raise the water level by less than an inch. I did not conduct an engineering review, but relied on*

the permittee and the IEPA's review to ensure these calculations are correct. The comments present no evidence to the contrary. This has clearly been included in the permit development and approval. There is no evidence that increased chloride concentrations increase the toxicity of algal blooms. The reference suggesting this relationship provided by the comments refers to the condition of freshwater algae flowing into the ocean where they die and release toxins. This specific situation, which occurs in the drainage from Lake Okeechobee in Florida, is not relevant to the discharges in the Big Muddy River.

The permit describes that the volumes of discharge will not exacerbate flooding, as indicated above, under worst case conditions and thus would exist within the range of natural-flow conditions under lower flows. The channel can thus "handle" the discharge without increasing the risk of flooding, the condition of the channel banks, vegetative cover, and in-stream substrates is known to be suboptimal throughout the watershed, but unrelated to this permit.

Comment: Increased chloride levels may increase toxicity of algal blooms in Big Muddy and other waters.

Response: *There is no evidence to indicate that the chloride levels in Big Muddy River will increase the toxicity of algal blooms in the river. On the contrary, references provided in the comments demonstrate the safety of chloride concentrations in the range of those which will be found in the Big Muddy River outside of the mixing zone with effects levels higher than in-stream concentrations.*

Suggestions that the discharges in Big Muddy River will contribute to the toxicity of algal blooms are unfounded as the chloride concentrations included in the study provided were not consistent with the concentrations which will be present in Big Muddy River but were more consistent with ocean water. The USGS reference specifically pertained to the introduction of freshwater blooms to marine conditions where salinity is well above the levels occurring in this case. Additionally, the ecological risks suggested from lake studies are not representative of conditions in the Big Muddy River as comparison of ecological effects from lentic to lotic systems is not feasible. In lakes, particularly those with no outflow, evaporation concentrates salts and continued elevated inputs will concentrate. In flowing systems, the dissolved salts disperse downstream, generally becoming more diluted until reaching the ocean. However, it is noteworthy that the Lind, et al study provided in the comments actually demonstrates, as other peer-reviewed literature demonstrates, the safety of chlorides discharges in concentrations that will be present in the river outside of the mixing zone.

6.0 CLOSING

The scope of this report is limited to the specific project and location described herein and represents my understanding of the factors as presented in this report. If these factors change as additional data concerning this report is obtained, I should be informed so that I may examine the data and, if necessary, modify or revise the opinions presented in this report.

Sincerely,

POTESTA & ASSOCIATES, INC.

Mindy Yeager Armstead

Mindy Yeager-Armstead, Ph.D.
Senior Scientist

MYA/rlh

CURRICULAM VITAE

Mary (Mindy) Yeager Armstead

Natural Resources and the Environment
Marshall University
John Marshall Way
Huntington, West Virginia 25755

Phone: 304-696-2923
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EDUCATION

Ph.D. Program in Aquatic Ecology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061. September 1994.
Dissertation: Abiotic and Biotic Factors Influencing the Decline of Native Unionid Mussels in the Clinch River, Virginia.

M.S. in Aquatic Ecology, Marshall University, Huntington, West Virginia, July 1991.
Thesis: An Analysis of Variation in a Disjunct Population of the Central Mudminnow, Umbra limi (Kirtland) in the Greenbottom Wildlife Management Area, Cabell County, West Virginia.

University of North Carolina-Charlotte, Charlotte, North Carolina
21 hours graduate course work, Fall 1988 - Spring 1989.

B.S. Biology, University of Charleston, Charleston, West Virginia.
May 1987 (Cum Laude).

EMPLOYMENT

2011 – 2016
Associate Professor, Marshall University, Interim Chair of the Department of Natural Resources and the Environment since July 2016. Original hiring was into Department of Integrated Science and Technology in August 2011. My original position was an Eminent Scholar appointment to develop research opportunities in the area of Aquatic Ecology.

2007 – 2011
Adjunct faculty, Wheeling Jesuit University, Bold Program – The position involved project oversight of undergraduate research projects and teaching research methods and statistics.

2002 – 2011
Adjunct faculty, Marshall University, College of Information Technology and Engineering – The position involves teaching environmental science classes in the

CERTIFICATIONS

Licensed Remediation Specialist, West Virginia

PROFESSIONAL ORGANIZATIONS AND AFFILIATIONS

Society of Environmental Toxicology and Chemistry
Society for Freshwater Science
Air & Waste Management Association
American Fisheries Society

PUBLICATIONS

Armstead, M.M., M. Wilson, A. Parsons-White. 2017. Demonstration of a novel control strategy for *Prymnesium paruvm* management in fish hatcheries. Submitted to North American Journal of Aquaculture 79(3): 238-244.

Armstead, M.M., L.B. Creathers, M. Wilson. 2016. The effects of elevated specific conductivity on the chronic toxicity of mining influenced streams using *Ceriodaphnia dubia. PLoS ONE 11(11): 0165683.doi:10.1371/journal.pone.0165683.*

Vellaisamy V.S., J.J. Tomblin, M.M. Yeager Armstead, E.E. Murray. 2013. Selenium (Sodium selenite) causes cytotoxicity and apoptotic mediated cell death in PLHC-1 fish cell line through DNA and mitochondrial membrane potential damage. Ecotoxicol. Environ. Saf. 87:80-88.

Vellaisamy V.S., M.M. Yeager Armstead, M.M. Cohenford, E.E. Murray. 2013. Arsenic trioxide (As_2O_3) induces apoptosis and necrosis mediated cell death through mitochondrial membrane potential damage and elevated production of reactive oxygen species in PLHC-1 fish cell line. Chemosphere 90(3): 1201-9.

Vellaisamy V.S., M.M. Yeager Armstead, E.E. Murray. 2013. Protective and antioxidant role of selenium on arsenic trioxide-induced oxidative stress and genotoxicity in the fish hepatoma cell line PLHC-1. Environ. Toxicol. Chem. Vol. 31(12): 2861-2869.

Armstead, Mindy M. and J.L. Yeager. 2006. *In-situ Toxicity Testing of Unionids.* In Freshwater Bivalve Ecotoxicology, J. H. Van Hassel and J. L. Farris, Editors. CRC Press.

Cherry, D.S., J.H. Van Hassel, M.M. Yeager, and J. Cairns, Jr. 1995. *Avoidance of twenty-four fish species to thermally influenced, chlorinated water in* Making Environment Science: A Festschrift in Honor of John Cairns, Jr. J.R. Pratt, N. Bowers, and J.R. Stauffer, editors. Ecoprint, Portland, Oregon.

PUBLISHED ABSTRACTS AND PRESENTATIONS 2010 TO PRESENT

Hendricks, S. (Presenter), M. Armstead, B. Ford, J. Fox, and D. White. 2017. Sensing and Educating the Nexus to Sustain Ecosystems (SENSE): A Kentucky-West Virginia Partnership. Poster Presentation at the Kentucky Water Research Institute Annual Meeting. Lexington, Kentucky. March 20-21, 2017.

Armstead, M. (Presenter), M. Wilson. 2016. Effects of total dissolved solids on benthic macroinvertebrate communities and individual taxa from streams in West Virginia. Platform Presentation at the 7th SETAC World Congress/SETAC North America 37th Annual Meeting in Orlando, Florida. November 8-12 2016.

Edwards, G.G., D. Brady, M. Armstead, and M. Wilson. 2016. Development of culturing and rearing methodology for Ephemeroptera taxa. Accepted for Poster Presentation at the 7th SETAC World Congress/SETAC North America 37th Annual Meeting in Orlando, Florida. November 8-12 2016.

Chapman, M., M. Armstead, and M. Wilson. 2016. Changes in physical factors following low-level disturbance in a West Virginia watershed. Accepted for Poster Presentation at the 7th SETAC World Congress/SETAC North America 37th Annual Meeting in Orlando, Florida. November 8-12 2016.

Armstead, M.M (Presenter), Wilson, M., Amanda Chapman. 2015. *Ongoing evaluation of the effects of watershed disturbance on aquatic ecosystems.* Oral presentation at the Second Environmental Considerations in Energy Production Conference. Pittsburgh, Pennsylvania. September 20-23, 2015

Armstead, M.M., Wilson, M. (Presenter). 2015. *An evaluation of seasonal selenium bioaccumulation in mining influenced streams.* Oral presentation at the Second Environmental Considerations in Energy Production Conference. Pittsburgh, Pennsylvania. September 20-23, 2015.

Rowsey, K. (Presenter), Armstead, M.M., Wilson, M. 2015. *Development of Culturing Methods for Native Mayfly Taxa for use in laboratory toxicity testing.* Oral presentation at the Second Environmental Considerations in Energy Production Conference. Pittsburgh, Pennsylvania. September 20-23, 2015.

Chapman, A., Armstead, M.M., Wilson, M., Kinney, J. 2015. *The effects of elevated dissolved solids on benthic macroinvertebrate taxa.* Poster presentation at the Society for Freshwater Science Annual Meeting. Milwaukee, Wisconsin. May 17-21, 2015.

Rowsey, K., Armstead, M.M., Wilson, M., 2015. *Investigation of parthenogenesis in Ephemeroptera and development of methods for rearing native mayfly taxa in laboratory*

Keller, L., Armstead, M. M., Wilson, M., 2013. *Trophic Transfer Modeling of Selenium – how much data do we need.* Poster presentation at Harmonizing Across Disciplines 34th Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, Tennessee. (November 20, 2013).

Parsons White, Armstead, M. M., A., Wilson, M., 2013. *Evaluation of a novel control method for Prymnesium parvum.* Poster presentation at Harmonizing Across Disciplines 34th Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, Tennessee. (November 18, 2013).

Yeager, J., Armstead, M. M. 2013. *Baetidae dominance in the Tug Fork watershed in West Virginia.* Oral presentation at the Society of Freshwater Science. Jacksonville, Florida. (May 23, 2013).

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Kinney, J., Armstead, M. M., Wilson, M., 2013. *Effects of elevated dissolved solids on benthic macroinvertebrate communities.* Poster presentation at the Society of Freshwater Science. Jacksonville, Florida. (May 23, 2013).

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Alliance Consulting, Inc.
Engineers • Constructors • Scientists

BENTHIC MACROINVERTEBRATE COMMUNITY SURVEY OF THE BIG MUDDY RIVER

WILLIAMSON ENERGY, LLC DIFFUSER LOCATION

Prepared for

WILLIAMSON ENERGY, LLC
WILLIAMSON COUNTY, ILLINOIS

ALLIANCE PROJECT NO. B16-454-1413
DECEMBER 2019

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BENTHIC MACROINVERTEBRATE COMMUNITY SURVEY OF THE BIG MUDDY RIVER WILLIAMSON ENERGY, LLC DIFFUSER LOCATION WILLIAMSON COUNTY, ILLINOIS

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Alliance attempted to identify areas to use as sample reaches for the survey in accordance with established wadeable collection methods provided by the USEPA (1999) and the Illinois EPA (2006) for sampling benthic macroinvertebrate communities. Alliance personnel walked the entire length of the Big Muddy River from the sampling location to the water diffuser location and evaluated the potential stream habitat to obtain a benthic sample according to the wadeable collection protocol. However, it was determined that this was not feasible due to lack of preferred habitat (riffles and/or runs) and the inaccessibility of the river due to steep banks and/or depth of the river to reach snags or submerged aquatic vegetation (Appendix B). The entire reach of the stream in the project area was determined to be 100% pool with no available riffle, run, or glide habitat, and the depth of the river made it far too deep for wadeable collection methods.

3.2 Stream Habitat Assessment

Upon evaluation of the project reach it was deemed that traditional methods of habitat assessment for wadable streams were not applicable based on the physical conditions of the survey area. A total of 32 photographs were taken along the stream reach for documentation of the stream conditions at the time of sampling (Figures, Drawing No. B16-454-A3). The substrate found within the reach consisted primarily of fine grained clay, silt, and sandy sediments. Additionally, large portions of the channel exhibited no substantial bedload material and was primarily hard packed clay substrate commonly found within streams in southern Illinois.

3.3 Benthic Macroinvertebrate Sampling

Alliance was requested to sample benthic macroinvertebrates downstream of the project area within the Big Muddy River (BMR). Benthic macroinvertebrates were sampled using an Ekman Dredge dropped from an abandoned railroad bridge at the sampling location. The dredge was dropped 20 times from multiple points on the upstream and downstream side of the bridge to best represent the sampling reach due to lack of preferred habitat and inaccessibility issues, which prevented Alliance personnel from collecting a sample in a more traditional manner.

Following field preservation of benthic macroinvertebrates, individual specimens were sorted, preserved with 95 percent denatured ethanol, and were identified to the lowest practical level (to family level in most cases) by Alliance personnel located in Beaver, West Virginia.

The following are benthic macroinvertebrate community metrics used to analyze the composition of the benthic community sampled in this study:

Number of Coleopteran Taxa: The number of different taxa identified belonging to the Order Coleoptera (beetles). This metric generally decreases with increasing impairment.

Number of Ephemeropteran Taxa: The number of different taxa identified belonging to the order Ephemeroptera (mayflies). This metric generally decreases with increasing impairment.

Number of Intolerant Taxa: The total number of different taxa determined to be sensitive to degradation according to the IEPA. This metric should decrease with increasing degradation.

Alliance reviewed the relative abundance of pollution tolerant species as a measure of the general health of the benthic community. Taxa such as Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), collectively referred to as EPT, are often pollution sensitive, whereas taxa such as *Chironomidae* (midges) have a relatively high tolerance for pollution. Skewed populations of specific groups provide insight into the existence of environmental stress factors.

4.0 RESULTS

4.1 Biological Monitoring Survey

The surveys were performed by Alliance on November 20th, 2019 at the established monitoring station on the Big Muddy River (Figures, Drawing No. B16-454-A4). Data collected includes aquatic organism community data and associated metrics.

4.2 Station Big Muddy River

The biological monitoring Station BMR is located approximately 0.77 miles directly downstream of the proposed diffuser location on the Big Muddy River (Figures, Drawing No. B16-454-A4).

4.2.1 Benthics for Big Muddy River

In total 274 individuals, representing 10 taxa were identified during the benthic survey (Table 1). A diversity score of 0.9 (Shannon-Wiener Diversity Index) (Table 2). *Chironmidae* made up 76% of the sample with 209 individuals. A low percent EPT score of 12.04% was recorded showing a lack of sensitive organisms. The mIBI scored 23.8, which is a rating of fair and 80.7% of the sample was made up of tolerant taxa. The metrics reflect a stream with poor habitat quality, low biodiversity, and a struggling benthic macroinvertebrate community.

5.0 CONCLUSIONS

Concerning the benthic macroinvertebrate community, Alliance reviewed several metrics and community characteristics which evaluate the overall health of the macroinvertebrate community. Metrics such as percent tolerant taxa, EPT taxa richness, and the Shannon-Wiener Diversity index are often good indicators of aquatic life health.

The sampled site showed a tolerant taxa percentage of 80.7%. The station had a low percentage of EPT taxa collected at 12.04%. *Chironomidae* dominated the sample at 76% which would be indicative of a more pollutant tolerant benthic community. The Shannon-Wiener Diversity Index scores the site at 0.90 showing a low diversity of organisms. The mIBI scored at 23.8 which indicates a benthic community in fair health.

Metrics recorded based on the samples collected reflect a stream with poor habitat quality, low biodiversity, and a struggling benthic macroinvertebrate community. Some factors likely

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ILLINOIS DEPARTMENT OF NATURAL RESOURCES

Authorization is hereby granted, under 520 ILCS 5/3.22 and 515 ILCS 5/20-100 of the Illinois Compiled Statutes and 17 ILL. Adm. Code 520 to:

Last Name: **Patterson** First Name: **Alex** Permit Number: **A19.5984**

Issued: **3/7/2019** **Expires: 12/31/2019**

Business Name: Alliance Consulting, Inc.

Street Address: 124 Philpott Lane

City: Beaver State: WV Zip Code: 25813

for strictly scientific, educational or zoological purposes, to take the Illinois fauna identified below subject to the following provisions:

May legally capture, by scientifically accepted methods, only the specific aquatic life species listed on the accompanying Illinois Department of Natural Resources (IDNR) scientific permit application/project proposal (on file in Springfield, IL) strictly for scientific, educational, and/or zoological purposes (except endangered and threatened species). After data has been humanely collected from these species, all animals shall be released unharmed at or near the original site of capture. Deceased animals and/or animal parts must be buried or given to a public or state scientific educational or zoological institution. A federal permit is required for all projects involving federally regulated species. If endangered and threatened species are to be taken, the IDNR Division of Natural Heritage, Endangered Species Coordinator must be notified and must approve in writing all project related activities of the permit application.
Possession/Transportation of injurious aquatic life species requires appropriate permits in addition to the previously stated. The IDNR Aquaculture Specialist can be contacted to request and seek approval of all project activities of the permit applicant prior to activities being initiated. If such species are encountered as part of previously authorized projects, they may be kept for deposition into state, scientific, educational, or zoological institutions, if appropriate precautions are taken to further restrict potential release into the environment AND immediate reporting of escape to dnr.aquaculture@illinois.gov . (All aquatic life may be immediately returned unharmed from where they were taken. 515 ILCS 5/10-100.)
Authorization: Statewide, exclusive of nature preserves, and IDNR owned and managed properties.
Individuals authorized to work under direction of applicant include: Braden Hoffman, Bethany Wolfe, Jennifer Arp-Bazzie, Brandon Alderman, Blake Davis, Bo Wolfe

I agree to the following provisions and terms of this Scientific Permit.

Permittee's Signature: _____ (Permit not valid unless signed)

Approved By: _____ Office of Resource Conservation Date: 3/8/19

TERMS FOR SCIENTIFIC PERMIT

1. This permit is valid only for the approved methods, locations and activities stated on the permit.
2. All permitted activities shall be performed by or under the direct supervision of the permittee. Permittee must be present with persons involved in actual taking of fauna.
3. Under no circumstances shall a scientific permit be used in lieu of sport or commercial licenses.
4. This permit is valid only for species not listed as Illinois Threatened or Endangered (https://www.dnr.illinois.gov/conservation/NaturalHeritage/Pages/EndangeredandThreatenedSpecies.aspx). If a Threatened or Endangered species is incidentally captured, the specimen must be released and the occurrence must be reported to tara.kieninger@illinois.gov within 5 business days.
5. This permit does not allow the privilege of trespass. Landowner permission is required. Activities on Department sites are not permitted without the prior approval of the Site Superintendent. Activities on Illinois Nature Preserves and Land and Water Reserves must have prior approval from the Illinois Nature Preserve Commission.
6. Permittee must carry this permit at all times when taking specimens and be presented, upon request, to Department personnel.
7. Fauna taken and/or salvaged and rehabilitated must be released to the wild or permanently donated to a public or state scientific educational or zoological institution
8. This permit does not supersede Federal permits, which may be necessary for the permitted work.
9. All gear left unattended must be tagged bearing name and scientific permit number of permittee.
10. Use of rotenone or any other toxic materials for taking of fauna must have written approval from the Department prior to using such materials, and may need a variance from the Illinois Environmental Protection Agency.
11. An annual report must be submitted to the Department by January 31 of each year.
12. This permit may be revoked or suspended if the Department finds that a permittee has falsified information on the application, failed to comply with the provisions of this permit, or violated state or federal laws.

The Department of Natural Resources is an equal opportunity employer.



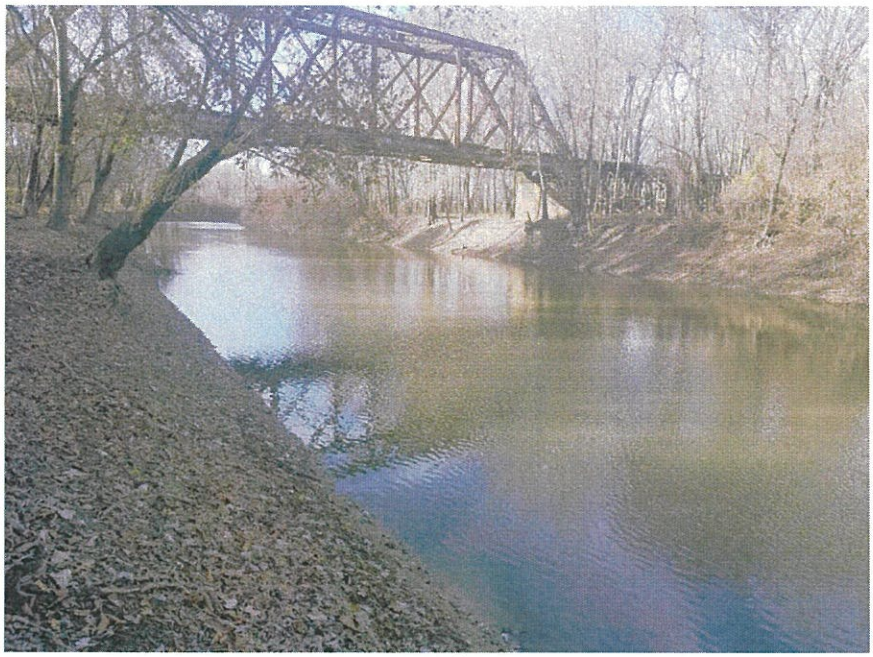
1. BM-1, upstream



2. BM-1, habitat



5. BM-2, habitat



6. BM-2, downstream



9. BM-3, downstream



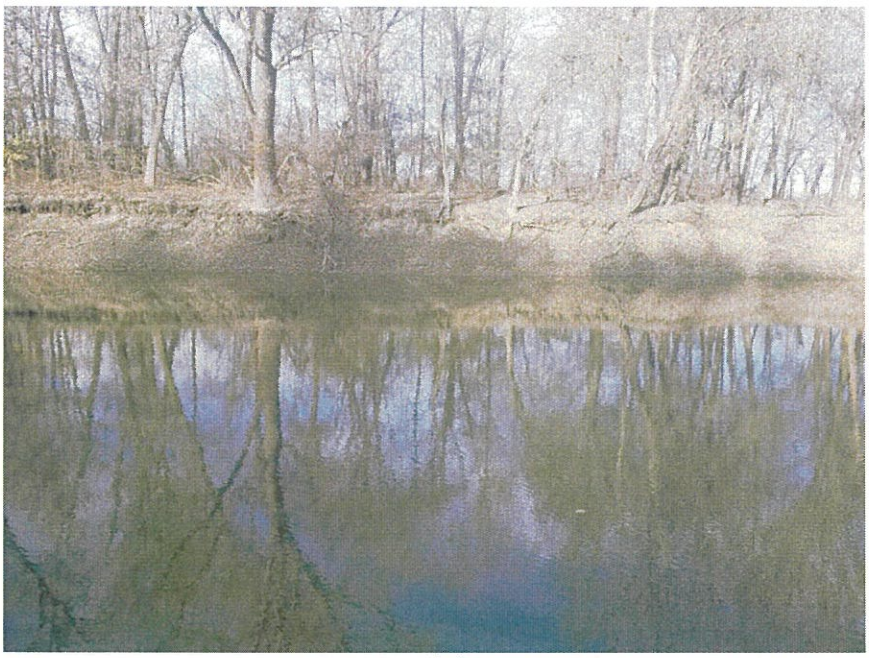
10. BM-4, upstream



13. BM-5, upstream



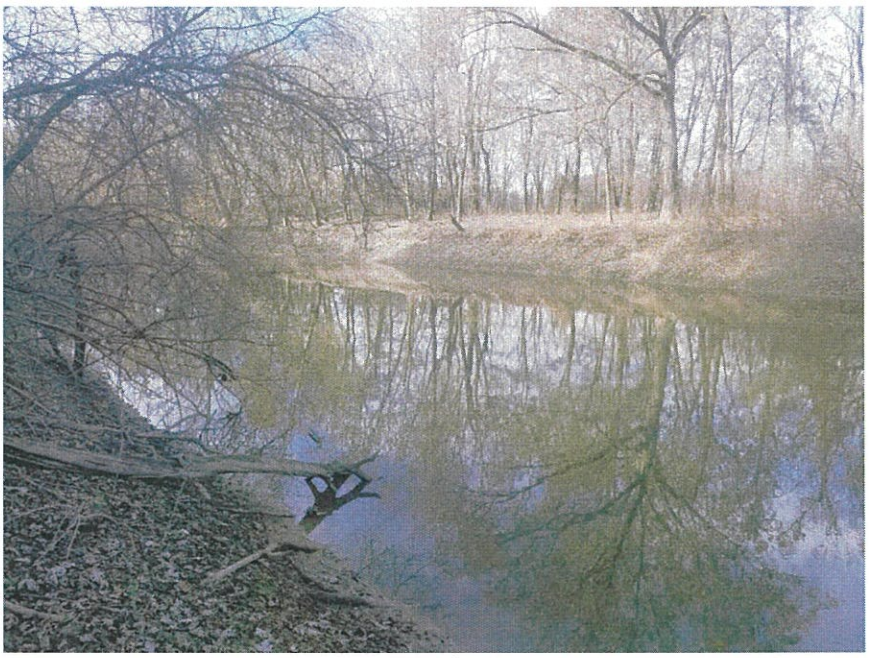
14. BM-5, habitat



17. BM-6, habitat



18. BM-6, downstream



21. BM-7, downstream



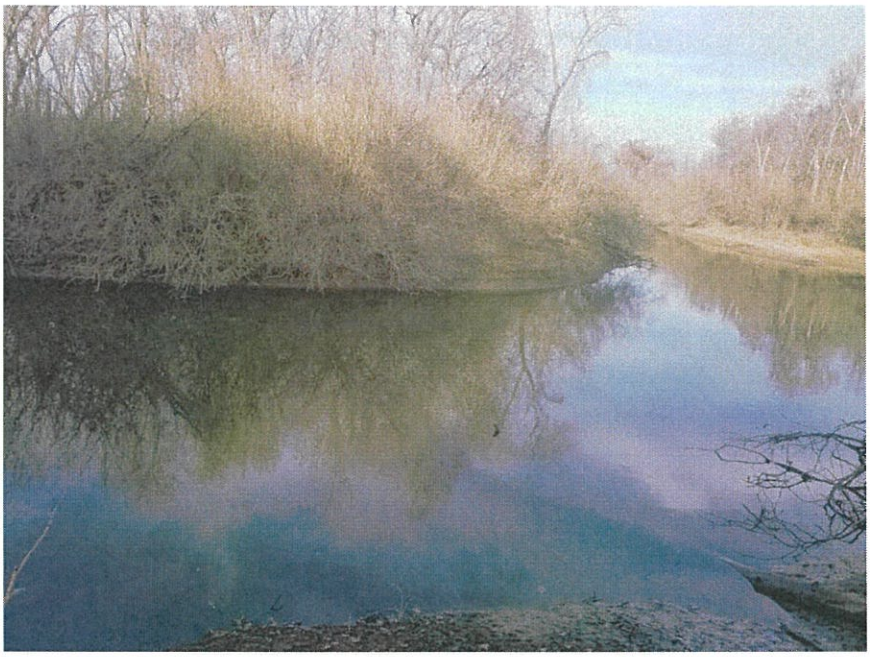
22. BM-8, upstream



25. BM-9, upstream



26. BM-9, habitat



29. BM-10, habitat



30. BM-10, downstream



33. BM-11, downstream



34. BM-12, upstream



37. BM-13, upstream



38. BM-13, habitat



41. BM-14, habitat



42. BM-14, downstream



45. BM-15, downstream



46. BM-16, upstream



49. BM-17, upstream



50. BM-17, habitat



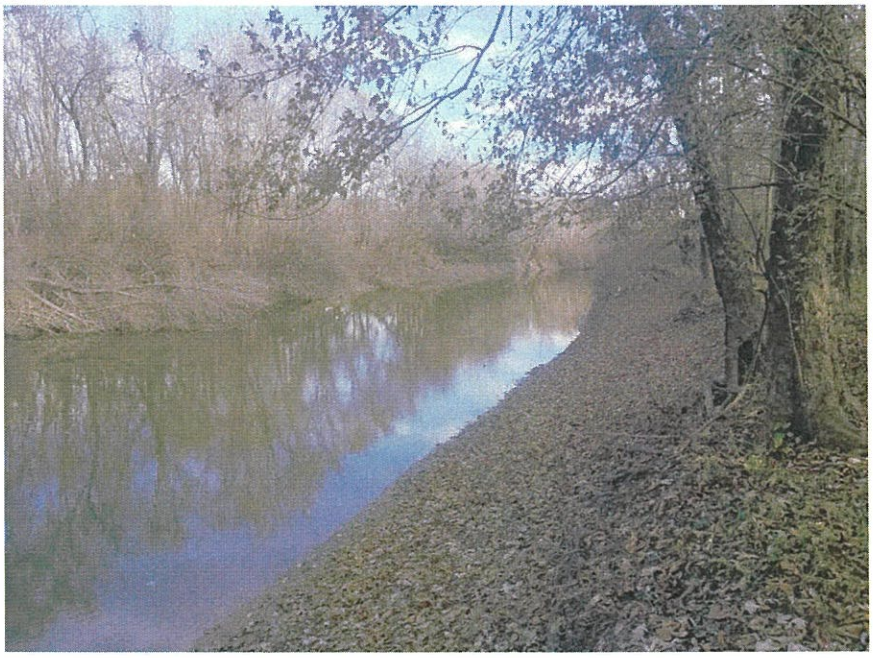
53. BM-18, habitat



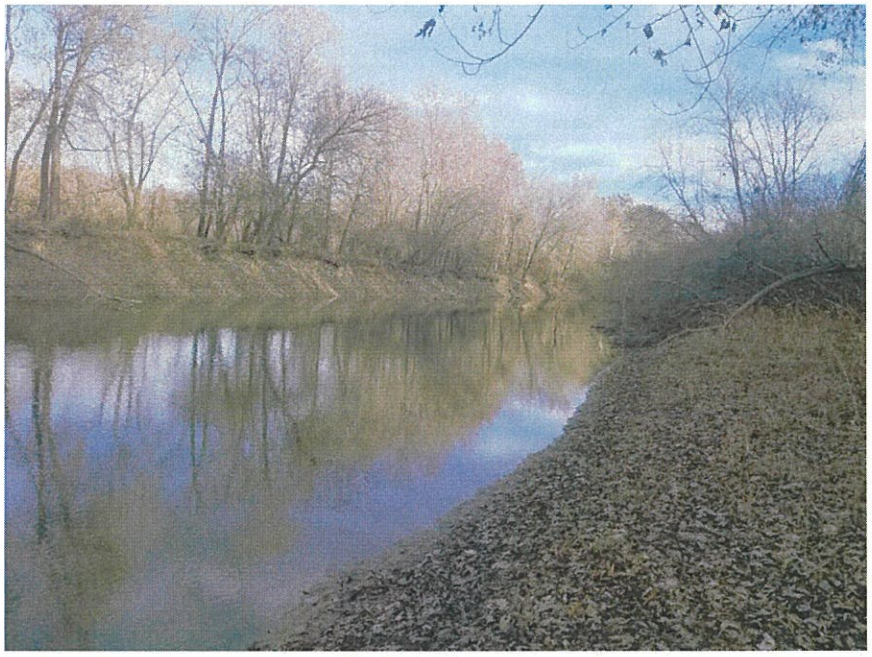
54. BM-18, downstream



57. BM-19, downstream



58. BM-20, upstream



61. BM-21, upstream



62. BM-21, habitat



65. BM-22, habitat



66. BM-22, downstream



69. BM-23, downstream



70. BM-24, upstream



73. BM-25, upstream



74. BM-25, habitat



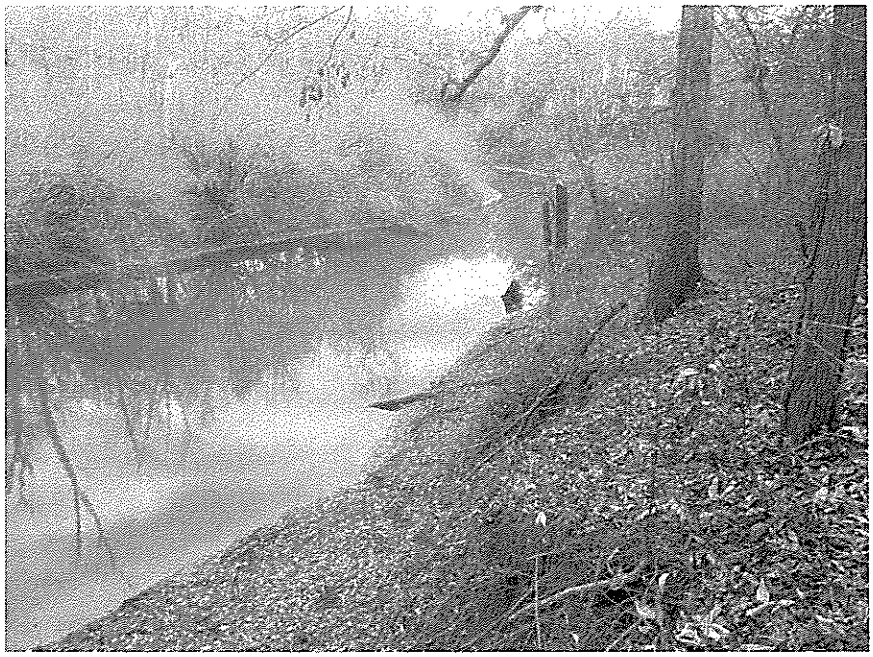
77. BM-26, habitat



78. BM-26, downstream



81. BM-27, downstream



82. BM-28, upstream



85. BM-29, upstream



86. BM-29, habitat



89. BM-30, habitat



90. BM-30, downstream



93. BM-31, downstream



94. BM-32, upstream

APPENDIX C

SUMMARY OF MACROINVERTEBRATE COMMUNITY SAMPLED

APPENDIX D

SUMMARY OF MACROINVERTEBRATE METRIC RESULTS

Table 1: BENTHIC RESULTS DATA				
Taxon	**Feeding Group**	**Tolerance Value**	**Tolerance Level**	**Sampling Station BM-1**
Amphipoda				
Gammaridae-Gammarus	omnivore	4	Facultative	1
Bivalvia				
Unionidae-ND	filter/collector	8	Tolerant	5
Coleoptera				
Psephenidae-ND	scraper	4	Facultative	1
Diptera				
Ceratopogonidae-ND	predator	5.7	Facultative	18
Chironomidae-ND	gatherer/collector	6	Tolerant	209
Ephemeroptera				
Ephemeridae-Ephemera	gatherer/collector	3.1	Facultative	30
Isopoda				
Asellidae-Asellus	gatherer/collector	9.4	Tolerant	7
Trichoptera				
Hydropsychidae-ND	filterer/collector	4	Facultative	1
Leptoceridae-ND	gatherer/collector	4	Facultative	1
Philopotamidae-ND	filterer/collector	3	Sensitive	1
			Totals	274

R00552

FIGURES



SCALE

0 250 500 1,000 1,500 Feet

1 inch = 500 feet

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Engineers · Constructors · Scientists
124 PHILPOTT LANE
BEAVER, WV 25813
(304) 255-0491

SAMPLING LOCATION MAP

WILLIAMSON ENERGY, LLC

DIFFUSSER LOCATION

PREPARED FOR

WILLIAMSON ENERGY, LLC
P.O. BOX 357
JOHNSTON CITY, IL 62951

DRAWN BY	BAH	12-11-19
CHECKED BY	BAH	12-11-19
APPROVED BY		

DRAWING NUMBER
B16-454-A4

R000554

2445-116-B
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BENTHIC MACROINVERTEBRATE COMMUNITY SURVEY OF THE BIG MUDDY RIVER

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BENTHIC MACROINVERTEBRATE COMMUNITY SURVEY OF THE BIG MUDDY RIVER WILLIAMSON ENERGY, LLC DIFFUSER LOCATION WILLIAMSON COUNTY, ILLINOIS

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FIGURES

Drawing No. B16-454-A3 – Habitat Assessment Map
Drawing No. B16-454-A4 – Sampling Location Map

BENTHIC MACROINVERTEBRATE COMMUNITY SURVEY OF THE BIG MUDDY RIVER WILLIAMSON ENERGY, LLC DIFFUSER LOCATION WILLIAMSON COUNTY, ILLINOIS

1.0 INTRODUCTION

Alliance Consulting, Inc. (Alliance) was contracted by Williamson Energy (Williamson) to perform a benthic macroinvertebrate survey for a proposed diffuser location in Franklin County, Illinois.

The benthic survey was performed by Alliance on November 20, 2019. The survey was completed following the protocols set forth by the U.S. Environmental Protection Agency (USEPA), Illinois Environmental Protection Agency (Illinois EPA), and the Illinois Department of Natural Resources (IDNR).

The purpose of the survey was to obtain data on the condition and composition of the aquatic macroinvertebrate communities present in the Big Muddy River downstream of the project area. This data will be used to help assess the impacts of the proposed project on the aquatic community.

2.0 SITE LOCATION

The sampling site is located on the Big Muddy River approximately 1.2 miles southeast of Ziegler, Illinois and approximately 0.77 miles downstream of the proposed diffuser location (37.524392°N, -89.23009°W).

The project area is located within the Central Lowland Physiographic Province and Interior River valleys and Hills ecoregion. The topography of the region is characterized by low lying flatland (typically agricultural) to gently rolling hills. The geology of the area is heavily influenced from glaciation.

The land cover attributes of the sample site are primarily composed of agricultural cropland and bottomland forest with heavily forested, but often narrow, riparian buffer zones.

3.0 METHODS

All work performed by Alliance to complete the survey of the benthic communities generally followed the protocols set forth by the USEPA, and the Illinois EPA, benthics were collected in accordance with the conditions of Illinois DNR 2019 Scientific Collecting Permit (No. A18.5984) (Appendix A).

3.1 Stream Site Selection

Using topographic maps, aerial photographs, and field reconnaissance of the project site,

Alliance attempted to identify areas to use as sample reaches for the survey in accordance with established wadeable collection methods provided by the USEPA (1999) and the Illinois EPA (2006) for sampling benthic macroinvertebrate communities. Alliance personnel walked the entire length of the Big Muddy River from the sampling location to the water diffuser location and evaluated the potential stream habitat to obtain a benthic sample according to the wadeable collection protocol. However, it was determined that this was not feasible due to lack of preferred habitat (riffles and/or runs) and the inaccessibility of the river due to steep banks and/or depth of the river to reach snags or submerged aquatic vegetation (Appendix B). The entire reach of the stream in the project area was determined to be 100% pool with no available riffle, run, or glide habitat, and the depth of the river made it far too deep for wadeable collection methods.

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Upon evaluation of the project reach it was deemed that traditional methods of habitat assessment for wadable streams were not applicable based on the physical conditions of the survey area. A total of 32 photographs were taken along the stream reach for documentation of the stream conditions at the time of sampling (Figures, Drawing No. B16-454-A3). The substrate found within the reach consisted primarily of fine grained clay, silt, and sandy sediments. Additionally, large portions of the channel exhibited no substantial bedload material and was primarily hard packed clay substrate commonly found within streams in southern Illinois.

3.3 Benthic Macroinvertebrate Sampling

Alliance was requested to sample benthic macroinvertebrates downstream of the project area within the Big Muddy River (BMR). Benthic macroinvertebrates were sampled using an Ekman Dredge dropped from an abandoned railroad bridge at the sampling location. The dredge was dropped 20 times from multiple points on the upstream and downstream side of the bridge to best represent the sampling reach due to lack of preferred habitat and inaccessibility issues, which prevented Alliance personnel from collecting a sample in a more traditional manner.

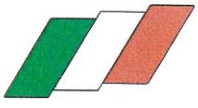
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The following are benthic macroinvertebrate community metrics used to analyze the composition of the benthic community sampled in this study:

Number of Coleopteran Taxa: The number of different taxa identified belonging to the Order Coleoptera (beetles). This metric generally decreases with increasing impairment.

Number of Ephemeropteran Taxa: The number of different taxa identified belonging to the order Ephemeroptera (mayflies). This metric generally decreases with increasing impairment.

Number of Intolerant Taxa: The total number of different taxa determined to be sensitive to degradation according to the IEPA. This metric should decrease with increasing degradation.



Percent Individuals as Scrapers: The overall percentage of individual macroinvertebrates within the subsample belonging to the Scraper functional feeding group. This metric generally decreases with increasing impairment.

Shannon-Wiener Diversity Index: An index that measures the diversity of a community by taking into account the number of taxa present (richness) and taxa evenness (McCune and Grace, 2002). Evenness is essentially how equal in abundance individuals of different taxa are to each other. A healthy community should have a high Shannon-Wiener Diversity Index value.

Taxa Richness: Indicative of community health through a measurement of the number of taxa present. Typically increases with increasing water quality and habitat quality. Majority of taxa should come from pollution sensitive groups, with fewer from facultative and tolerant groups.

Percent Contribution of Ephemeroptera, Plecoptera, and Trichoptera (EPT): Measures community health considering a community in good health should have a high percent contribution from the EPT groups as they are often pollution sensitive.

Macroinvertebrate Index of Biotic Integrity (mIBI): An indicator of stream ecosystem health and impairment. The index combines seven metrics (Macroinvertebrate Biotic Index, Total Taxa Richness, Number of Ephemeropteran Taxa, % EPT, Number of Coleopteran Taxa, Number of Intolerant Taxa, and % Scaper) that collectively represent the overall health and integrity of a stream ecosystem and its benthic macro-invertebrate community. The following is a list of the mIBI ratings based on score:

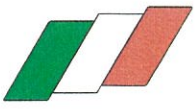
Macroinvertebrate IBI (mIBI) Quality Categories

Lower Boundary	Upper Boundary	Narrative Description
73	100	Exceptional
41.8	72.9	Good
20.9	41.7	Fair
0.0	20.8	Poor

Macroinvertebrate Biotic Index: Indicates presence/absence of pollution (specifically organic pollution) by summarizing the abundance of a taxon multiplied by its tolerance value, and divided by the total number of organisms in the sample (Hilsenhoff, 1977). The biotic index is based on a scale from 0 – 10, with 0 being the best possible score (no pollution) and 10 being the worst possible score (high pollution).

Macroinvertebrate Biotic Index (MBI)

Limits	Water Quality Narrative Description
< 6.0	Good
6.0 to 7.5	Fair
7.6 to 8.9	Poor
≥ 9.0	Very Poor



Alliance reviewed the relative abundance of pollution tolerant species as a measure of the general health of the benthic community. Taxa such as Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), collectively referred to as EPT, are often pollution sensitive, whereas taxa such as *Chironomidae* (midges) have a relatively high tolerance for pollution. Skewed populations of specific groups provide insight into the existence of environmental stress factors.

4.0 RESULTS

4.1 Biological Monitoring Survey

The surveys were performed by Alliance on November 20th, 2019 at the established monitoring station on the Big Muddy River (Figures, Drawing No. B16-454-A4). Data collected includes aquatic organism community data and associated metrics.

4.2 Station Big Muddy River

The biological monitoring Station BMR is located approximately 0.77 miles directly downstream of the proposed diffuser location on the Big Muddy River (Figures, Drawing No. B16-454-A4).

4.2.1 Benthics for Big Muddy River

In total 274 individuals, representing 10 taxa were identified during the benthic survey (Table 1). A diversity score of 0.9 (Shannon-Wiener Diversity Index) (Table 2). *Chironmidae* made up 76% of the sample with 209 individuals. A low percent EPT score of 12.04% was recorded showing a lack of sensitive organisms. The mIBI scored 23.8, which is a rating of fair and 80.7% of the sample was made up of tolerant taxa. The metrics reflect a stream with poor habitat quality, low biodiversity, and a struggling benthic macroinvertebrate community.

5.0 CONCLUSIONS

Concerning the benthic macroinvertebrate community, Alliance reviewed several metrics and community characteristics which evaluate the overall health of the macroinvertebrate community. Metrics such as percent tolerant taxa, EPT taxa richness, and the Shannon-Wiener Diversity index are often good indicators of aquatic life health.

The sampled site showed a tolerant taxa percentage of 80.7%. The station had a low percentage of EPT taxa collected at 12.04%. *Chironomidae* dominated the sample at 76% which would be indicative of a more pollutant tolerant benthic community. The Shannon-Wiener Diversity Index scores the site at 0.90 showing a low diversity of organisms. The mIBI scored at 23.8 which indicates a benthic community in fair health.

Metrics recorded based on the samples collected reflect a stream with poor habitat quality, low biodiversity, and a struggling benthic macroinvertebrate community. Some factors likely

contributing to impairment are the lack of heterogeneity in stream habitat (i.e. very little riffle/run habitat), bank instability and substrate composition.

If you have any questions or require clarification, please do not hesitate to call.

Respectfully submitted,

ALLIANCE CONSULTING, INC.

Alex Patterson
Staff Scientist

Braden A. Hoffman
Senior Project Manager

AP/BAH:kjs

File: \\Aci-zeus\projects\Projects\Williamson Energy (1413)\2016\B16-454-1413\Benthic Survey\2019\benthic survey.doc

6.0 LITERATURE CITED

Hilsenhoff, W.L. 1977. Using a Biotic Index to Evaluate Water Quality/Streams. Wisconsin Department of Natural Resources Technical Bulletin No. 100. Madison, Wisconsin.

McCune, B., Grace, J.B., and D.L. Urban. 2002. Analysis of Ecological Communities. MjM Software Design. Gleneden Beach, Oregon.

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Illinois Department of Natural Resources (IDNR) IBR Calculator. Metric and Total IBI Score. [Web]. 2014. http://dnr.illinois.gov/IBICalculation/ResultsForm.aspx#SampleSummary

Illinois Environmental Protection Agency. 2011. Standard Operating Procedure for Sample Processing for the Macroinvertebrtate Index of Biotic Integrity (mIBI). Springfield, Illinois.

APPENDIX A

COLLECTION PERMIT

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

Authorization is hereby granted, under 520 ILCS 5/3.22 and 515 ILCS 5/20-100 of the Illinois Compiled Statutes and 17 ILL. Adm. Code 520 to:

Last Name: **Patterson** First Name: **Alex** Permit Number: **A19.5984**

Issued: **3/7/2019** **Expires: 12/31/2019**

Business Name: Alliance Consulting, Inc.

Street Address: 124 Philpott Lane

City: Beaver State: WV Zip Code: 25813

for strictly scientific, educational or zoological purposes, to take the Illinois fauna identified below subject to the following provisions:

May legally capture, by scientifically accepted methods, only the specific aquatic life species listed on the accompanying Illinois Department of Natural Resources (IDNR) scientific permit application/project proposal (on file in Springfield, IL) strictly for scientific, educational, and/or zoological purposes (except endangered and threatened species). After data has been humanely collected from these species, all animals shall be released unharmed at or near the original site of capture. Deceased animals and/or animal parts must be buried or given to a public or state scientific educational or zoological institution. A federal permit is required for all projects involving federally regulated species. If endangered and threatened species are to be taken, the IDNR Division of Natural Heritage, Endangered Species Coordinator must be notified and must approve in writing all project related activities of the permit application.
Possession/Transportation of injurious aquatic life species requires appropriate permits in addition to the previously stated. The IDNR Aquaculture Specialist can be contacted to request and seek approval of all project activities of the permit applicant prior to activities being initiated. If such species are encountered as part of previously authorized projects, they may be kept for deposition into state, scientific, educational, or zoological institutions, if appropriate precautions are taken to further restrict potential release into the environment AND immediate reporting of escape to dnr.aquaculture@illinois.gov . (All aquatic life may be immediately returned unharmed from where they were taken. 515 ILCS 5/10-100.)
Authorization: Statewide, exclusive of nature preserves, and IDNR owned and managed properties.
Individuals authorized to work under direction of applicant include: Braden Hoffman, Bethany Wolfe, Jennifer Arp-Bazzie, Brandon Alderman, Blake Davis, Bo Wolfe

I agree to the following provisions and terms of this Scientific Permit.

Permittee's Signature: _____ (Permit not valid unless signed)

Approved By: _____ Office of Resource Conservation Date: 3/8/19

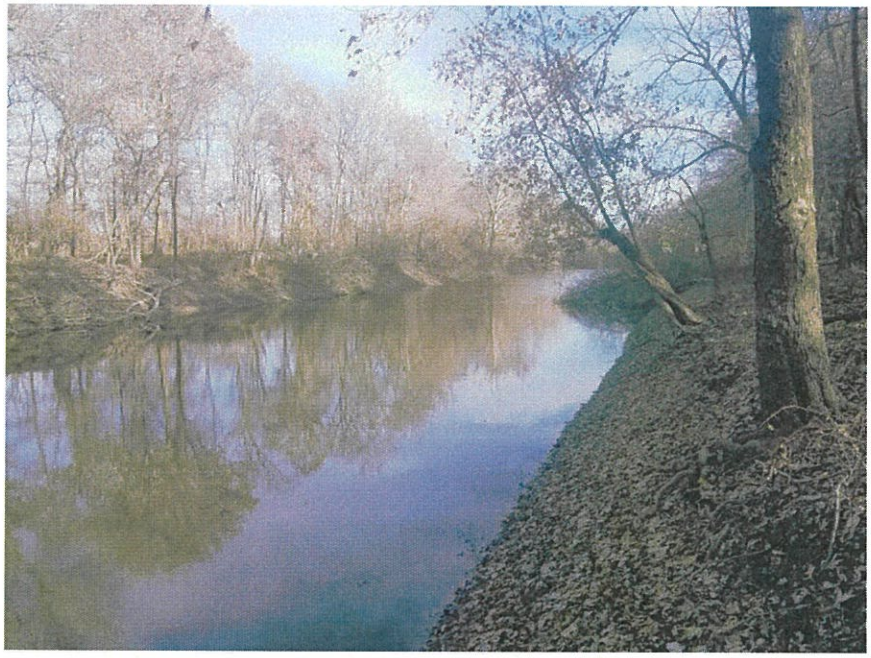
TERMS FOR SCIENTIFIC PERMIT

1. This permit is valid only for the approved methods, locations and activities stated on the permit.
2. All permitted activities shall be performed by or under the direct supervision of the permittee. Permittee must be present with persons involved in actual taking of fauna.
3. Under no circumstances shall a scientific permit be used in lieu of sport or commercial licenses.
4. This permit is valid only for species not listed as Illinois Threatened or Endangered (https://www.dnr.illinois.gov/conservation/NaturalHeritage/Pages/EndangeredandThreatenedSpecies.aspx). If a Threatened or Endangered species is incidentally captured, the specimen must be released and the occurrence must be reported to tara.kieninger@illinois.gov within 5 business days.
5. This permit does not allow the privilege of trespass. Landowner permission is required. Activities on Department sites are not permitted without the prior approval of the Site Superintendent. Activities on Illinois Nature Preserves and Land and Water Reserves must have prior approval from the Illinois Nature Preserve Commission.
6. Permittee must carry this permit at all times when taking specimens and be presented, upon request, to Department personnel.
7. Fauna taken and/or salvaged and rehabilitated must be released to the wild or permanently donated to a public or state scientific educational or zoological institution
8. This permit does not supersede Federal permits, which may be necessary for the permitted work.
9. All gear left unattended must be tagged bearing name and scientific permit number of permittee.
10. Use of rotenone or any other toxic materials for taking of fauna must have written approval from the Department prior to using such materials, and may need a variance from the Illinois Environmental Protection Agency.
11. An annual report must be submitted to the Department by January 31 of each year.
12. This permit may be revoked or suspended if the Department finds that a permittee has falsified information on the application, failed to comply with the provisions of this permit, or violated state or federal laws.

The Department of Natural Resources is an equal opportunity employer.

APPENDIX B

HABITAT MAPPING PHOTOGRAPHS



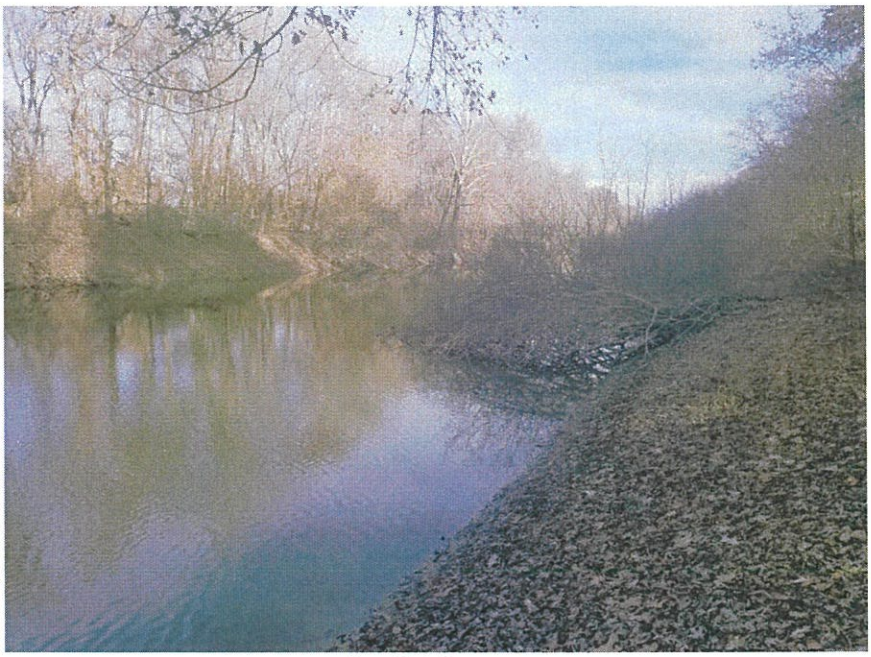
1. BM-1, upstream



2. BM-1, habitat



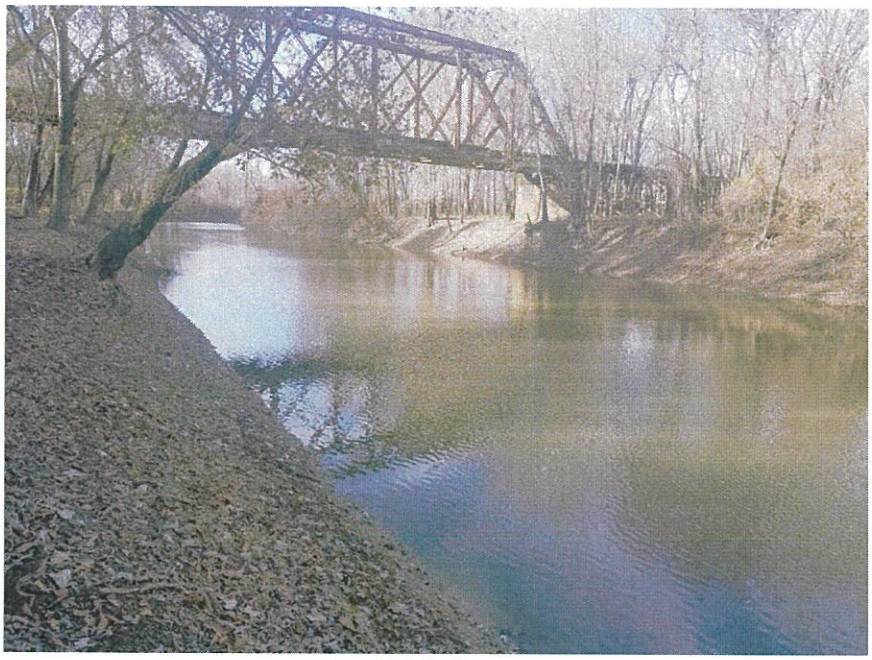
3. BM-1, downstream



4. BM-2, upstream



5. BM-2, habitat



6. BM-2, downstream



7. BM-3, upstream



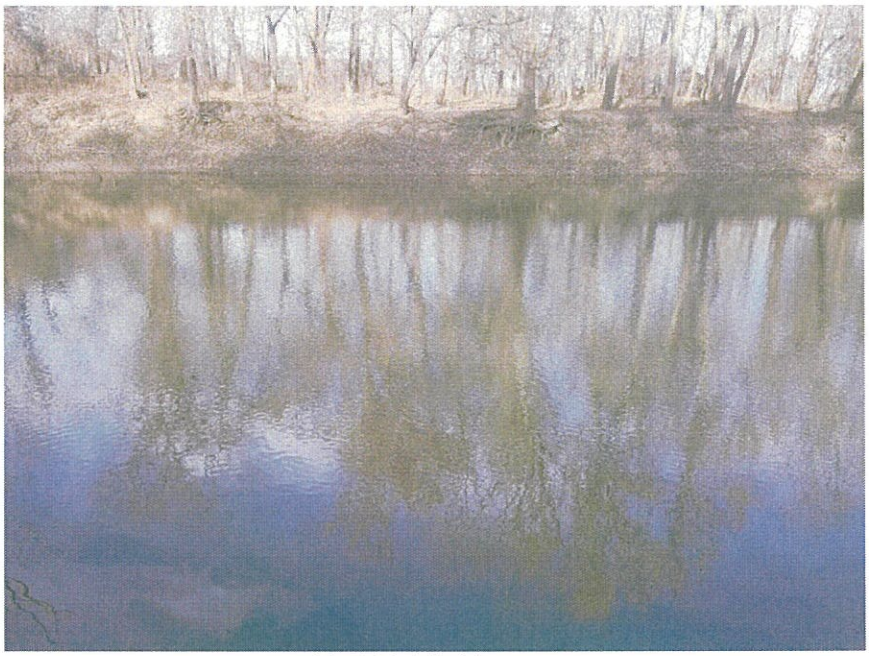
8. BM-3, habitat



9. BM-3, downstream



10. BM-4, upstream



11. BM-4, habitat



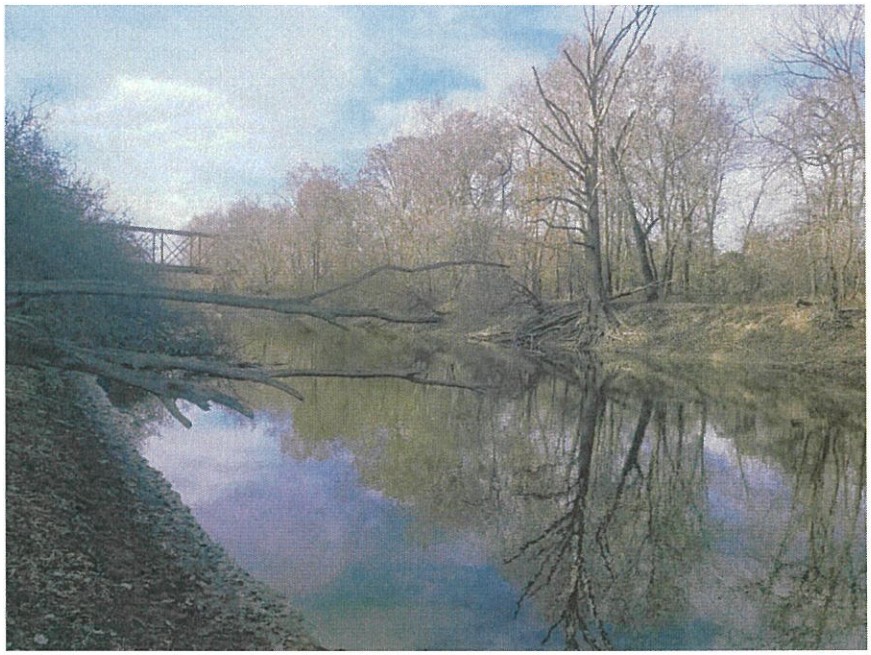
12. BM-4, downstream



13. BM-5, upstream



14. BM-5, habitat



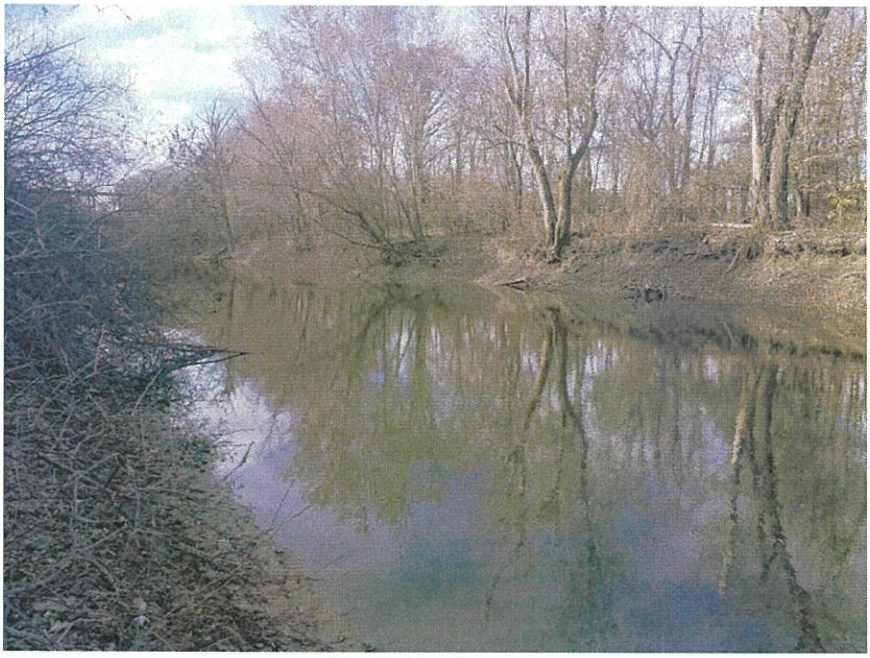
15. BM-5, downstream



16. BM-6, upstream



17. BM-6, habitat



18. BM-6, downstream



19. BM-7, upstream



20. BM-7, habitat



21. BM-7, downstream



22. BM-8, upstream



23. BM-8, habitat



24. BM-8, downstream



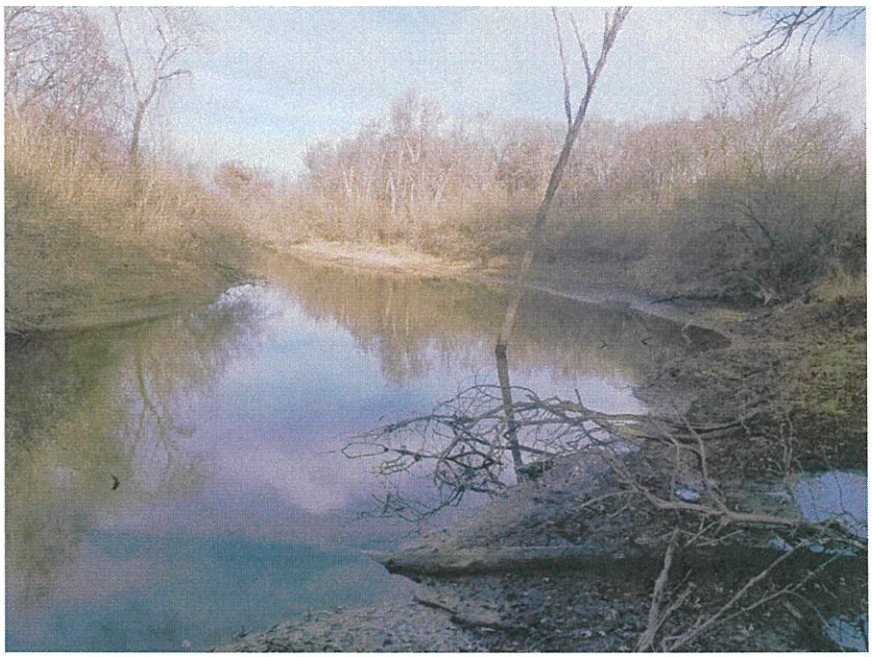
25. BM-9, upstream



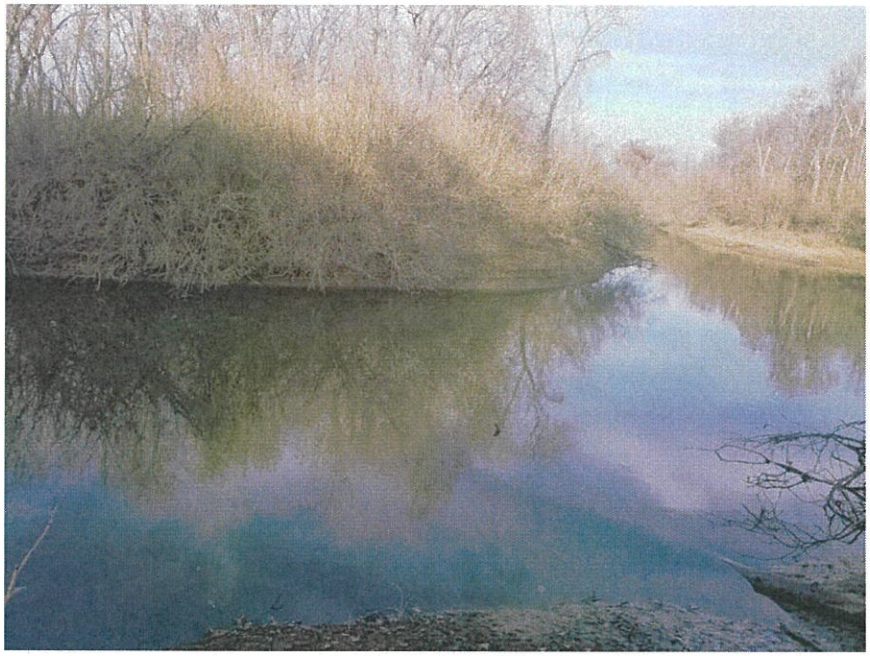
26. BM-9, habitat



27. BM-9, downstream



28. BM-10, upstream



29. BM-10, habitat



30. BM-10, downstream



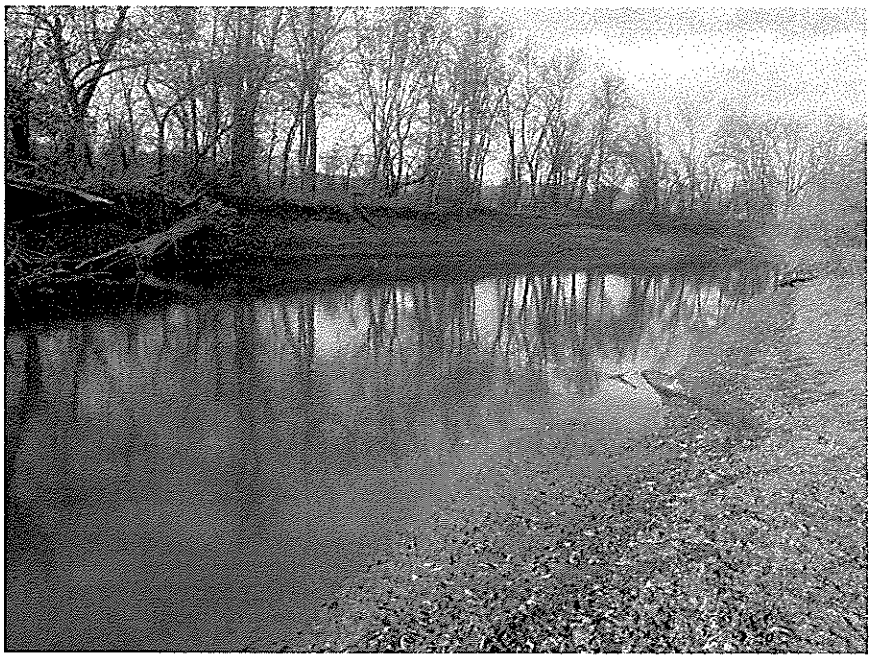
31. BM-11, upstream



32. BM-11, habitat



33. BM-11, downstream



34. BM-12, upstream



35. BM-12, habitat



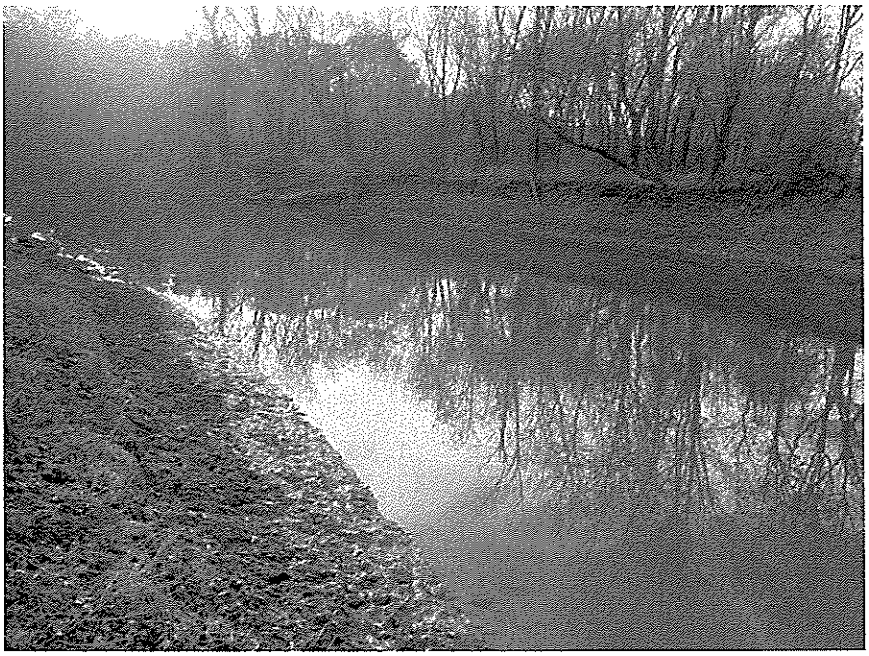
36. BM-12, downstream



37. BM-13, upstream



38. BM-13, habitat



39. BM-13, downstream



40. BM-14, upstream



41. BM-14, habitat



42. BM-14, downstream



43. BM-15, upstream



44. BM-15, habitat



45. BM-15, downstream



46. BM-16, upstream



47. BM-16, habitat



48. BM-16, downstream



49. BM-17, upstream



50. BM-17, habitat



51. BM-17, downstream



52. BM-18, upstream



53. BM-18, habitat



54. BM-18, downstream



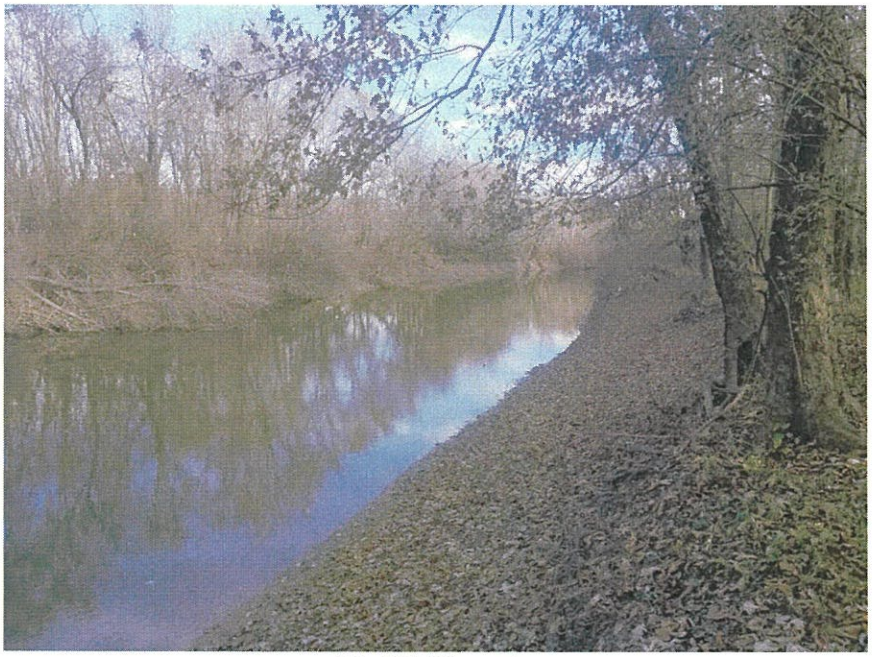
55. BM-19, upstream



56. BM-19, habitat



57. BM-19, downstream



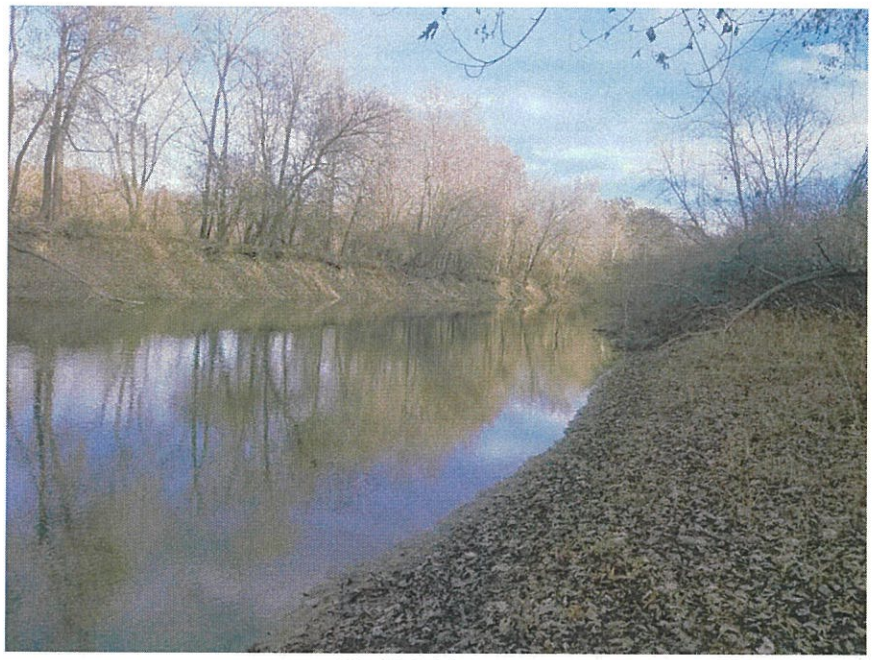
58. BM-20, upstream



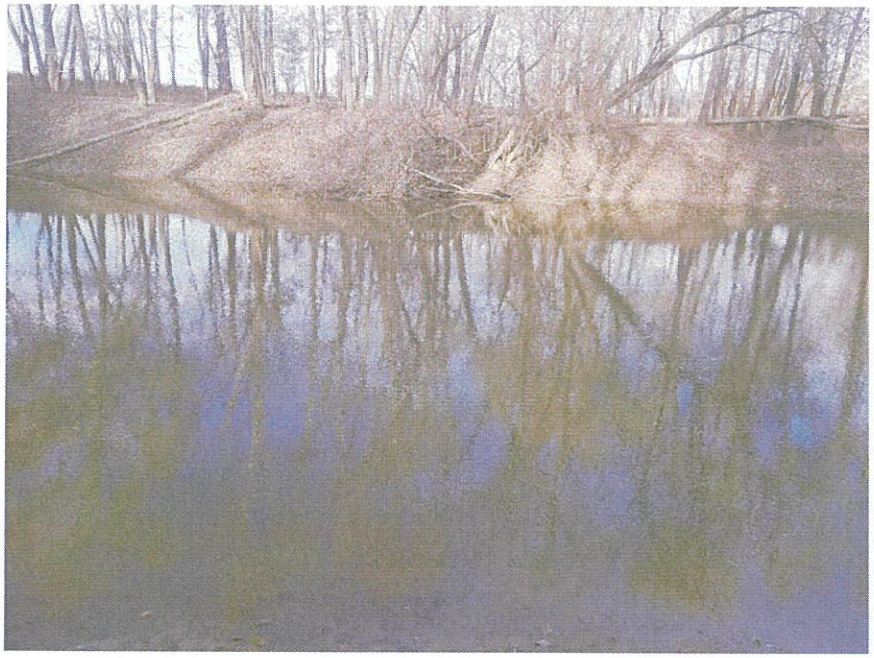
59. BM-20, habitat



60. BM-20, downstream



61. BM-21, upstream



62. BM-21, habitat



63. BM-21, downstream



64. BM-22, upstream



65. BM-22, habitat



66. BM-22, downstream



67. BM-23, upstream



68. BM-23, habitat



69. BM-23, downstream



70. BM-24, upstream



71. BM-24, habitat



72. BM-24, downstream



73. BM-25, upstream



74. BM-25, habitat



75. BM-25, downstream



76. BM-26, upstream



77. BM-26, habitat



78. BM-26, downstream



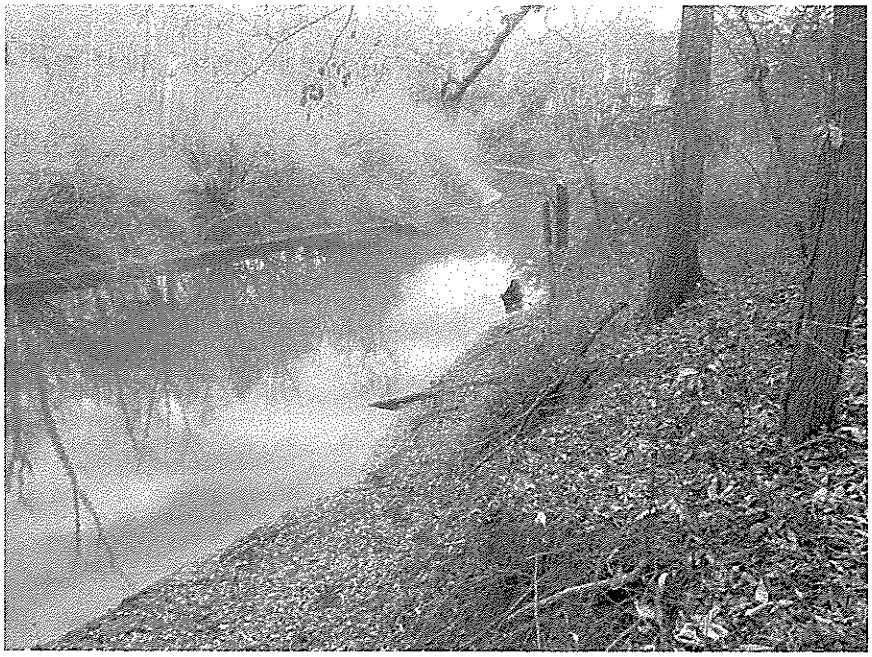
79. BM-27, upstream



80. BM-27, habitat



81. BM-27, downstream



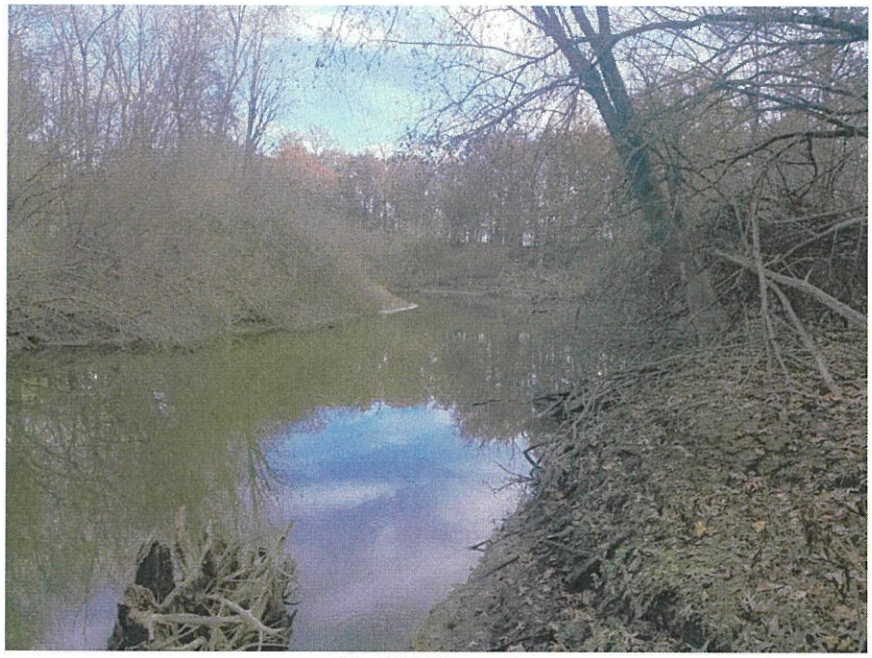
82. BM-28, upstream



83. BM-28, habitat



84. BM-28, downstream



85. BM-29, upstream



86. BM-29, habitat



87. BM-29, downstream



88. BM-30, upstream



89. BM-30, habitat



90. BM-30, downstream



91. BM-31, upstream



92. BM-31, habitat



93. BM-31, downstream



94. BM-32, upstream



95. BM-32, habitat



96. BM-32, downstream

APPENDIX C

SUMMARY OF MACROINVERTEBRATE COMMUNITY SAMPLED

Alliance Consulting, Inc.

Engineers · Constructors · Scientists

Benthic Macroinvertebrate Sampling

Field Sampling	
Stream Name	Big Muddy River
Site/Station ID	**BM-1**
Project #	B16-454-1413
Method Used	1 m^2 kick
Date Collected	11/20/2019
Sample Collector(s)	Daniel Brady; Jeff Rabbitt
Sample Deliverer(s)	Daniel Brady

Laboratory Analysis	
Total # of Grids	100
# of Grids Picked	100
Total # of Ind.	274
Method Used	300 count subsample
Sample picker(s)	Daniel Brady
Date Picked	12/04/2019
Sample Identifier(s)	Daniel Brady
Date Identified	12/04/2019

Chain of Custody	
Collector(s)	Daniel Brady
	Jeff Rabbitt
Deliverer(s)	Daniel Brady
Picker(s)	Daniel Brady
Identifier(s)	Daniel Brady
Analyzer(s)	Daniel Brady

Order	Family	Count
Amphipoda	Gammaridae	1
Coleoptera	Psephenidae	1
Diptera	Ceratopogonidae	18
	Chironomidae	209
Ephemeroptera	Ephemeridae	30
Isopoda	Asellidae	7
Trichoptera	Hydropsychidae	1
	Leptoceridae	1
	Philopotamidae	1
Unionida	Unionidae	5
Total # of Individuals		**274**

APPENDIX D

SUMMARY OF MACROINVERTEBRATE METRIC RESULTS

TABLES

Table 1: BENTHIC RESULTS DATA				
Taxon	**Feeding Group**	**Tolerance Value**	**Tolerance Level**	**Sampling Station BM-1**
Amphipoda				
Gammaridae-Gammarus	omnivore	4	Facultative	1
Bivalvia				
Unionidae-ND	filter/collector	8	Tolerant	5
Coleoptera				
Psephenidae-ND	scraper	4	Facultative	1
Diptera				
Ceratopogonidae-ND	predator	5.7	Facultative	18
Chironomidae-ND	gatherer/collector	6	Tolerant	209
Ephemeroptera				
Ephemeridae-Ephemera	gatherer/collector	3.1	Facultative	30
Isopoda				
Asellidae-Asellus	gatherer/collector	9.4	Tolerant	7
Trichoptera				
Hydropsychidae-ND	filterer/collector	4	Facultative	1
Leptoceridae-ND	gatherer/collector	4	Facultative	1
Philopotamidae-ND	filterer/collector	3	Sensitive	1
			Totals	274

R00619

Table 2

Summary of Benthic Metric Results	
Metric	**Station**
	BM
Total Individuals	274
Total Taxa	10
Sensitive Individuals	1
% Sensitive Individuals	0.4%
# Sensitive Taxa	1
Facultative Individuals	52
% Facultative Individuals	19.0%
# Facultative Taxa	5
Tolerant Individuals	221
% Tolerant Individuals	80.7%
# Tolerant Taxa	3
No. of Coleoptera Taxa	1
No. of Ephemeroptera Taxa	1
No. of Intolerant Taxa	1
% Scrapers	0.36
% EPT	12.04
Shannon-Wiener Diversity Index	0.90
Macroinvertebrate Biotic Index (MBI)	5.73
Macroinvertebrate Index of Biotic Integrity (MIBI)	23.80
mIBI Rating	Fair

FIGURES



Legend

PHOTO LOCATIONS

SCALE

0 250 500 1,000 1,500 Feet

1 inch = 500 feet

Alliance Consulting, Inc.
Engineers · Constructors · Scientists
124 PHILPOTT LANE
BEAVER, WV 25813
(304) 255-0491

HABITAT ASSESSMENT MAP

WILLIAMSON ENERGY, LLC
DIFFUSSER LOCATION
PREPARED FOR
WILLIAMSON ENERGY, LLC
P.O. BOX 357
JOHNSTON CITY, IL 62951

DRAWN BY	BAH	12-11-19
CHECKED BY	BAH	12-11-19
APPROVED BY		

DRAWING NUMBER
B16-454-A3

R00022



SCALE

0 250 500 1,000 1,500 Feet

1 inch = 500 feet

Alliance Consulting, Inc.
Engineers · Constructors · Scientists
124 PHILPOTT LANE
BEAVER, WV 25813
(304) 255-0491

SAMPLING LOCATION MAP

WILLIAMSON ENERGY, LLC

DIFFUSSER LOCATION

PREPARED FOR

WILLIAMSON ENERGY, LLC
P.O. BOX 357
JOHNSTON CITY, IL 62951

DRAWN BY	BAH	12-11-19
CHECKED BY	BAH	12-11-19
APPROVED BY		

DRAWING NUMBER

B16-454-A4

R00623

2445-716-B
R00625

ILLINOIS NATURAL
HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

Freshwater Mussels of the Big Muddy River

Diane K. Shasteen, Alison L. Price, Sarah A. Bales

INHS Technical Report 2012 (11)

Prepared for:

Illinois Department of Natural Resources: Office of Resource Conservation
U.S. Fish & Wildlife Service
Illinois Natural History Survey

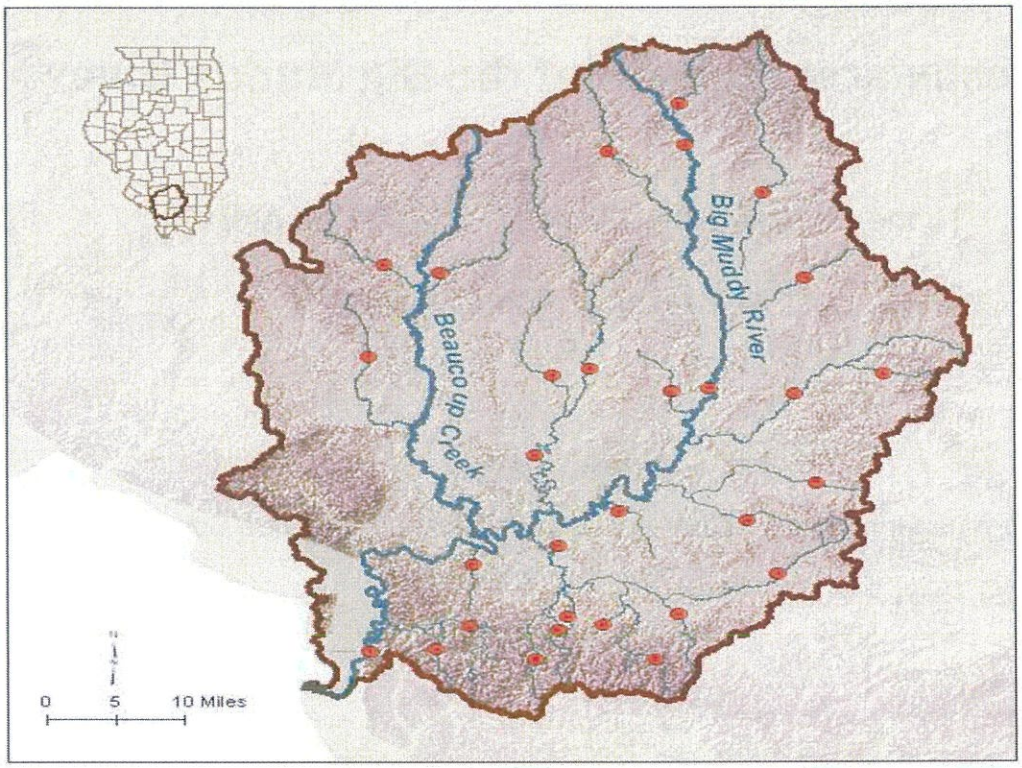
Issued March 7, 2012

Prairie Research Institute, University of Illinois at Urbana Champaign
William Shilts, Executive Director

Illinois Natural History Survey
Brian D. Anderson, Director
1816 South Oak Street
Champaign, IL 61820
217-333-6830

R00626

Freshwater Mussels of the Big Muddy River



2012

Illinois Natural History Survey, Prairie Research Institute, University of Illinois
Illinois Department of Natural Resources

Diane Shasteen, Alison Price, Sarah Bales

Preface

While broad geographic information is available on the distribution and abundance of mussels in Illinois, systematically collected mussel-community data sets required to integrate mussels into aquatic community assessments do not exist. In 2009, a project funded by a US Fish and Wildlife Service State Wildlife Grant was undertaken to survey and assess the freshwater mussel populations at wadeable sites from 33 stream basins in conjunction with the Illinois Department of Natural Resources (IDNR)/Illinois Environmental Protection Agency (IEPA) basin surveys. Inclusion of mussels into these basin surveys contributes to the comprehensive basin monitoring programs that include water and sediment chemistry, instream habitat, macroinvertebrate, and fish, which reflect a broad spectrum of abiotic and biotic stream resources. These mussel surveys will provide reliable and repeatable techniques for assessing the freshwater mussel community in sampled streams. These surveys also provide data for future monitoring of freshwater mussel populations on a local, regional, and watershed basis.

Agency Contacts
Kevin S. Cummings, INHS, ksc@inhs.illinois.edu (217) 333-1623
Bob Szafoni, IDNR, Robert.szafoni@illinois.gov, (217) 348-0175
Ann Marie Holtrop, IDNR, ann.holtrop@illinois.gov, (217) 785-4325

Suggested Citation
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Introduction

Freshwater mussel populations have been declining for decades and are among the most seriously impacted aquatic animals worldwide (Bogan 1993, Williams et al. 1993). It is estimated that nearly 70% of the approximately 300 North American mussel taxa are extinct, federally-listed as endangered or threatened, or in need of conservation status (Williams et al. 1993, Strayer et al. 2004). In Illinois, 25 of the 62 extant species (44%) are listed as threatened or endangered (Illinois Endangered Species Protection Board 2011). While broad geographic information is available on the distribution and abundance of mussels in Illinois, systematically collected mussel-community data sets required to integrate mussels into aquatic community assessments do not exist. Sampling of mussels has been very sporadic and limited in the Big Muddy River basin and no known reports pertaining to mussel communities of the basin have been published. This report summarizes the mussel survey conducted in the Big Muddy River basin in 2009-2010 in conjunction with IDNR and IEPA basin surveys.

The Big Muddy River basin drains 3798 km^2 (2360 mi^2) in the southern part of Illinois and contains principal tributaries of Casey Fork, Middle Fork Big Muddy, Beaucoup Creek, Little Muddy River, and Crab Orchard Creek (Page et al. 1992). Originating near Cravat in Jefferson County, the Big Muddy River basin drains through the counties of Jefferson, Washington, Perry, Franklin, Williamson, and Jackson. The river mainstem forms the Jackson /Union county line and joins the Mississippi River south of Grand Tower (Figure 1). The Big Muddy River basin flows through four natural divisions, including the Lower Mississippi River Bottomlands, Ozark, Shawnee Hills, and Southern Till Plain (Schwegman 1973). The Southern Till Plain comprises the majority of the basin which is characterized by hilly upland topography and a broad flood plain (Forbes and Richardson 1908).

Land-use and Instream Habitat

In the Big Muddy River basin, land use varies slightly by county with approximately 50 to 75% of the area in agriculture. Forested lands account for 8 to nearly 25% of the landscape with the larger forested areas being located in Jackson and Williamson counties (IDA 2000). Three of the largest cities in southern Illinois with populations between 15,000 and 28,000 (Marion, Mt. Vernon, and Carbondale) are also located in this basin (IEPA 1996, US Census Bureau 2010). In 1965, the Big Muddy River was dammed near Benton and thus Rend Lake, the second largest inland impoundment in the state, was created (Page et al. 1992, USACE 2005). This reservoir provides over 15 million gallons of water per day to approximately 300,000 people in over 60 communities throughout the basin. It is also used extensively for recreational activities including boating, fishing, waterfowl hunting and camping (USACE 2005). These recreational activities are also popular in the Shawnee National Forest, Giant City State Park, Lake Kinkaid and Murphysboro, Crab Orchard National Wildlife Refuge, and LaRue Pine Hills Ecological Area,

which are all located within the Big Muddy River basin. In the southwestern part of this basin, especially near the Murphysboro area, strip mining for coal was prevalent during the early 20th century and pollution from the remaining spoil banks continues to be a problem in the basin (Page et al. 1992).

During glacial activity in the region, the Mississippi River exceeded its sediment transporting capacity thus closing off the mouths of its tributary streams, including the Big Muddy River. The Big Muddy River temporarily formed a lake; once the natural process of removing sediment returned to the Mississippi River a deeper channel emerged. As the Big Muddy River drained, soils typical of a lake bed were left behind (LeTellier 1971). Today, the soils of the Big Muddy basin consist of impervious clays, silt and fine sand. The substrates in all of the streams of this basin were dominated by some combination of sand, silt, and clay. Excessive siltation along with large woody debris was common at many sites within the basin (Figure 2 and 3). Most of the sites in the basin had wadeable water depths; however sampling sites were limited on the mainstem of the Big Muddy and on Beaucoup Creek due to non-wadeable water depths (e.g., depth>1m).

Methods

During the 2009/2010 surveys, freshwater mussel data were collected at 30 sites: 3 mainstem and 27 tributary sites in the Big Muddy River basin (Figure 1, Table 1). Locations of sampling sites are listed in Table 1 along with information regarding IDNR/IEPA sampling at the site. In most cases, mussel survey locations were the same as IDNR/IEPA sites.

Live mussels and shells were collected at each sample site to assess past and current freshwater mussel occurrences. Live mussels were surveyed by hand grabbing and visual detection (e.g. trails, siphons, exposed shell) when water conditions permitted. Efforts were made to cover all available habitat types present at a site including riffles, pools, slack water, and areas of differing substrates. A four-hour timed search method was implemented at each site. Live mussels were held in the stream until processing.

Following the timed search, all live mussels and shells were identified to species and recorded (Table 2). For each live individual, shell length (mm), gender, and an estimate of the number of growth rings were recorded. Shell material was classified as recent dead (periostracum present, nacre pearly, and soft tissue may be present) or relict (periostracum eroded, nacre faded, shell chalky) based on condition of the best shell found. A species was considered extant at a site if it was represented by live or recently dead shell material (Szafoni 2001). The nomenclature employed in this report (Appendix 1) follows Turgeon et al. (1998) except for recent taxonomic changes to the gender ending of lilliput (*Toxolasma parvum*), which follows Williams et al. (2008). Voucher specimens were retained and deposited in the Illinois Natural History Survey

Mollusk Collection. All non-vouchered live mussels were returned to the stream reach where they were collected.

Parameters recorded included extant and total species richness, presence of rare or listed species, and individuals collected, expressed as catch-per-unit-effort (CPUE; Table 2). A population was considered to indicate recent recruitment if individuals less than 30 mm in length or with 3 or fewer growth rings were recorded. Finally, mussel resources were classified as Unique, Highly Valued, Moderate, Limited, or Restricted (Table 2) based on the above parameters (Table 3) and following criteria outlined in Table 4 (Szafoni 2001).

Results

Species Richness

A total of 19 species of freshwater mussels were observed in the Big Muddy River basin, all of which were collected live (Table 2). Across all sites, the number of live species collected, the number of extant species collected (live + dead), and the total number of species collected (live + dead + relict) ranged from 0 to 13. The giant floater (*Pyganodon grandis*) had the most occurrences across sites sampled with live mussels present (11 of 30 sites; 37%; Figure 4). The lilliput (*Toxolasma parvum*), paper pondshell (*Utterbackia imbecillis*), pondhorn (*Uniomerus tetralasmus*) and white heelsplitter (*Lasmigona complanata*) were other commonly occurring species (Figure 4), occupying 17% of these sites. Site 6, the Big Muddy River near Benton, had the greatest species richness with 12 live species.

Abundance and Recruitment

A total of 358 individuals were collected across 30 sites. The number of live specimens collected at a given site ranged from 0 to 133, with an average of 16 mussels per site where live mussels were collected (22 of 30 sites; Table 2). A total of 120 collector-hours were spent sampling with an average of three mussels collected per hour. Nine sites yielded more than 10 live individuals and 2 of the 9 sites (sites 6 and 15) yielded more than 45 live individuals. The most common species collected in the Big Muddy basin were giant floater (*n*=131), mapleleaf (*Quadrula quadrula*; n=37), white heelsplitter (n=34), lilliput (n=24), and pink papershell (*Potamilus ohiensis;* n=20), which together comprised approximately 70% of the individuals collected.

Recruitment for each species was determined by the presence of individuals less than 30mm or with 3 or fewer growth rings. Smaller (i.e., younger) mussels are harder to locate by hand grab methods and large sample sizes can be needed to accurately assess population reproduction. However, a small sample size can provide evidence of recruitment if it includes individuals that are small or possess few growth rings. Alternatively, a sample consisting of very large (for the species) individuals with numerous growth rings suggests a senescent population.

Recruitment at individual sites ranged from none observed to high across the basin. Recruitment levels, referred to in Table 3 as Reproduction Factor, varied from one to five, and three of the sites in the Big Muddy River basin exhibited high to very high recruitment. Recruitment was over 50% at site 7, Andy Creek, and 30 to 50% at sites 1 and 9, Snow Creek and Middle Fork Big Muddy (Figure 5). Sites 2 and 29, Big Muddy River and Cedar Creek, exhibited recruitment from 1 to 30% of species collected. Recruitment may be occurring at site 30, Big Muddy mainstem, where dead shells of nearly all species collected were less than 3 years of age. All other sites in the Big Muddy River basin (24 of 30) exhibited no observed recruitment during this survey.

Mussel Community Classification

Based on the data collected in the 2009/2010 basin surveys, nearly 75% of the sites in the Big Muddy River basin have Restricted or Limited mussel communities using the current MCI classification system (Table 4, Figure 5). No sites are ranked as Unique or Highly Valued in the basin. Eight sites (sites 1, 2, 6, 7, 9, 15, 23, and 29) in the Big Muddy River basin were ranked as Moderate mussel resources.

Noteworthy Finds

According to historical records, 25 species are known from the Big Muddy River basin (Tiemann et al. 2007). All 19 species found during this survey had been recorded in the basin historically. However, three of these species had not been recorded live since 1969; these species included Wabash pigtoe (*Fusconaia flava*), pondmussel (*Ligumia subrostrata*), and deertoe (*Truncilla truncata*). Historic species not detected during this survey include creeper (*Strophitus undulatus*), spike (*Elliptio dilatata*), pimpleback (*Quadrula pustulosa*), plain pocketbook (*Lampsilis cardium*), pink heelsplitter (*Potamilus alatus*), and fawnsfoot (*Truncilla donaciformis*).

A possible range expansion may be occurring with the Louisiana fatmucket (*Lampsilis hydiana)* which occurs in the upper Arkansas, White and St. Francis rivers and in Louisiana and East Texas (NatureServe 2011). Specimens collected during this survey were classified as *Lampsilis siliquoidea* (*hydiana*) due to morphological features that resemble the Louisiana fatmucket (pers. comm. Kevin Cummings). Additional genetic testing would need to be conducted to correctly determine which species, *Lampsilis siliquoidea* or *Lampsilis hydiana*, exists in the Big Muddy basin.

Discussion

Our survey documented 19 species from the Big Muddy River basin, all were recorded live. No new species were found that had previously been undetected and six species previously detected were not found during our survey. Of these six species, only the plain pocketbook has

been documented as live in the basin. This species was found at three tributaries in the late 1990's to early 2000's; however these streams were not sampled during our survey. These sites would need to be surveyed to determine if this species is still present in the basin. Of the remaining five species not collected, deertoe and creeper have been documented only by relict shell, and the pink heelsplitter, pimpleback, and spike have not been documented since the late 1800's, early 1900's. All of these species were collected from the Big Muddy mainstem. These particular species, except for spike, are widespread and common throughout most of Illinois (Cummings and Mayer 1992) and all of these species are known from other major Mississippi River tributaries including the Rock, Illinois, and Kaskaskia Rivers (INHS Mollusk Collection Database). Sampling the mainstem of the Big Muddy was hindered by non-wadeable water depths; therefore additional sampling by alternative means would need to be conducted to determine if these species have indeed been extirpated from the basin.

Recruitment

Data collected during this survey indicate that very recent recruitment may not be occurring at most (25 of 30) sites in the Big Muddy basin. Only 3 of the 30 sites exhibited high to very high recruitment and 2 other sites had moderate recruitment noted. This finding suggests that most mussel communities of the Big Muddy may not be viable and self-maintaining. Although very few mussels collected during this basin survey fell into the category of 3 age rings or younger, many of them ranged from 4 to 10 years of age. This would indicate that the populations observed in most streams are within the age range thought to be reproductively active (Haag and Staton 2003). Therefore, we cannot conclusively state that the mussel communities of this system are void of recruitment. Recruitment may also be occurring on the Big Muddy mainstem near the Mississippi as nearly all of the dead shells found at site 30 were less than 3 years of age. Sampling methods to target juvenile mussels would be necessary to better assess the reproductive status of these populations.

Mussel community of the Big Muddy River basin

There is limited mussel community information relating to this basin from past surveys and reports. Nearly 90% of the sites sampled had no historical data available (Table 2), and there is no known intensive survey for mussels in this basin. Our surveys documented the existence of 19 species in the Big Muddy River basin from which 25 species were known historically. Additionally, our surveys found that all 19 species were represented by live individuals. Five of the six species not collected during this survey are represented by either relict shell or pre-1930 collections.

Other major Mississippi tributaries such as the Kaskaskia, Rock, and Illinois Rivers have a larger mussel fauna base according to historical records and recent surveys. Historically, these basins

contained 43, 47, and 49 species, respectively, while the Big Muddy has only 25 recorded species (Tiemann et al. 2007). Several theories could be offered on the disparity of species in this basin including the inability to conduct wadeable surveys, challenging diving conditions, lack of river access by vehicle, or the lack of suitable substrate composition for varying species. Substrates such as gravel, cobble, and boulder are practically nonexistent in the Big Muddy basin. As mentioned in the introduction, the substrate of the Big Muddy is predominately impervious clay, silt, and sand. The Big Muddy basin provides suitable substrates for many mussel species such as the giant floater, white heelsplitter, and other Anodontines. However, many species that occur in the other major Mississippi tributaries such as mucket (*Actinonaias ligamentina*), black sandshell (*Ligumia recta*), and threehorn wartyback (*Obliquaria reflexa*) prefer a mixture of substrate types including gravel, sand, and cobble (Cummings and Mayer 1992). Sedimentation and siltation of the streams in this basin may be another factor influencing the lack of these species. These factors are listed as impairments for aquatic life for many mainstem sites on the Big Muddy and several tributaries within the basin (IEPA 2010). With the lack of coarser substrates from the basin both today and historically, it may be safe to assume that many of these species have never existed in the basin. However, this statement cannot be made conclusively, due to a lack in historical information.

Living up to its name, sampling in the Big Muddy basin is challenging at best due to water depths (Big) and high turbidity (Muddy). The Big Muddy mainstem and many of its larger tributaries, such as Beaucoup and Drury Creeks, are not easily surveyed for freshwater mussels, thus it is difficult to accurately determine species richness of the basin. It is possible that the Big Muddy River provides a haven for the recruitment of many mussel species, based on the dead shells less than 3 years of age found at site 30, the nature of its substrates, and the river's connection with the Mississippi River. We are unable to conclusively state that the Big Muddy is serving as a source population for mussel species because of the lack of historical data and difficulty in sampling the basin. Additional sampling, either diving or boating to shallow areas on the lower portion of the mainstem and larger tributaries, would be needed to adequately determine the mussel fauna of this basin.

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Table1. 2009/2010 Big Muddy River Intensive Basin Survey. Types of samples include MU-mussel sampling, BE-boat electrofishing, ES-electric fish seine, SH-fish seine hauls, FF-fish flesh contaminate, H-habitat, M-macroinvertebrate, S-sediment, W-water chemistry. *Drury Creek Survey not completed due to water depth >3m.

Site Number	IEPA Code	Stream	Types of Samples	County	Location	Watershed Area (km^2)
1	NL-01	Snow Creek	MU, ES,H,M,S,W	Jefferson	6 mi NW Mt Vernon; Rd 1850N	49.60
2	N-05	Big Muddy River	MU, ES,H,M,S	Jefferson	1.5 mi NE Woodlawn Co Rd; 1450N	154.04
3	NK-02	Rayse Creek	MU	Jefferson	3.7 mi W Woodlawn; Rd 1400N	119.89
4	NJ-26	Casey Fork	MU	Jefferson	SE Mt Vernon; DNS Rt 142	196.87
5	NI-01	Gun Creek	MU, ES,H,M,S,W	Jefferson	3.3 mi E Ina	35.62
6	N-06	Big Muddy River	MU, BE,H,M,S,W	Franklin	Rt 14 Br; 3 mi W Benton	1287.86
7	NZN-15	Andy Creek	MU, ES,H,M,S,W	Franklin	Satch Road; 1.6 mi NE of Christopher	33.54
8	NHG-01	Akin Creek	MU, ES,H,M,S,W	Franklin	N Botail Road; 8.8 mi E of Benton	21.98
9	NH-23	Middle Fork	MU, BE,H,M,S	Franklin	2.2 mi SE Bent; Us Rt 34	329.47
10	NG-05	Pond Creek	MU, SH,H,M,S,W	Williamson	Liberty School Rd; 4.7 mi SE of West Frankfort	31.84
11	NGA-02	Lake Creek	MU, ES,H,M,S,W	Williamson	Co Rd 1200E; 0.3 mi S Johnston City	40.90
12	NF-01	Hurricane Creek	MU, ES,H,M,S,W	Williamson	4 mi WNW Herrin	60.67
13	NE-04	Little Muddy River	MU	Perry	Rt 14 Br; 2 mi E Old Duquoin	426.62
14	NEB-02	Reese Creek	MU, ES,H,M,S,W	Perry	2 mi E Duquoin on Park St	60.79
15	NE-05	Little Muddy River	MU, BE,H,M,S,W	Jackson	1.3 mi E of Elkville	684.39
16	ND-04	Crab Orchard Creek	MU, ES,H,M,S,W	Williamson	Rt 13 Br; E edge of Marion	82.52
17	NDJ-01	Wolf Creek	MU, ES,H,M,S,W	Williamson	E Rt 148; old railroad	44.74
18	NDD-03	Grassy Creek	MU, ES,H,M,S,W	Williamson	At Wolf Creek Rd	14.84
19	NDDA-01	Little Grassy	MU, ES,H,M,S,W	Williamson	6 mi SSW Carterville	47.11
20	NDC-99*	Drury Creek	ES,H,M,S,W	Jackson	0.2 mi US Makanda business dist	47.29
21	NDCB-01	Indian Creek	MU, ES,H,M,S,W	Jackson	2.5 mi NE Makanda	14.01
22	NDCA-01	Sycamore Creek	MU, ES,H,M,S,W	Jackson	2 mi E of Boskydell	5.27
23	ND-01	Crab Orchard Creek	MU, BE,H,M,S,W	Jackson	4 mi NE Carbondale	693.93
24	NCK-02	Swanwick Creek	MU, ES,H,M,S,W	Perry	Misty Road; 5.8 mi NW of Pinckneyville	117.41
25	NCI-01	Little Beaucoup Creek	MU, ES,H,M,S,W	Perry	6 mi NNE Pinckneyville	46.96
26	NCDB-01	Little Galum Creek	MU, SH,H,M,S,W	Perry	Galum Cr Rd; 0.5 mi N Pyramid St	30.47
27	NZL-01	Mud Creek	MU, ES,H,M,S,W	Jackson	West Lake Road; 2.1 mi SE of Muphysboro	25.54
28	NAC-02	Cave Creek	MU, ES,H,M,S,W	Jackson	Jerusalem Hill Road; 0.2 mi W of Ponoma	15.24
29	NA-03	Cedar Creek	MU, ES,H,M,S	Jackson	1 mi S Brewer School on Dutch Ridge	80.38
30	N-99	Big Muddy River	MU, BE,H,M,S	Jackson	5 mi E Grandtower at Rattlesnake Ferry	6064.97

R00636

Table 2. Mussel data for sites sampled during 2009/2010 surveys (Table 1). Numbers in columns are live individuals collected; "D" and "R" indicates dead or relict shells collected. Shaded boxes are historic collections at the specific site location obtained from the INHS Mollusk Collection records. Species in bold are federally or state-listed species or species in Greatest Need of Conservation by IL DNR. Proportion of total is number of individuals of a species divided by total number of individuals at all sites. Extant species is live + dead shell and total species is live + dead + relict shell. NDA represents no historical data available. MCI scores and Resource Classification are based on values in Tables 3 and 4 (R= Restricted, L= Limited, M= Moderate, HV= Highly Valued, and U= Unique). *Includes *Strophitus undulatus*, *Elliptio dilatata*, *Quadrula pustulosa*, *Lampsilis cardium*, *Potamilus alatus*, and *Truncilla donaciformis*, historical species not collected during this survey.

	Site Number																						Proportion of Total
	1	2	3	5	6	7	9	11	13	14	15	16	17	19	23	24	25	26	27	28	29	30	
Anodontinae																							
Anodonta suborbiculata					1		2				D												1%
Arcidens confragosus											4				D							D	1%
Lasmigona complanata					19					1	9				1						4		9%
Pyganodon grandis		12	1	R	30		23	2	2	21	19	R	D	12	D	D			1		8	D	37%
Strophitus undulatus																							0%
Utterbackia imbecillis	1	1			D		3				1										2	D	2%
Ambleminae																							
Amblema plicata		1			4				1		3												3%
Elliptio dilatata																							0%
Fusconaia flava					1																		0%
Megalonaias nervosa					16										1								5%
Quadrula pustulosa																							0%
Quadrula quadrula					26				2		6				3								10%
Tritogonia verrucosa					1																		0%
Uniomerus tetralasmus	1	R				2				1							2	D	R	1			2%
Lampsilinae																							
Lampsilis cardium																							0%
Lampsilis siliquoidea (hydiana)		3														D							1%
Lampsilis teres					4						4				1						5		4%
Leptodea fragilis					8				1	1	D				1							D	3%
Ligumia subrostrata	4	4	2									R		4									4%
Potamilus alatus																							0%
Potamilus ohiensis					19						1											D	6%
Toxolasma parvum	16	3	3											1							1		7%
Toxolasma texasiensis	1	5	D			4	D			D													3%
Truncilla donaciformis																							0%
Truncilla truncata					4										6								3%
																							Total
Individuals	23	29	6	0	133	6	28	2	6	24	47	0	0	17	13	0	2	0	1	1	20	0	358
Live Species	5	7	3	0	12	2	3	1	4	4	8	0	0	3	6	0	1	0	1	1	5	0	19
Extant Species	5	7	4	0	13	2	4	1	4	5	10	0	1	3	8	2	1	1	1	1	5	5	19
Total Species	5	9	4	1	13	2	4	1	4	5	10	2	1	3	8	2	1	1	2	1	5	5	19
Historical Species	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	2	NDA	NDA	NDA	1	NDA	NDA	1	6	25*
Catch per unit effort (CPUE)	5.76	7.02	1.50	0.00	33.33	1.50	6.97	0.50	1.50	6.00	11.78	0.00	0.00	4.25	3.25	0.00	0.50	0.00	0.25	0.25	5.00	0.00	
Mussel Community Index (MCI)	10	10	7	0	11	10	10	4	7	7	10	0	0	6	8	0	4	0	4	4	9	0	
Resource Classification	M	M	L	R	M	M	M	R	L	L	M	R	R	L	M	R	R	R	R	R	M	R	

R00637



Figure 2. Big Muddy near Benton, Illinois (Site 6). Note excessive sedimentation and turbidity of river. Alison Price and A. J. Berger measuring mussels sunk up to thighs and waist in silt.



Figure 3. Casey Fork near Mt. Vernon, Illinois (Site 4). Note large woody debris in stream, silt/clay banks, and turbidity of river.

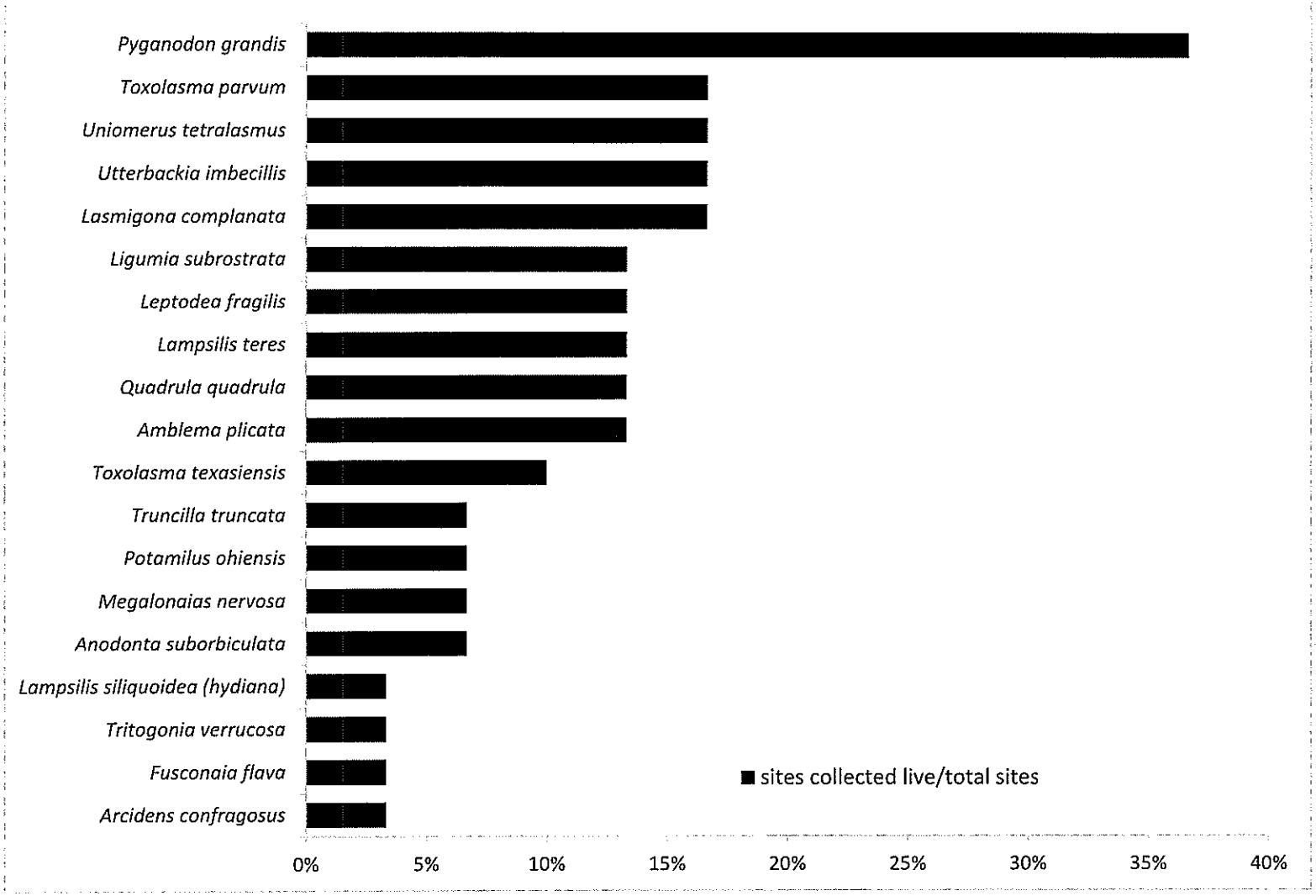


Figure 4. Number of sites where a species was collected live compared to the number of total sites sampled (30 total sites).

R00639

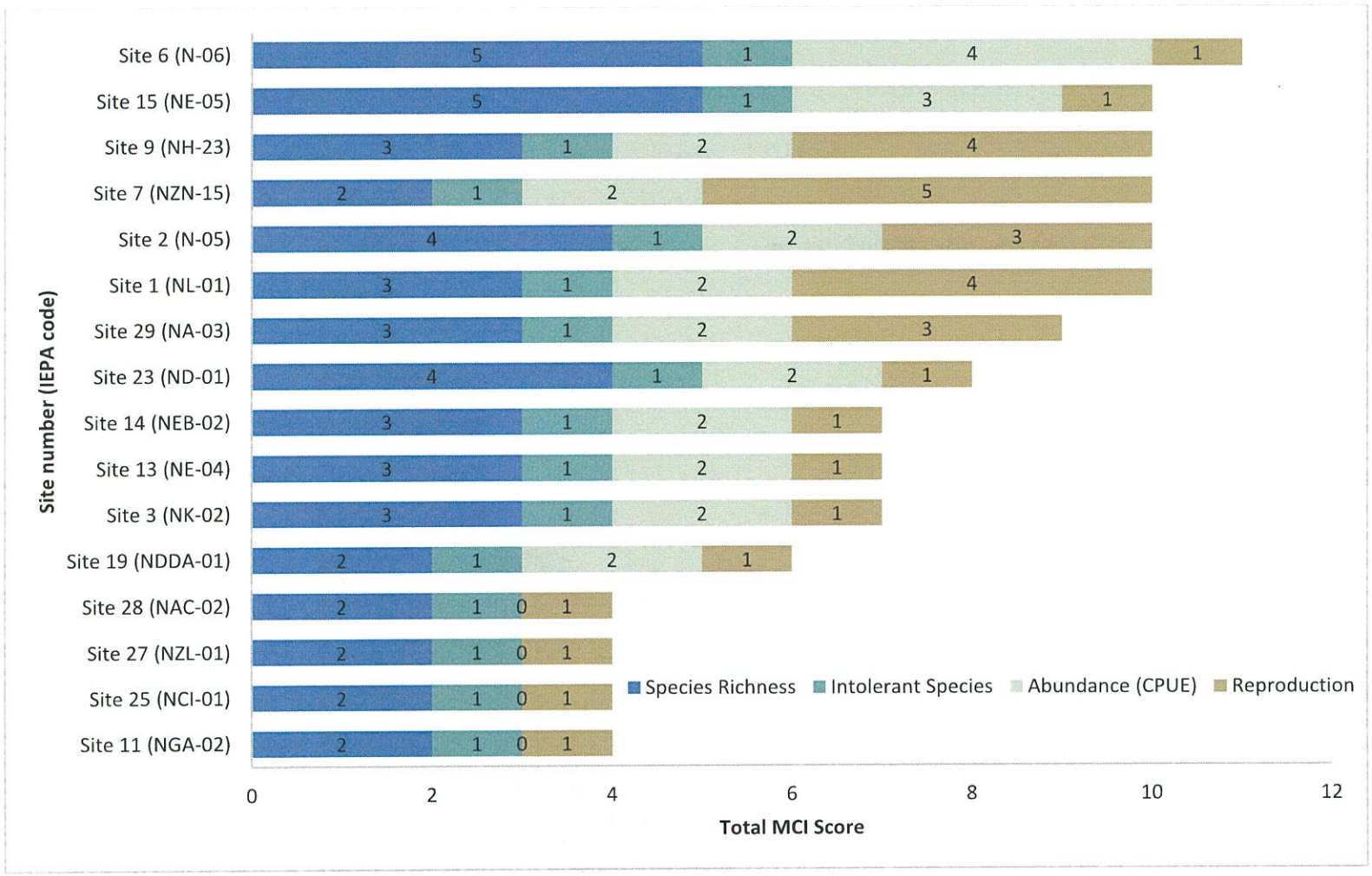


Figure 5. Comparison of Mussel Community Index (MCI) and MCI component scores for Big Muddy River basin sites based on factor values from Table 3.

R00640

Appendix 1. Scientific and common names of species. ST= state threatened.

Scientific Name	Common Name	Status
	Subfamily Anodontinae	
Anodonta suborbiculata	flat floater	
Arcidens confragosus	rock pocketbook	
Lasmigona complanata	white heelsplitter	
Pyganodon grandis	giant floater	
Strophitus undulatus	creeper	
Utterbackia imbecillis	paper pondshell	
	Subfamily Ambleminae	
Amblema plicata	threeridge	
Elliptio dilatata	spike	ST
Fusconaia flava	Wabash pigtoe	
Megalonaias nervosa	washboard	
Quadrula pustulosa	pimpleback	
Quadrula quadrula	mapleleaf	
Tritogonia verrucosa	pistolgrip	
Uniomerus tetralasmus	pondhorn	
	Subfamily Lampsilinae	
Lampsilis cardium	plain pocketbook	
Lampsilis siliquoidea hydiana	Louisiana fatmucket	
Lampsilis teres	yellow sandshell	
Leptodea fragilis	fragile papershell	
Ligumia subrostrata	pondmussel	
Potamilus alatus	pink heelsplitter	
Potamilus ohiensis	pink papershell	
Toxolasma parvum	lilliput	
Toxolasma texasiensis	Texas lilliput	
Truncilla donaciformis	fawnsfoot	
Truncilla truncata	deertoe	

2445-16-B
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AquAeTer

optimizing
resources | water, air, earth

MEMORANDUM

TO: **James Plumley**
CC: Clayton Cross
FROM: John Michael Corn, P.E. (TN)
DATE: January 17, 2020
JOB NO.: 192590
RE: **Updated CORMIX Model Results**

AquAeTer previously submitted a mixing zone report detailing the conceptual diffuser design for the proposed diffuser on the Big Muddy River. At that time, we utilized the data available to us from the USGS Plumfield gage for the channel geometry. An additional consideration for the diffuser design was the amount of debris carried by the River. During one of our reconnaissance trips on the stream, we could not access the current location from the USGS gage site due to a log jam. For that reason, we wanted to keep the ports as low as possible to reduce the possibilities of log strikes, both from the standpoint of reducing the risk of damage to the ports and to reduce the risk of log jams forming at the diffuser.

Prior to the Public Comment Period, Mr. Scott Thwaite of the Illinois Environmental Protection Agency (IEPA) requested that we revise the modeling to reduce bottom attachment.

MODEL RESULTS

The model results are shown in Table 1. The changes made to the model will be discussed in further detail in the section following this one. For most cases, Case 1 maximum flow being the exception, the distances required to achieve the necessary dispersion of 34.0:1 were shorter than those reported in the Mixing Zone Report. The Case 1 maximum flow scenario required approximately ten feet further downstream to meet 34:1. For all cases, the cross-sectional area of the plume(s) was(were) less than 25% of the cross-sectional area of the River.

In looking that the independent calculations, the plume from each port is expected to be stable. This means that the plumes will emanate from the port and expand outward in a bell-shaped geometry. This is important to keep in mind since CORMIX uses rectangular shapes for all model subsections after the initial jet zone.

Table 1. Model Results

SCENARIO	RIVER FLOW (cfs)	ACTIVE PORT(S)	TOTAL DISCHARGE (gpm)
Case 1, Min.	30	Port 1	102
Case 1, Max.	>=116	Port 1	396
Case 2, Min.	117	Ports 1 & 2	396
Case 2, Max.	>=233	Ports 1 & 2	793
Case 3, Min.	234	Ports 1, 2, & 3	793
Case 3, Max.	>=440	Ports 1, 2, & 3	1,499
Case 4, Min.	441	Ports 1, 2, 3, & 4	1,499
Case 4, Max.	>=906	Ports 1, 2, 3, & 4	3,085
Case 5, Min.	907	Ports 1, 2, 3, 4, & 5	3,085
Case 5, Max.	>=1,734	Ports 1, 2, 3, 4, & 5	5,905

SCENARIO	ACTIVE PORT(S)	ACUTE ZONE DISTANCE (ft)	ORIGINAL PREDICTED TOTAL MIXING ZONE DISTANCE (ft)	REVISED PREDICTED TOTAL MIXING ZONE DISTANCE (ft)
Case 1, Min.	Port 1	7.1	50	35
Case 1, Max.	Port 1	5.8	37	47
Case 2, Min.	Ports 1 & 2	4.4	36.6	36.6
Case 2, Max.	Ports 1 & 2	6.9	88	88
Case 3, Min.	Ports 1, 2, & 3	11.2	46	46
Case 3, Max.	Ports 1, 2, & 3	9.3	116	116
Case 4, Min.	Ports 1, 2, 3, & 4	13.9	176	176
Case 4, Max.	Ports 1, 2, 3, & 4	11.4	147	147
Case 5, Min.	Ports 1, 2, 3, 4, & 5	18.2		231.8
Case 5, Max.	Ports 1, 2, 3, 4, & 5	14.5		251

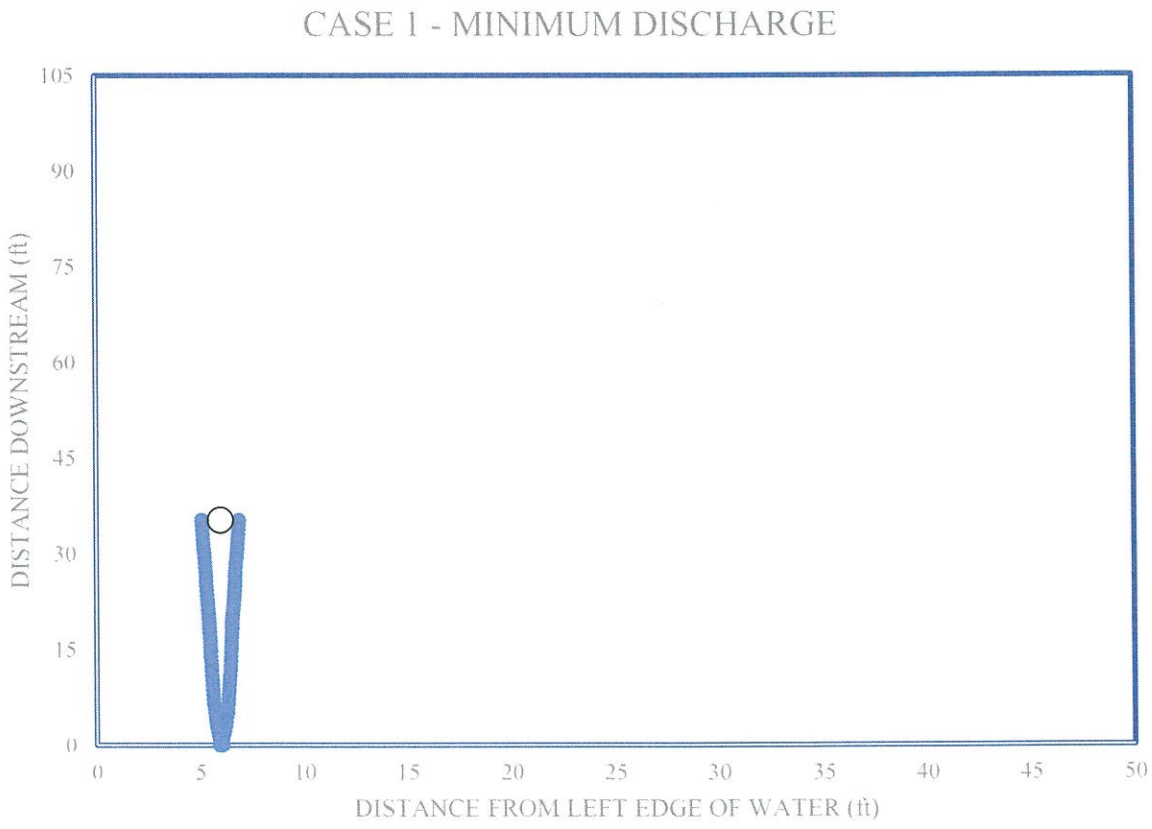
The results for each case will be discussed in more detail below, along with providing the graphics of the plan and profile views of the plume(s) for each Case.

Case 1 – 1st Port Only

Case 1 incorporates the minimum allowable flow based on the lowest projected flow for the Big Muddy River at the proposed diffuser location. Only the first port will be discharging during this condition. The discharge during this condition is 102 gallons per minute, which is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 1. The plan and profile for the maximum discharge condition under Case 1 are provided in Figure 2. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations.

Figure 1 Plan and Profile of the Model for Case 1 – Minimum Flow Condition



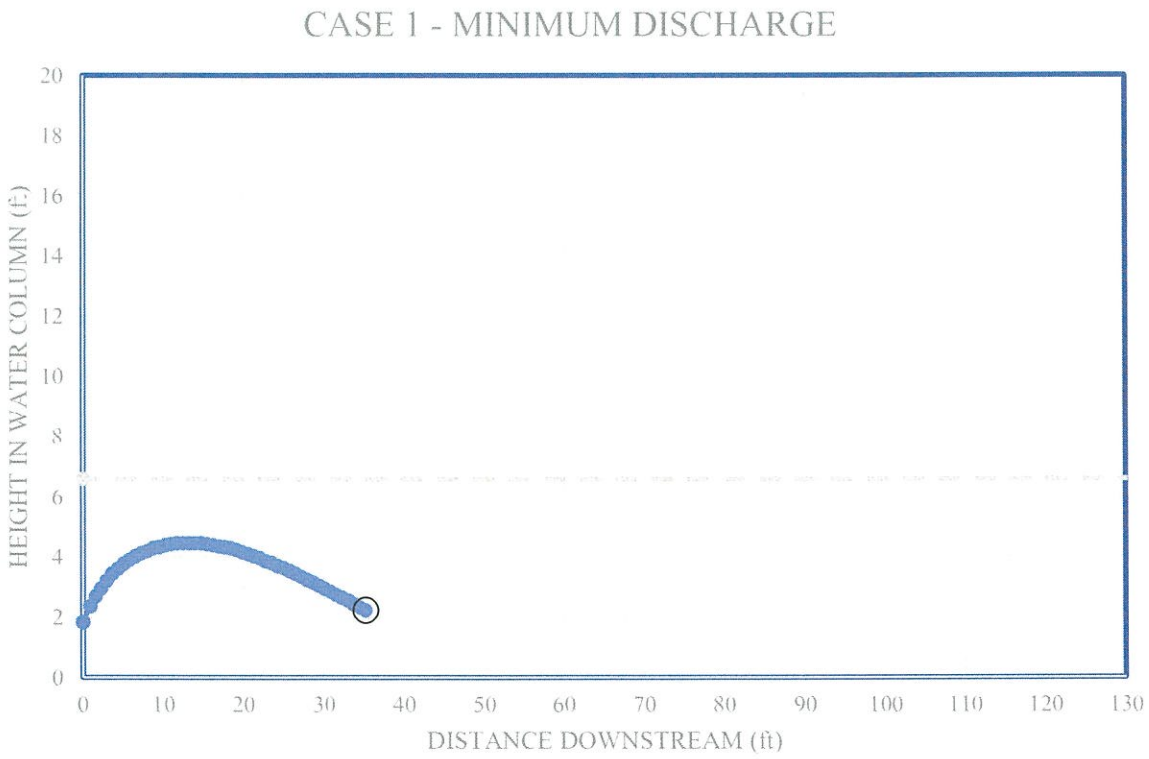
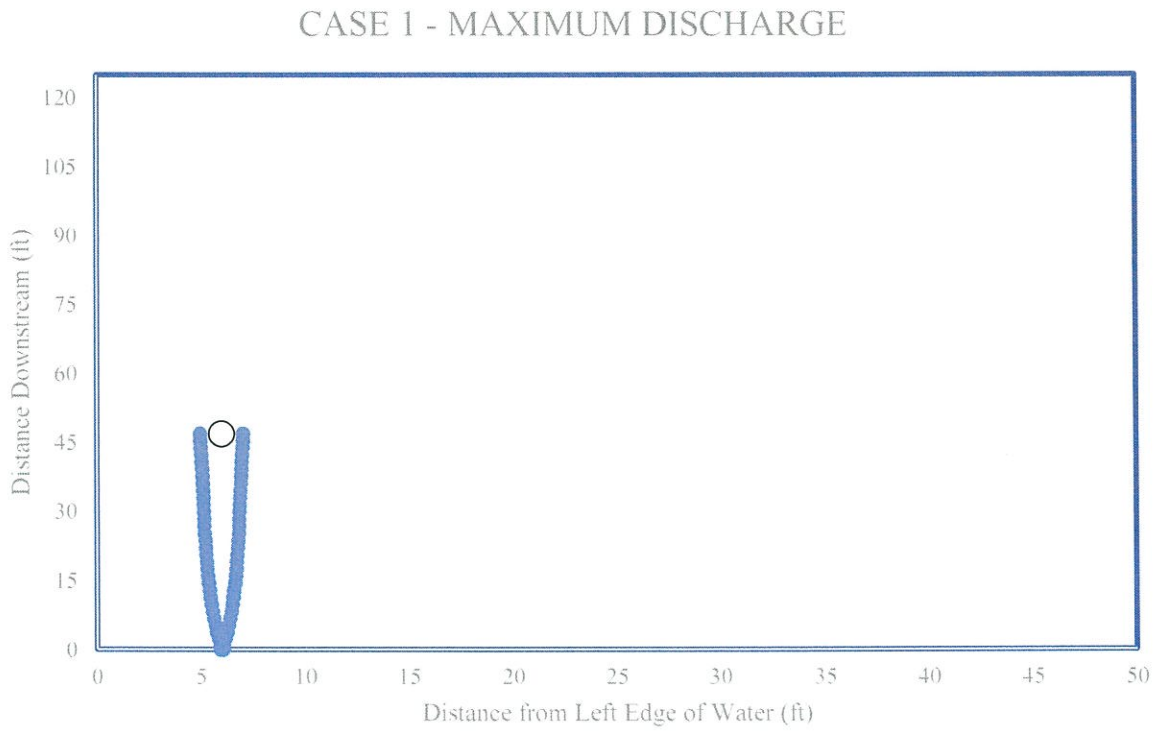
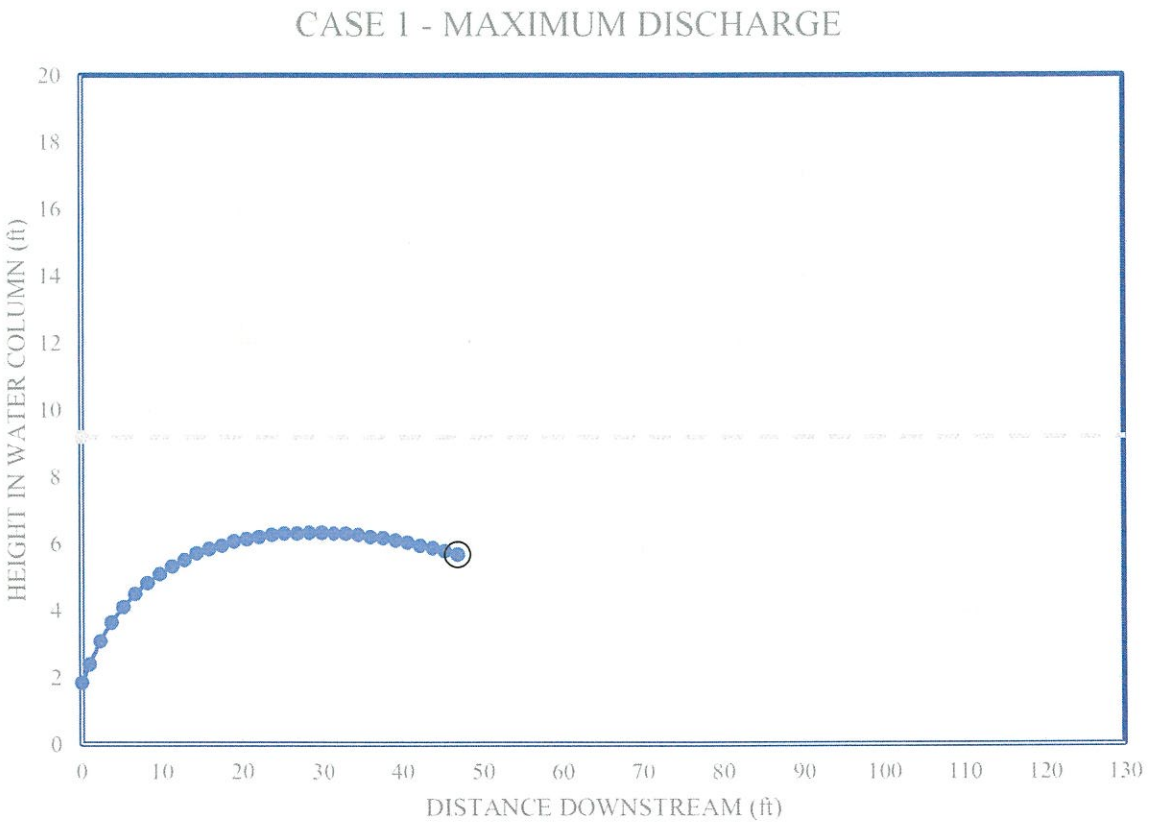


Figure 2. Plan and Profile of the Model for Case 1 – Maximum Flow Condition





These two scenarios represent the minimum and maximum flow conditions for Port 1 when only the first port is discharging. This occurs at lower River flows. The water quality criteria will be met at all flow conditions. For each of these cases, the plumes are less than 4% of the cross-sectional area.

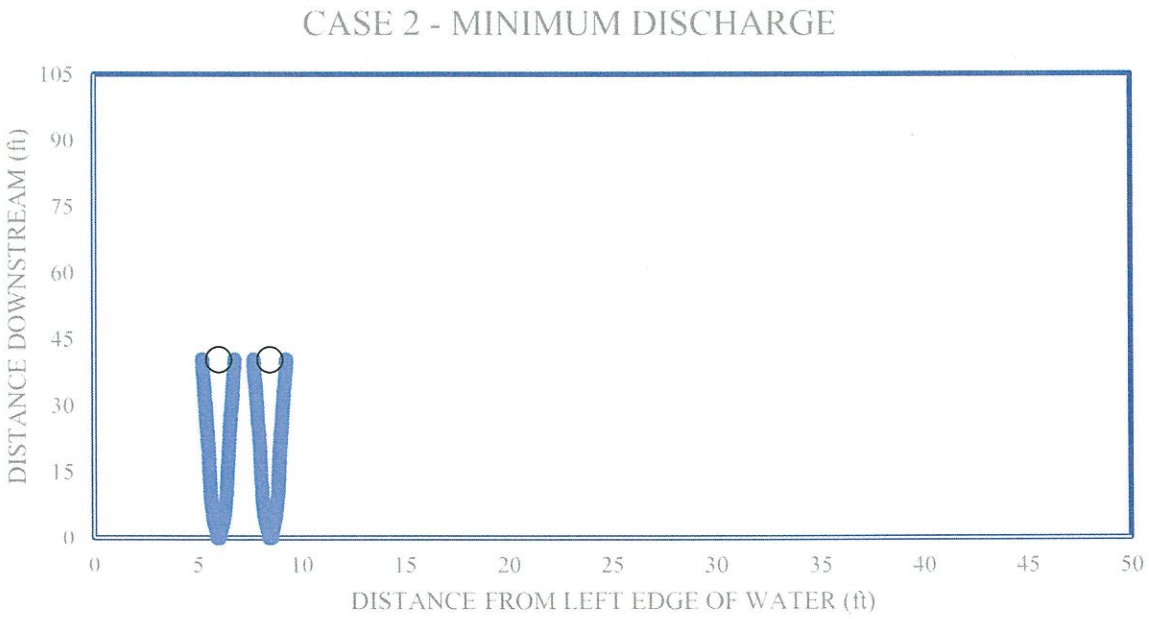
Case 2 – 1st and 2nd Ports Discharging

Case 2 begins at the maximum discharge for Case 1. Once the flow condition is met, the discharge is converted from the maximum discharge through Port 1 to equal discharges through Ports 1 and 2. In other words, the flows through Ports 1 and 2 at the Case 2 minimum flow condition are equivalent to the maximum discharge from Port 1 at Case 1. As with Case 1, the discharge during this condition is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 3. The plan and profile for the maximum discharge condition under Case 2 are provided in Figure 4. The profile picture appears as one line since the ports are equal. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations. For the minimum flow

condition, the plumes remain separate. For the maximum flow condition, the plumes merge near the point of meeting the water quality criteria.

Figure 3. Plan and Profile of the Model for Case 2 – Minimum Flow Condition



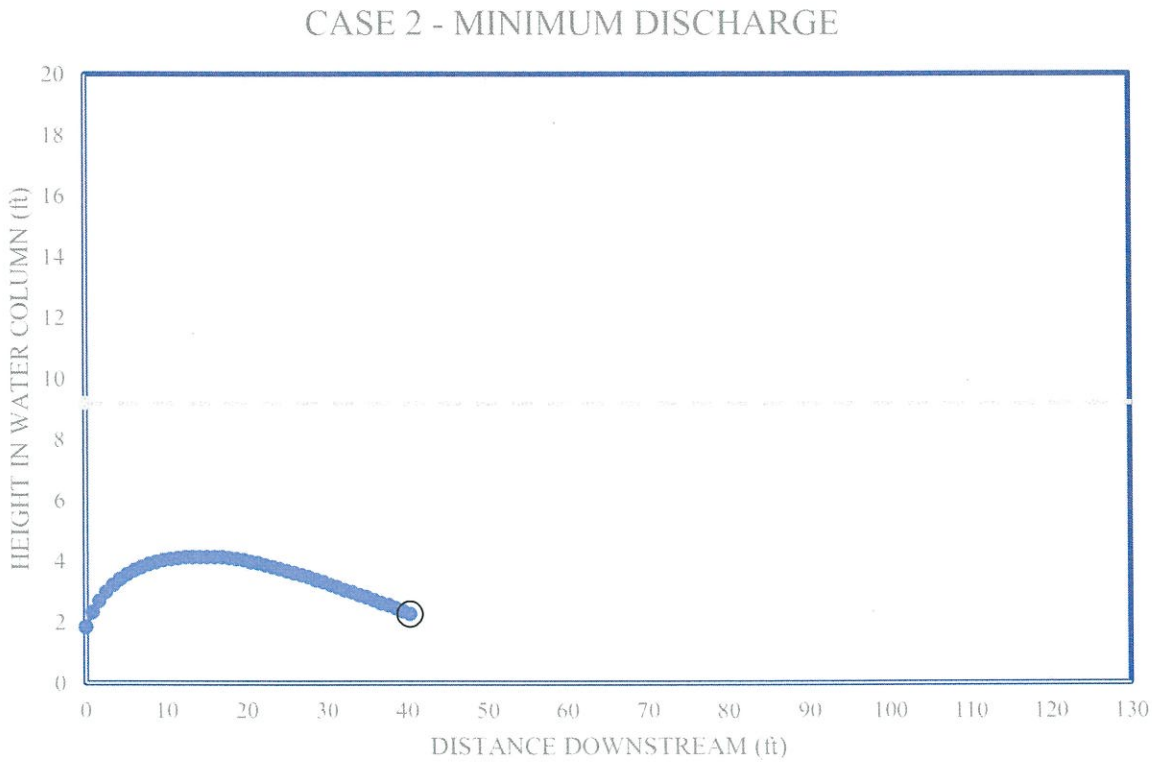
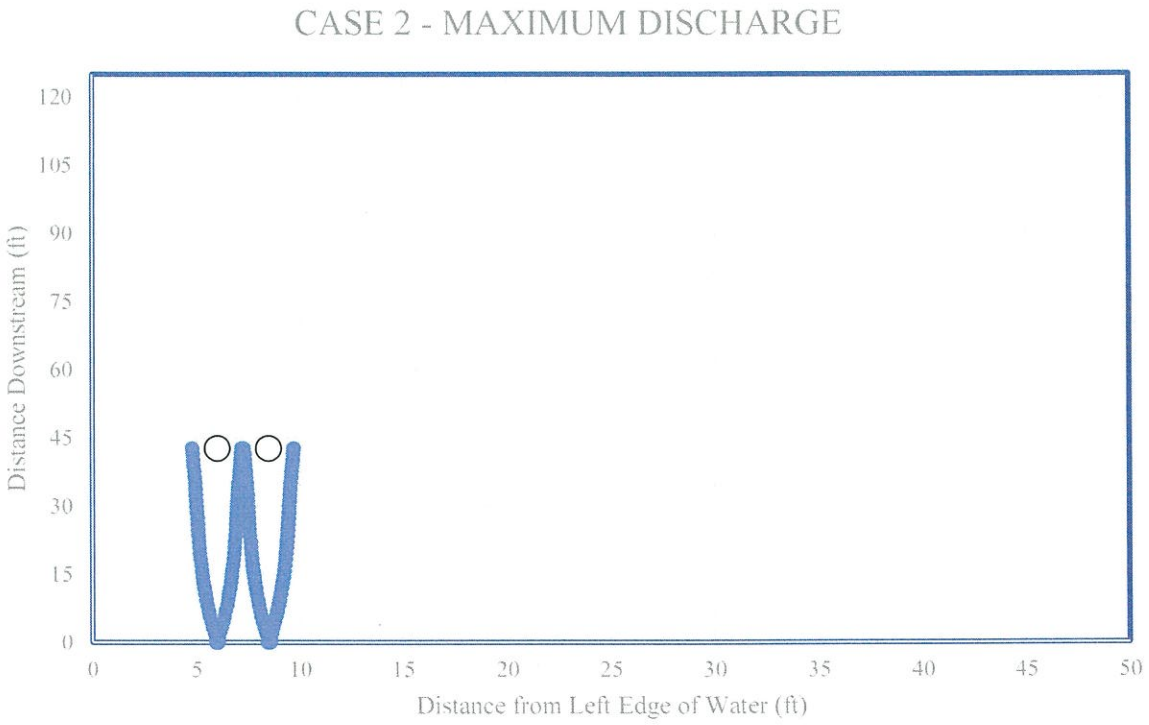
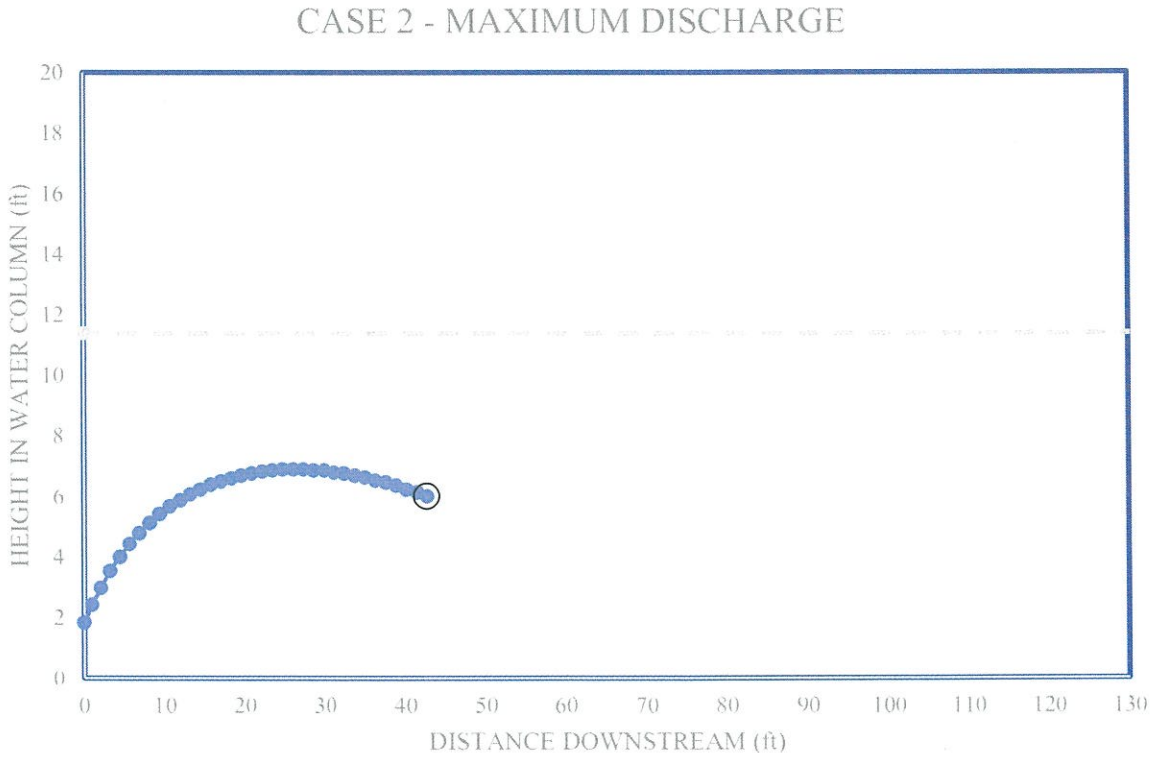


Figure 4. Plan and Profile of the Model for Case 2 – Maximum Flow Condition





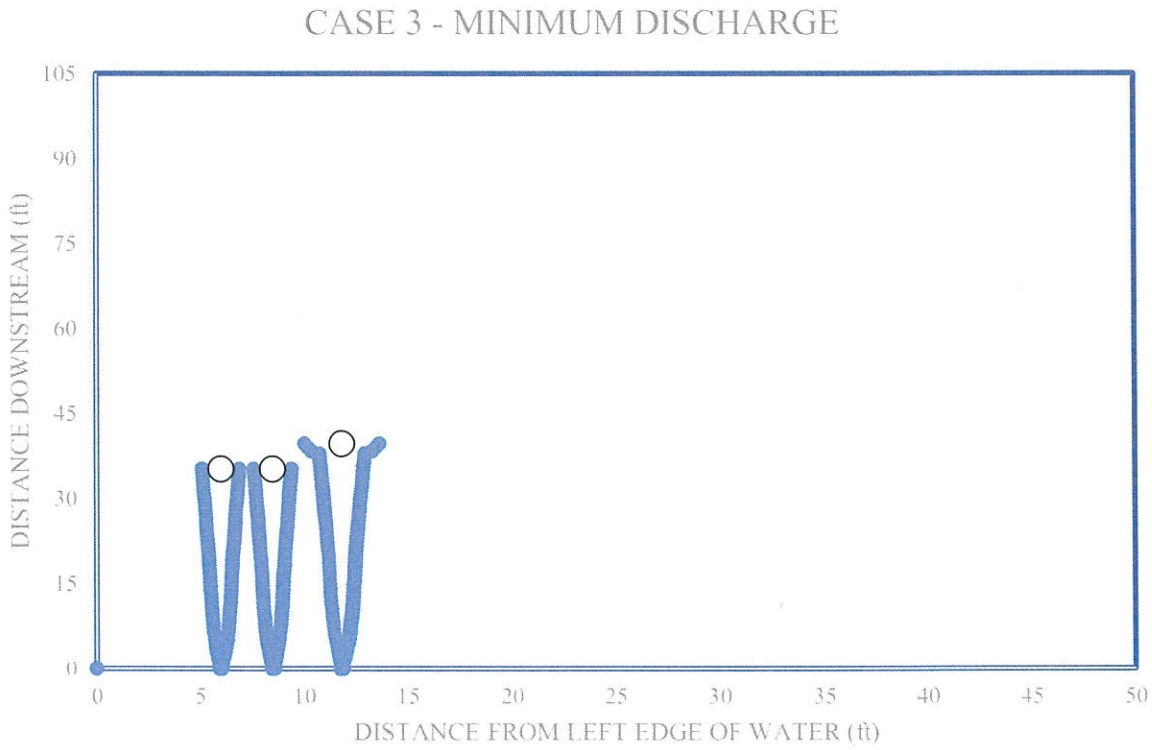
The water quality criteria will be met at all flow conditions for Case 2. For each of these scenarios, the plumes are less than 3% of the cross-sectional area. The calculation of the cross-sectional area accounts for both plumes at the point of meeting the water quality standard.

Case 3 – 1st, 2nd and 3rd Ports Discharging

Case 3 begins at the maximum discharge for Case 2. Once the flow condition is met, the discharge is converted from the maximum discharge through Ports 1 and 2 to discharges through Ports 1, 2 and 3. In other words, the flows through Ports 1, 2 and 3 at the Case 3 minimum flow condition are equivalent to the maximum discharge from Ports 1 and 2 at Case 2. As with Case 2, the discharge during this condition is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 5. The plan and profile for the maximum discharge condition under Case 3 are provided in Figure 6. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations.

Figure 5. Plan and Profile of the Model for Case 3 – Minimum Flow Condition



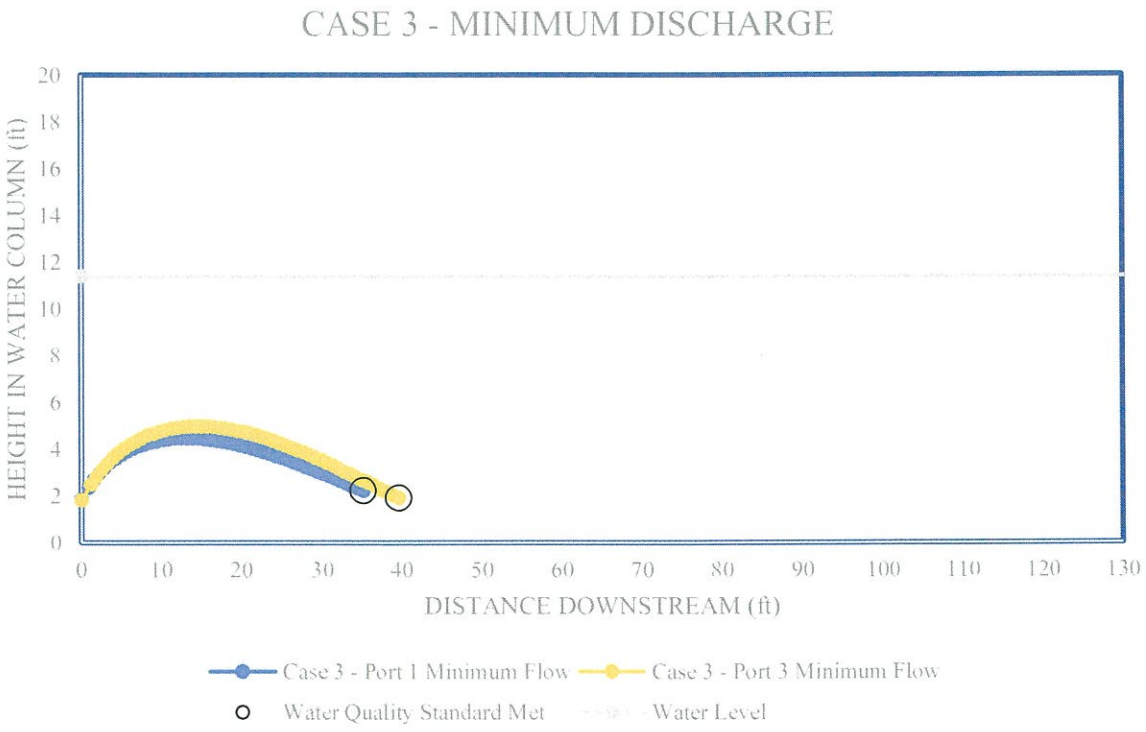
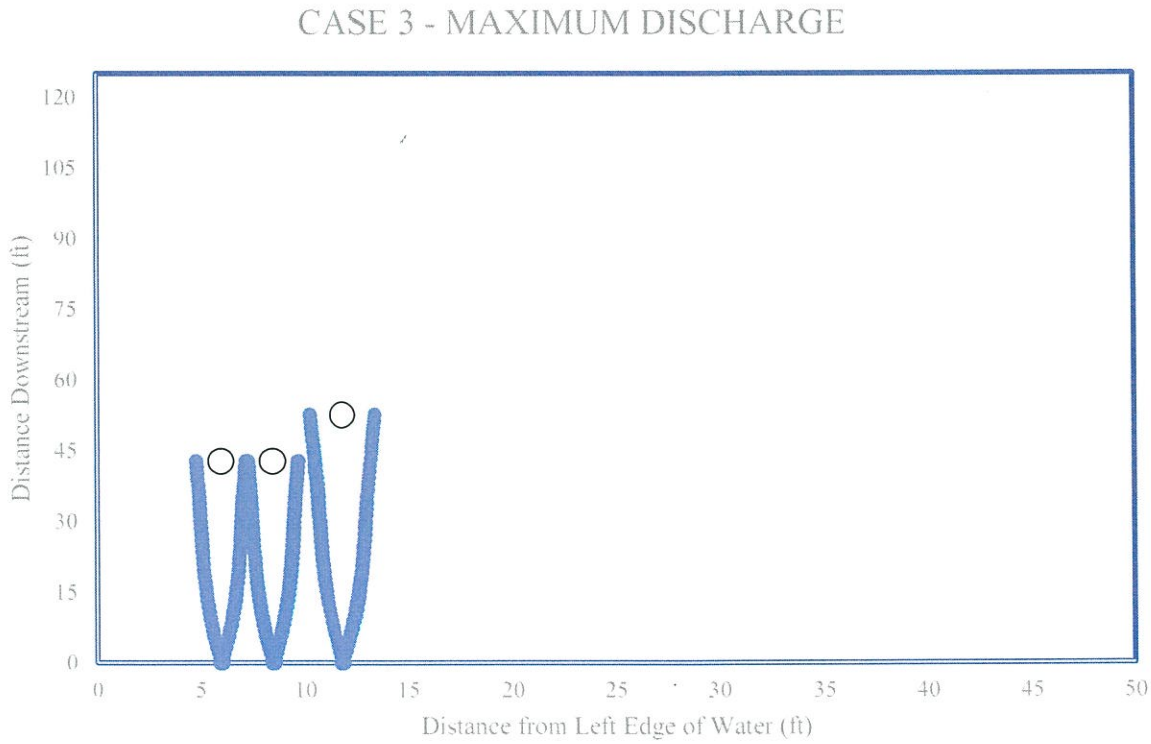
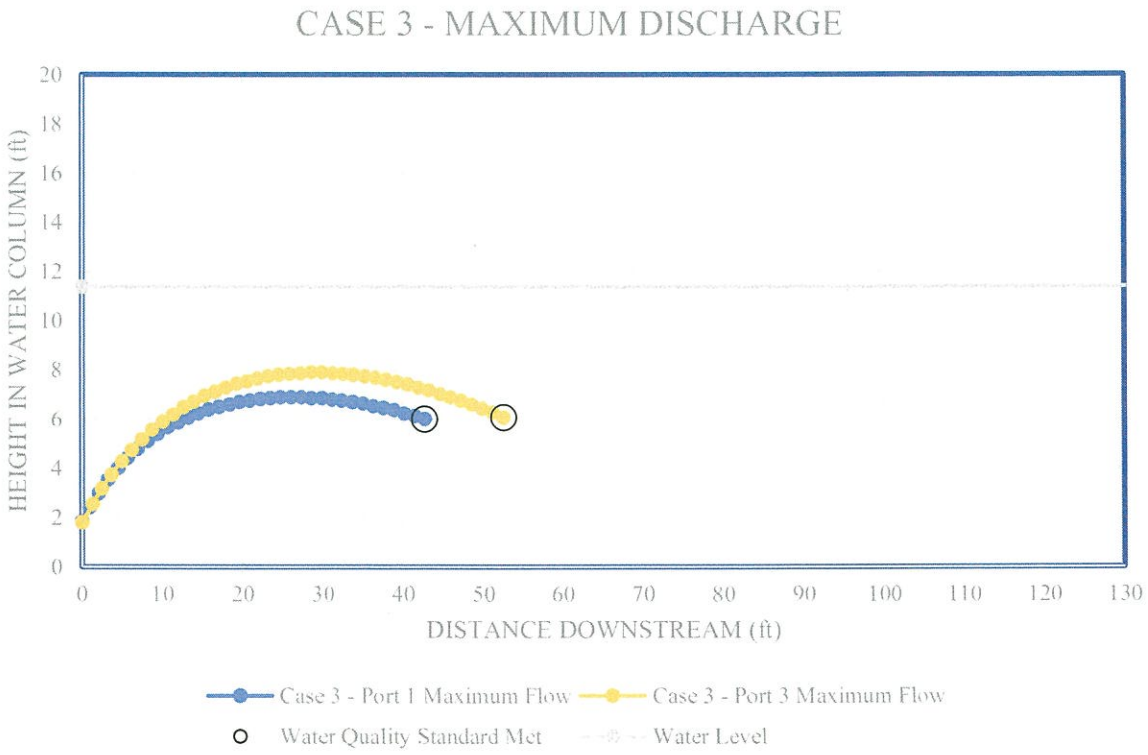


Figure 6. Plan and Profile of the Model for Case 3 – Maximum Flow Condition





The water quality criteria will be met at all flow conditions for Case 3. For each of these scenarios, the plumes are less than 6% of the cross-sectional area. Due to the staggered and unequal flow conditions for the ports after Port 2, the water quality criteria are met at different distances downstream. Ports 1 and 2 have been predicted to have the shortest distances. For those cases in which ports 3, 4, and/or 5 are discharging, the total mixing zone for each part includes the cross-sectional areas for each port.

Case 4 – 1st, 2nd, 3rd and 4th Ports Discharging

Case 4 begins at the maximum discharge for Case 3. Once the flow condition is met, the discharge is converted from the maximum discharge through Ports 1, 2 and 3 to discharges through Ports 1, 2, 3 and 4. In other words, the flows through Ports 1, 2, 3 and 4 at the Case 4 minimum flow condition are equivalent to the maximum discharge from Ports 1, 2, and 3 at Case 3. As with the previous cases, the discharge during this condition is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 7. The plan and profile for the maximum discharge condition under Case 4 are provided in Figure 8. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations.

Figure 7. Plan and Profile of the Model for Case 4 – Minimum Flow Condition

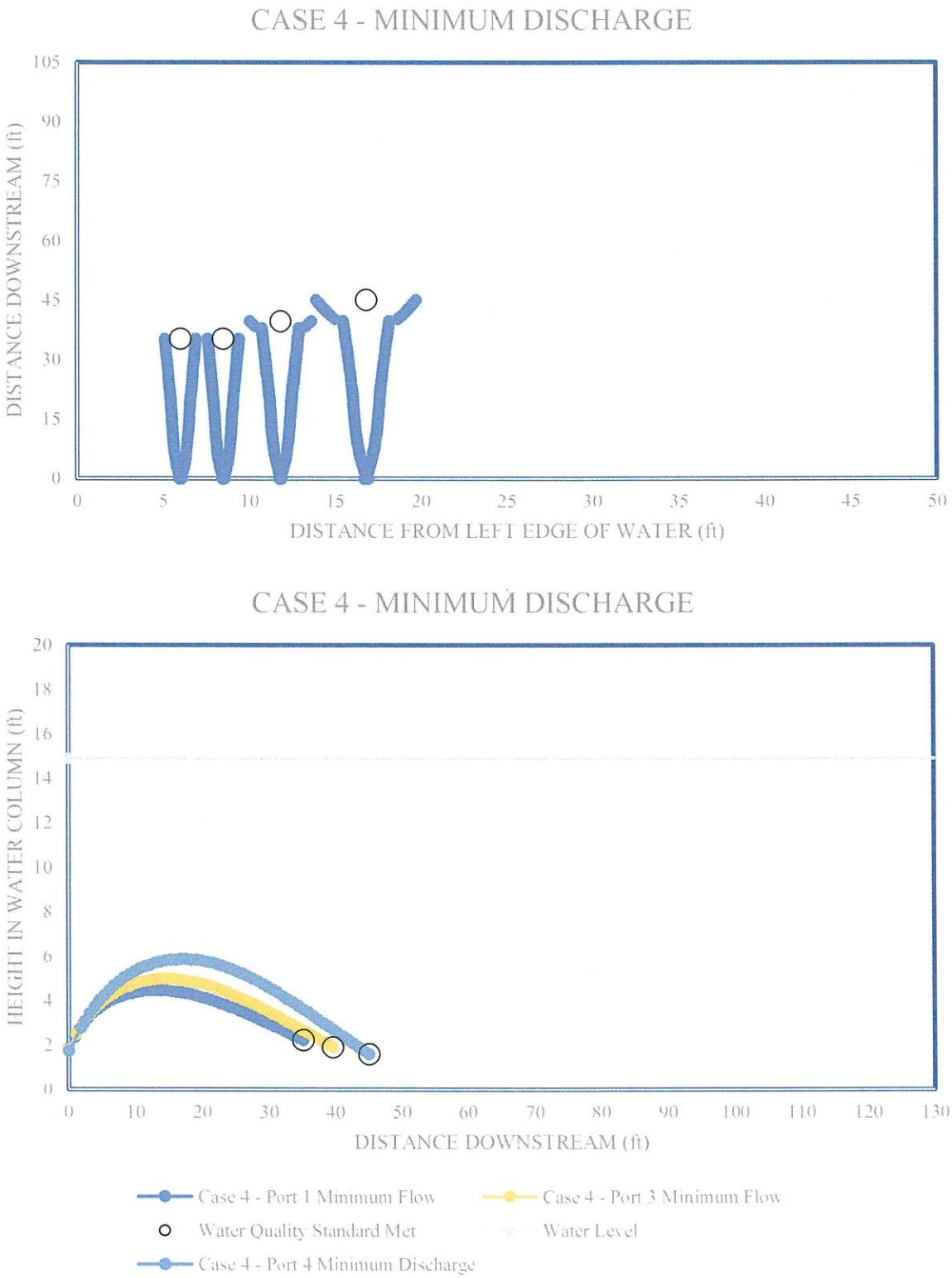
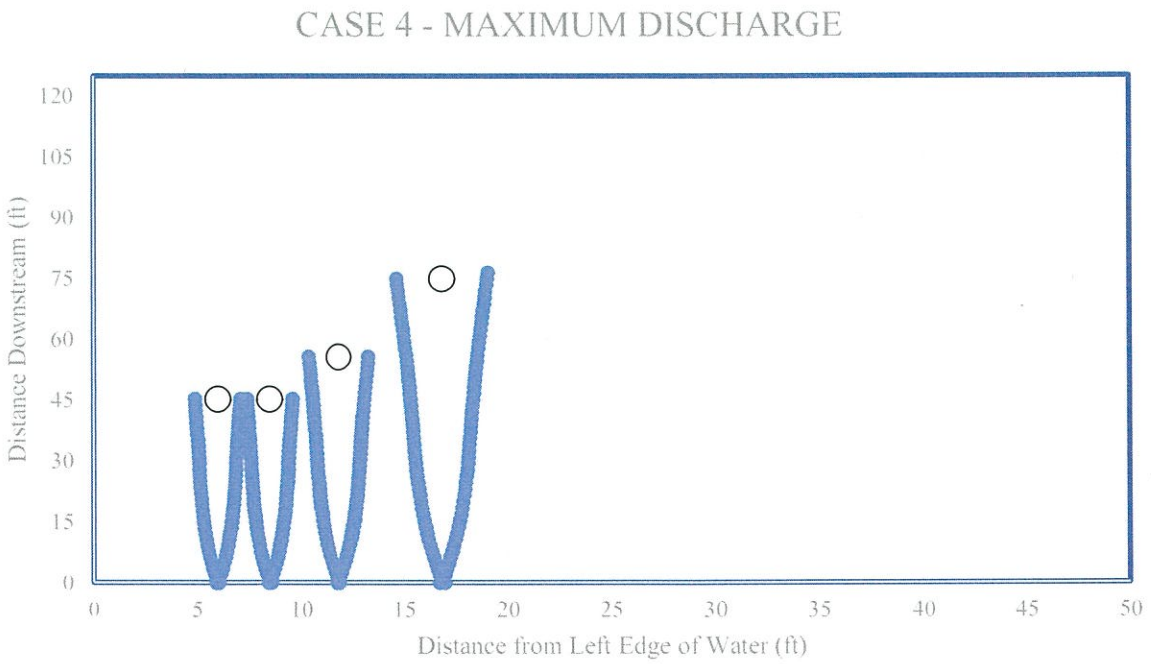
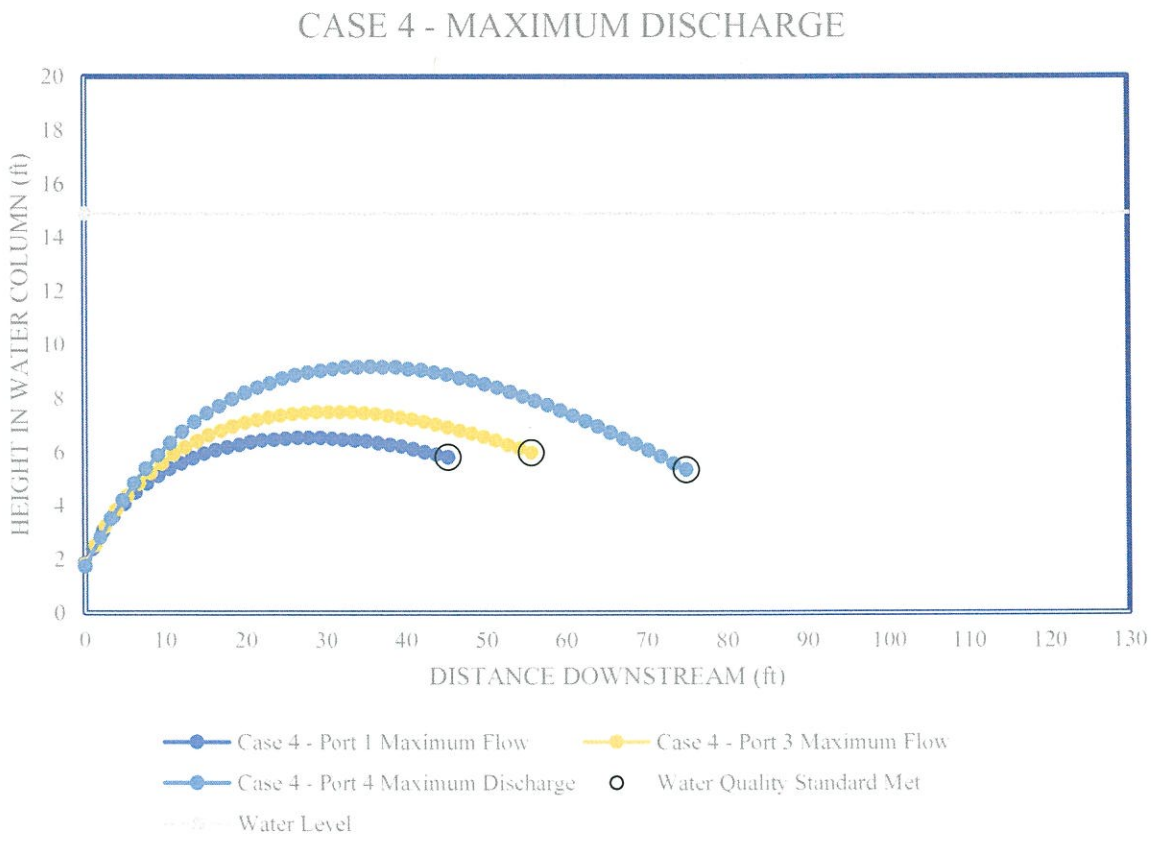


Figure 8. Plan and Profile of the Model for Case 4 – Maximum Flow Condition





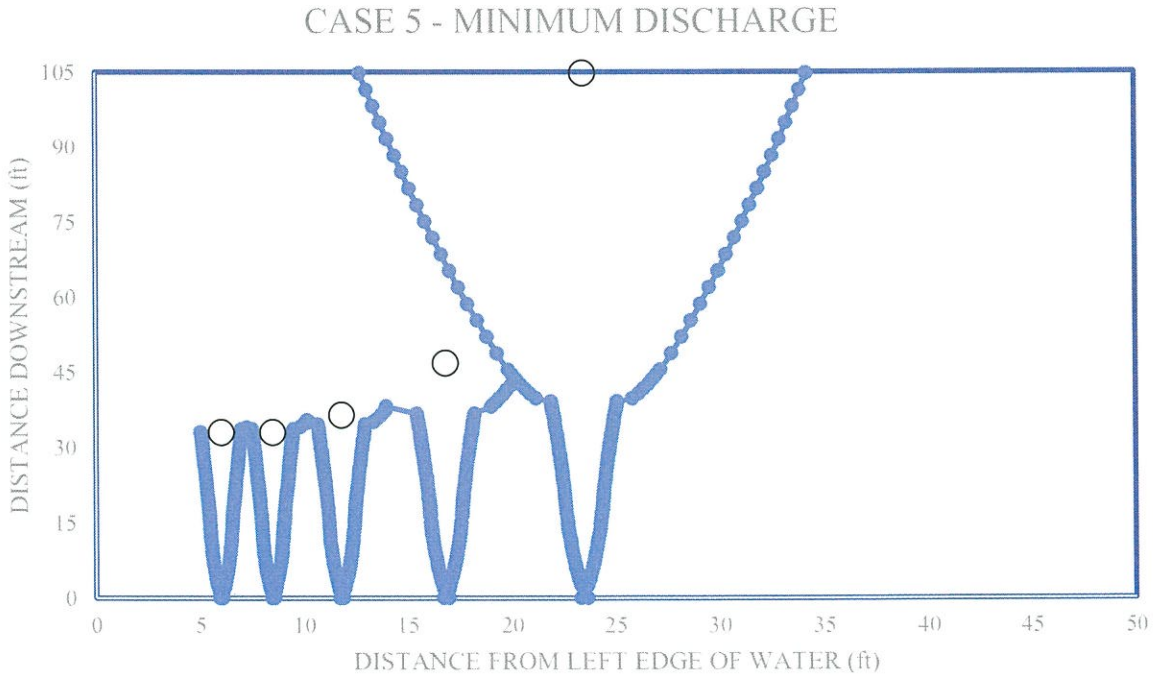
The water quality criteria will be met at all flow conditions for Case 4. For each of these scenarios, the plumes are less than 8% of the cross-sectional area. Due to the staggered and unequal flow conditions for the ports after Port 2, the water quality criteria are met at different distances downstream. Ports 1 and 2 have been predicted to have the shortest distances. For those cases in which ports 3, 4, and/or 5 are discharging, the total mixing zone for each part includes the cross-sectional areas for each port at the distance met by the respective port.

Case 5 – 1st, 2nd, 3rd, 4th and 5th Ports Discharging

Case 5 begins at the maximum discharge for Case 4. Once the flow condition is met, the discharge is converted from the maximum discharge through Ports 1, 2, 3 and 4 to discharges through Ports 1, 2, 3, 4 and 5. In other words, the flows through Ports 1, 2, 3, 4 and 5 at the Case 5 minimum flow condition are equivalent to the maximum discharge from Ports 1, 2, 3 and 4 at Case 4. As with the previous cases, the discharge during this condition is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 9. The plan and profile for the maximum discharge condition under Case 5 are provided in Figure 10. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations.

Figure 9. Plan and Profile of the Model for Case 5 – Minimum Flow Condition



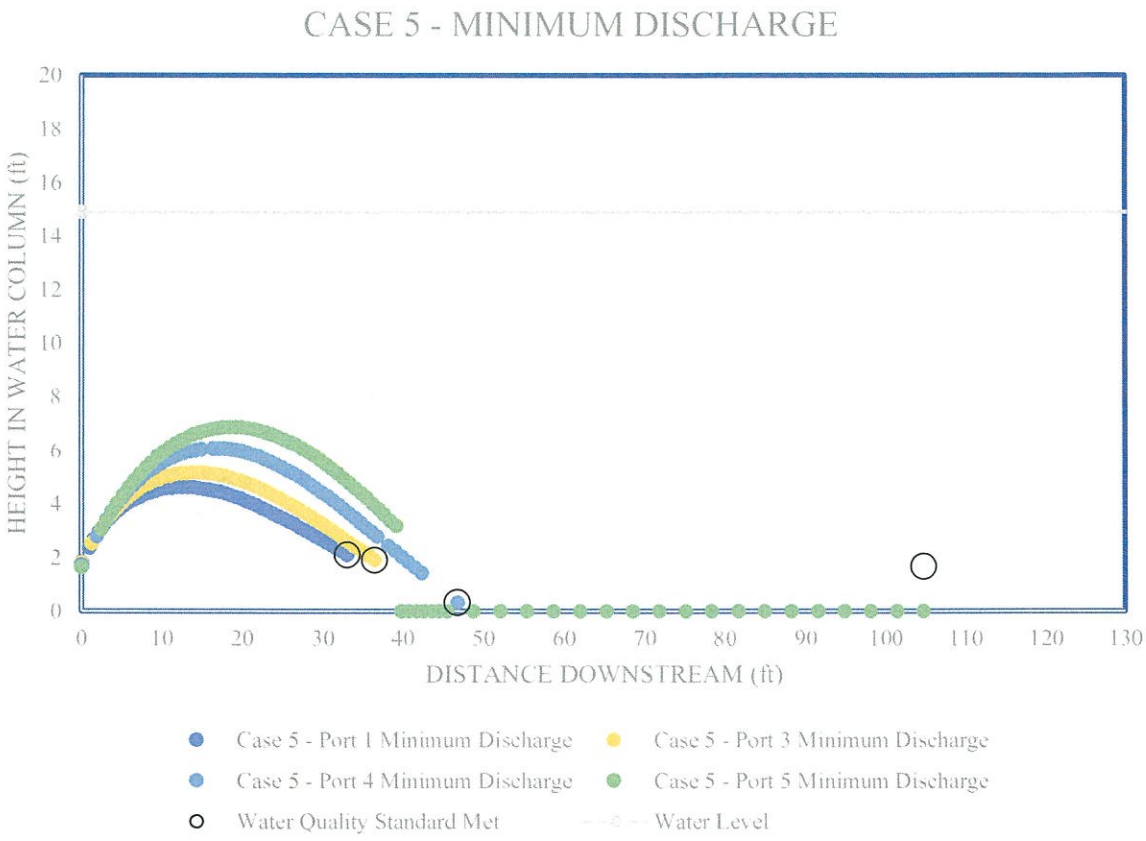


Figure 10. Plan and Profile of the Model for Case 5 – Maximum Flow Condition

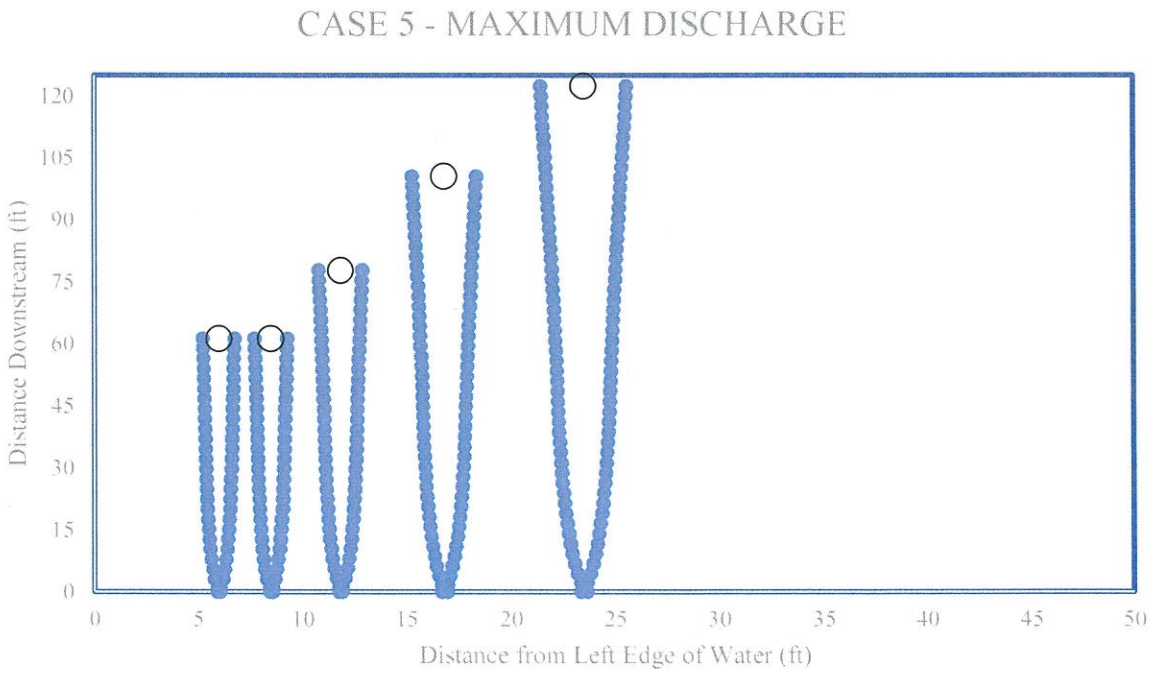


Figure 11. Transect at Proposed Diffuser Location, Excerpt from Horner & Shifrin Design documents

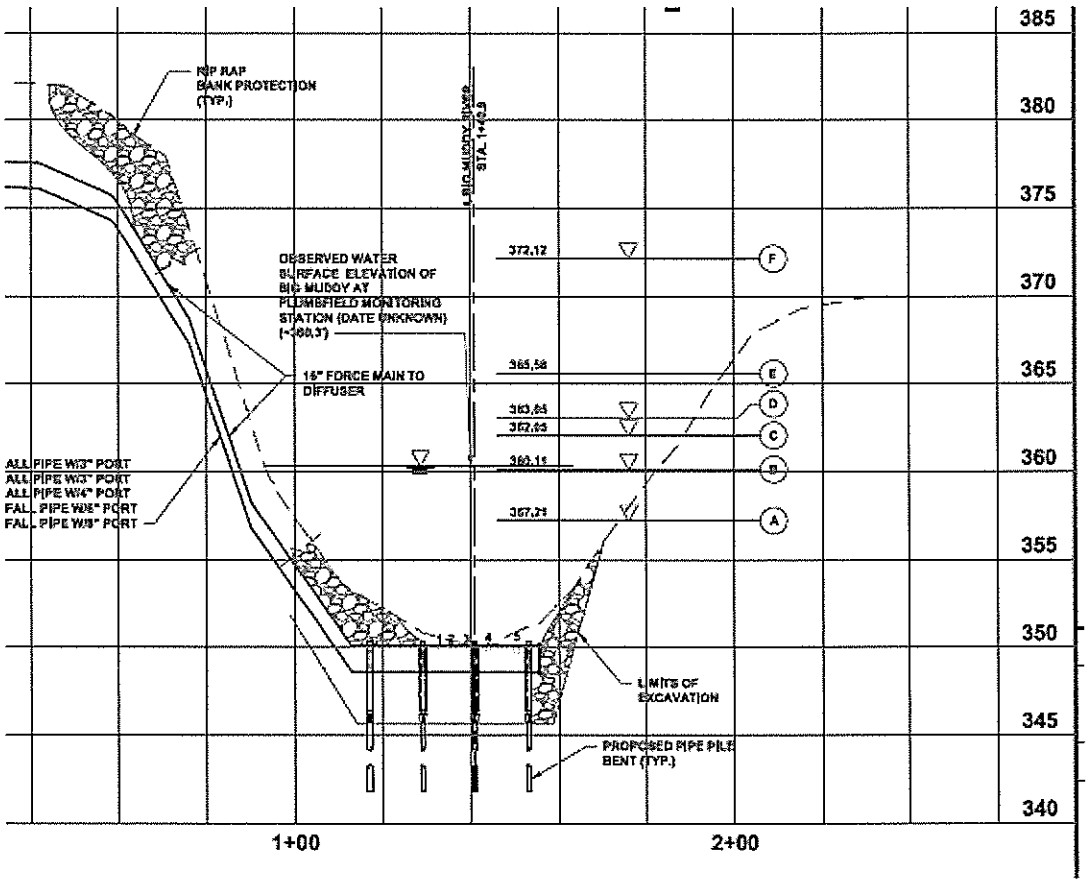


Table 2. Transect Dimensions

CASE	FLOW CONDITION	WATER COLUMN HEIGHT (ft)	AREA (ft^2)
Case 1	Minimum	6.6	376
	Maximum	9.2	605
Case 2	Minimum	9.2	605
	Maximum	11.4	807
Case 3	Minimum	11.4	807
	Maximum	12.5	903
Case 4	Minimum	12.5	903
	Maximum	14.9	1159
Case 5	Minimum	14.9	1159
	Maximum	14.9	1159

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Stage 3 TMDL Report

Upper Big Muddy Watershed

Prepared for:
Illinois EPA

DRAFT for Public Comment
October 15, 2018

LimnoTech
Water Environment | Scientists Engineers

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Upper Big Muddy River Watershed
Total Maximum Daily Load

Stage 3 Report

Prepared for:
Illinois EPA

Draft for Public Comment
October 15, 2018

Prepared by:
LimnoTech

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Executive Summary

Section 303(d) of the 1972 Clean Water Act requires States to define impaired waters and identify them on a list, which is called the 303(d) list. The State of Illinois 303(d) lists are published every two years and are available at: http://www.epa.state.il.us/water/tmdl/303d-list.html. This report focuses on assessments based on the 2012 303(d) list (IEPA, 2012), which was the version that was final at the start of this project. Section 303(d) of the Clean Water Act and USEPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting designated uses under technology-based controls. The TMDL process establishes the allowable loading of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and instream conditions. This allowable loading represents the maximum quantity of the pollutant that the waterbody can receive without exceeding water quality standards. The TMDL also takes into account a margin of safety, which reflects scientific uncertainty, as well as the effects of seasonal variation. By following the TMDL process, States can establish water quality-based controls to reduce pollution from both point and nonpoint sources, and restore and maintain the quality of their water resources (USEPA, 1991).

Load Reduction Strategies (LRSs) are being completed for causes that do not have numeric standards. LRSs for causes of impairment with target criteria will consist of loading capacity and the percent reduction needed to meet the target criteria.

The following waterbodies in the Upper Big Muddy River watershed are listed on the 2012 Illinois Section 303(d) List of Impaired Waters (IEPA, 2012) as not meeting their designated uses. IEPA conducted additional sampling in 2015 on 6 of the waterbodies to support the modeling presented in this report. This document presents TMDLs for the following segments and reservoirs to allow these waterbodies to fully support their designated uses:

- Upper Big Muddy River (IL_N-11)
- Andy Cr. (IL_NZN-13)
- Lake Cr. (IL_NGA-02)
- Beaver Cr. (IL_NGAZ-JC-D1)
- Middle Fork Big Muddy (IL_NH-06)
- Arrowhead (Williamson) Lake (IL_RNZX)
- Herrin Old Reservoir (IL_RNZD)
- Johnston City Lake (IL_RNZE)
- West Frankfort Old Lake (IL_RNP)
- West Frankfort New Lake (IL_RNQ)

LRSs for the following water bodies are also presented:

- Upper Big Muddy River (IL_N-06, IL_N-11, IL_N-17)
- Pond Cr. (IL_NG-02)
- Middle Fork Big Muddy (IL_NH-07)

This report covers each step of the TMDL process and is organized as follows:

- Problem Identification



- Stage 2 Sampling
- Development of Numeric Targets
- Development of Water Quality Models
- TMDL Development
- LRS Development
- Public Participation and Involvement
- Adaptive Implementation Process
- Clean Water Act Section 319

Illinois EPA conducts TMDLs following a three-stage process. Stage 1 includes watershed characterization, data analysis and model selection. Stage 2 involves data collection, and is conducted if necessary. Stage 3 includes model calibration and application, and TMDL and implementation plan development. Upper Big Muddy River Watershed Stage 1 work began in September, 2013. A public meeting to present the Stage 1 findings and the draft Stage 1 report was held in December 2013. The final Stage 1 report was completed in January, 2014, and recommended additional monitoring for dissolved oxygen modeling, and the delisting of the following stream segments for the noted impairments:

- Andy Cr. / IL_NZN-13 – Manganese
- Hurricane Creek / IL_NF-01 – Lindane
- M. Fk. Big Muddy / IL_NH-06 – Manganese
- M. Fk. Big Muddy / IL_NH-07 – Manganese
- Prairie Cr. / IL_NZM-01 – Sulfates

Stage 2 low flow sampling was conducted in 2015 to support dissolved oxygen modeling on several stream segments in the Upper Big Muddy River watershed. As a result of this sampling and data analysis, the following stream segments are recommended for delisting based on either the waters meeting the water quality standards during the sampling period, or the low dissolved ozygen conditions were flow related:

- Big Muddy R. / IL_N-17 - Dissolved Oxygen (Sampling met WQS)
- M. Fk. Big Muddy / IL_NH-06 - Dissolved Oxygen (Low DO is due to high sediment oxygen demand / low flow)
- M. Fk. Big Muddy / IL_NH-07 - Dissolved Oxygen (Low DO is due to high sediment oxygen demand / low flow)
- Pond Cr. / IL_NG-02 - Dissolved Oxygen (Sampling met WQS)

Further data analysis as a part of the Stage 3 TMDL/LRS preparation on the following segments has indicated that the listed impairment may not currently exist:

- Hurricane Creek / IL_NF-01 - Sedimentation/Siltation
- Herrin Old / IL_RNZD - Total Suspended Solids (TSS)
- Johnston City / IL_RNZE - Total Suspended Solids (TSS)
- West Frankfort Old / IL_RNP - Total Suspended Solids (TSS)
- West Frankfort New/ IL_RNQ - Total Suspended Solids (TSS)
- Lake Cr. / IL_NGA-02 - Phosphorus (Total)
- Big Muddy R. / IL_N-11 - Sulfates

The results of these data alayses will be reevaluated during the next 303(d) listing cycle to determine if these stream segments should continue to be listed as impaired.

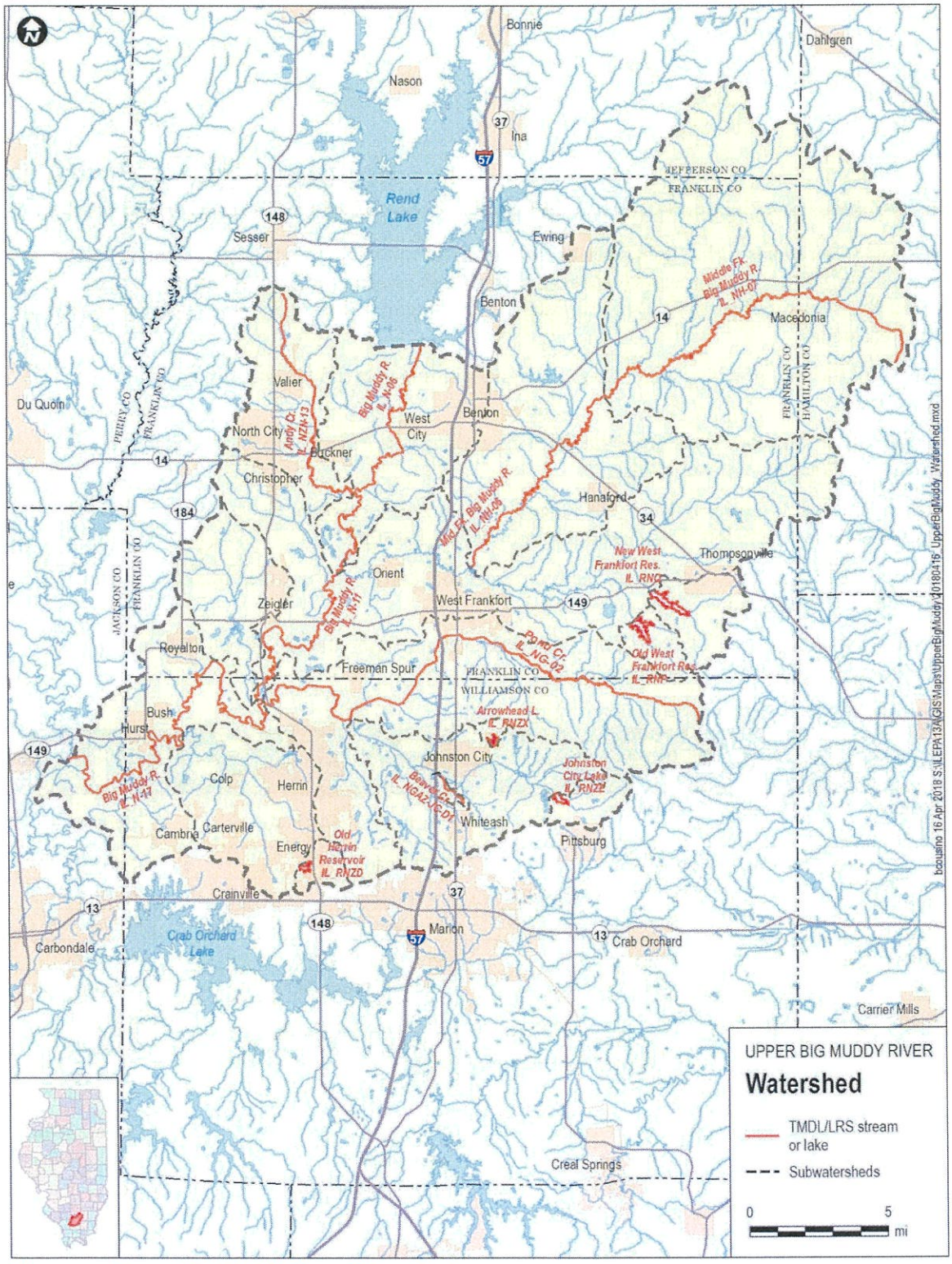


Figure 1-1. Upper Big Muddy River Watershed

1 Problem Identification

The impaired waterbodies within the Upper Big Muddy River watershed listed by the IEPA are listed below (Table 1-1), with the parameters (causes) they are listed for, and the impairment status of each designated use. The waterbodies that are proposed for delisting in the Table below are based on one of the following reasons:

1. Analysis of the data provided under Stage 1 that the existing data did not support the listed impairments.
2. Analysis of the data collected during the Stage 2 sampling performed for IEPA indicated that the impairments may not currently exist.
3. Analysis of the data collected during the Stage 2 sampling performed for IEPA indicated that the impairments are due to low flow conditions, not pollutant loading.
4. Based on a comparison of TSS data to the LRS target concentration developed by IEPA, it was determined that TSS reduction is not needed.
5. Based on a comparison of TP data to the LRS target concentration developed by IEPA, it was determined that TP reduction is not needed.

Table 1-1. Impaired Waterbody Summary

Waterbody/ Segment ID	Size (mile/ac)	Impaired Designated Use	Impairment Cause	Proposed Action
Big Muddy R. / IL_N-06	15.13 mi	Aquatic life	Sedimentation/Siltation	Prepare LRS
Big Muddy R. / IL_N-11	11.48 mi	Aquatic life	Sulfates	**Delist (1)**
		Primary contact recreation	Fecal Coliform	Prepare TMDL
		Aquatic life	Sedimentation/Siltation, TSS	Prepare LRS
Big Muddy R. / IL_N-17	21.48 mi	Aquatic life	Dissolved Oxygen	**Delist (2)**
		Aquatic life	Sedimentation/Siltation, TSS	Prepare LRS
Hurricane Creek / IL_NF-01	10.6 mi	Aquatic life	Lindane	**Delist (1)**
		Aquatic life	Sedimentation/Siltation	**Delist (4)**
Prairie Cr. / IL_NZM-01	9.06 mi	Aquatic life	Sulfates	**Delist (1)**
Andy Cr. / IL_NZN-13	11.7 mi	Aquatic life	Iron	Prepare TMDL
		Aquatic life	Manganese	Delist (1)
		Aquatic life	Dissolved Oxygen	Delist (3)
Herrin Old / IL_RNZD	51.3 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
		Aesthetic Quality	Total Suspended Solids (TSS)	**Delist (4)**
Pond Cr. / IL_NG-02	23.53 mi	Aquatic life	Chloride	Delist (1)
		Aquatic life	Dissolved Oxygen	**Delist (2)**

Waterbody/ Segment ID	Size (mile/ac)	Impaired Designated Use	Impairment Cause	Proposed Action
		Aquatic life	Sedimentation/Siltation	Prepare LRS
Lake Cr. / IL_NGA-02	12.33 mi	Aquatic life	Dissolved Oxygen	Prepare TMDL
		Aquatic life	Phosphorus (Total)	**Delist (5)**
Beaver Cr. / IL_NGAZ-JC-D1	1.7 mi	Aquatic life	Manganese	Prepare TMDL
Johnston City / IL_RNZE	64 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
		Aesthetic Quality	Total Suspended Solids (TSS)	**Delist (4)**
Arrowhead (Williamson) / IL_RNZX	30 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
M. Fk. Big Muddy / IL_NH-06	12.52 mi	Primary contact recreation	Fecal Coliform	Prepare TMDL
		Aquatic life	Dissolved Oxygen	**Delist (3)**
		Aquatic life	Manganese	**Delist (1)**
M. Fk. Big Muddy / IL_NH-07	19.74 mi	Aquatic life	Dissolved Oxygen	**Delist (3)**
		Aquatic life	Manganese	**Delist (1)**
		Aquatic life	Sedimentation/Siltation	Prepare LRS
West Frankfort Old / IL_RNP	146 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
		Aesthetic Quality	Total Suspended Solids (TSS)	**Delist (4)**
West Frankfort New/ IL_RNQ	214 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
		Aesthetic Quality	Total Suspended Solids (TSS)	**Delist (4)**

Delisting of the stream segments identified in the table able will occur as a part of a future 303(d) listing process based on the reasons noted above. TMDLs are currently only being developed for pollutants that have numerical water quality standards. Load Reduction Strategies (LRSs) are being developed for pollutants that do not have numerical water quality standards. All of the waterbodies that are being addressed in this Stage 3 report and the implementation plan are summarized in Table 1-2 below.

Table 1-2. TMDL & LRS Waterbody Summary

Waterbody/ Segment ID	Size (mile/ac)	Impaired Designated Use	Impairment Cause	Proposed Action
Big Muddy R. / IL_N-06	15.13 mi	Aquatic life	Sedimentation/Siltation	Prepare LRS
Big Muddy R. / IL_N-11	11.48 mi	Primary contact recreation	Fecal Coliform	Prepare TMDL
		Aquatic life	Sedimentation/Siltation, TSS	Prepare LRS
Big Muddy R. / IL_N-17	21.48 mi	Aquatic life	Sedimentation/Siltation, TSS	Prepare LRS
Andy Cr. / IL_NZN-13	11.7 mi	Aquatic life	Iron	Prepare TMDL
		Aquatic life	Dissolved Oxygen	Prepare TMDL
Herrin Old / IL_RNZD	51.3 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
Pond Cr. / IL_NG-02	23.53 mi	Aquatic life	Chloride	Prepare TMDL
		Aquatic life	Sedimentation/Siltation	Prepare LRS

Waterbody/ Segment ID	Size (mile/ac)	Impaired Designated Use	Impairment Cause	Proposed Action
Lake Cr. / IL_NGA-02	12.33 mi	Aquatic life	Dissolved Oxygen	Prepare TMDL
Beaver Cr. / IL_NGAZ-JC-D1	1.7 mi	Aquatic life	Manganese	Prepare TMDL
Johnston City / IL_RNZE	64 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
Arrowhead (Williamson) / IL_RNZX	30 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
M. Fk. Big Muddy / IL_NH-06	12.52 mi	Primary contact recreation	Fecal Coliform	Prepare TMDL
M. Fk. Big Muddy / IL_NH-07	19.74 mi	Aquatic life	Sedimentation/Siltation	Prepare LRS
West Frankfort Old / IL_RNP	146 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
West Frankfort New/ IL_RNQ	214 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL

2 Stage 2 Sampling

The Stage 1 report recommended additional sampling be conducted during low flow conditions to support dissolved oxygen modeling in support of TMDL development. In 2015, IEPA conducted Stage 2 sampling to support dissolved oxygen TMDL modeling. Samples were collected in September and October of 2015, and data were reported for CBOD5, BOD5, Nitrite-Nitrate Nitrogen, Ammonia, total kjeldahl nitrogen (TKN), total phosphorus, dissolved phosphorus, chlorophyll a, total suspended solids and volatile suspended solids, and sediment oxygen demand (SOD). Flow, velocity and channel morphometry were also recorded during sampling.

Figure 2-1 shows the locations sampled in 2015. The data collected at these locations were used in the dissolved oxygen modeling described in this report. TMDLs and LRSs for other parameters were based on existing data, previously collected by IEPA and described in the Stage 1 report (Attachment 1).

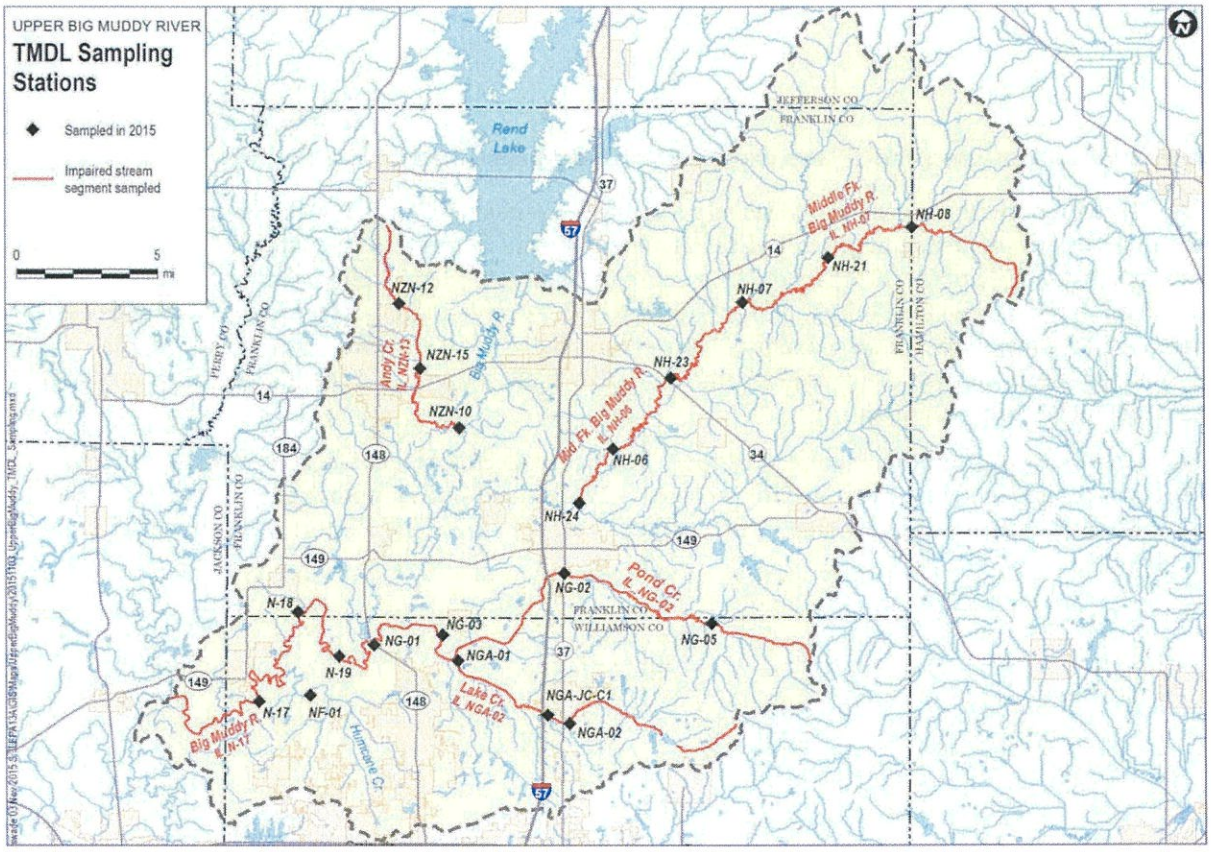


Figure 2-1. 2015 Sampling Locations in the Upper Big Muddy River Watershed



3 Development of Numeric Targets

Designated use, use support and water quality criteria for waterbodies in the Upper Big Muddy River watershed have been previously described in the Stage 1 Report (Attachment 1). This section describes the development of numeric TMDL and LRS targets.

3.1 Development of TMDL and LRS Targets

The TMDL target is a numeric endpoint specified to represent the level of acceptable water quality that is to be achieved by implementing the TMDL. Where possible, the water quality criterion for the pollutant of concern is used as the numeric endpoint.

3.1.1 Phosphorus (Total)

The General Use standards for phosphorus are in Section 302.205 of Title 35. For the phosphorus TMDLs in the lakes within the Upper Big Muddy River watershed, the target is set at the water quality criterion for total phosphorus of 0.05 mg/L.

When appropriate numeric standards do not exist, surrogate parameters must be selected to represent protection of the designated use. For streams and rivers in the Upper Big Muddy River watershed, IEPA has developed a total phosphorus LRS target of 0.217 mg/L (IEPA, 2016). This target is based on an average of validated, real-world data (1999-2013) for the nearby Upper Kaskaskia watershed, which contains several streams that are in full support of aquatic life. This LRS target was ultimately not used to develop a total phosphorus LRS because the average phosphorus concentrations measured in the stream segments listed for TP impairment were below this LRS target concentration.

3.1.2 Dissolved Oxygen

The General Use standards for dissolved oxygen are in Section 302.206 of Title 35. For the Upper Big Muddy River watershed dissolved oxygen TMDLs in streams, the target is set at the water quality criterion for daily minimum dissolved oxygen of 5.0 mg/L recognizing that this is the more conservative of the seasonal minimal dissolved oxygen criteria (recall that between August and February, the minimum is 3.5 mg/L). The QUAL2E models used to calculate the TMDLs predicts a daily average dissolved oxygen concentration and does not directly predict daily minimum values. QUAL2E results can be translated into a form comparable to a daily minimum, by subtracting the observed difference between daily average and daily minimum dissolved oxygen from the model output.

3.1.3 Iron

The General Use standards for iron are in Section 302.208 of Title 35. A single-value standard of 1.0 mg/L applies to dissolved iron, and this is the target used for TMDL development for the Andy Creek (IL_NZN-13) segment.

3.1.4 Manganese

The General Use standards for manganese are in Section 302.208 of Title 35. The water quality standards for dissolved manganese are given by the following equations:

Acute Standard:

$WQS = e^{A+Bln(H)} \times 0.9812$

where A = 4.9187 and B = 0.7467;

and ln(H) is the natural logarithm of the hardness in mg/L.

Chronic Standard:

$WQS = e^{A+Bln(H)} \times 0.9812$

where A = 4.0635 and B = 0.7467;

and ln(H) is the natural logarithm of the hardness in mg/L.

The chronic standard was used to develop the manganese TMDL for Beaver Cr. (IL_NGAZ-JC-D) in the Upper Big Muddy River watershed. The calculated target for this stream segment is shown in section 4.2.6.

3.1.5 Fecal Coliform

The General Use standards for fecal coliform bacteria are in Section 302.209 of Title 35. During the months May through October (swimming-season), based on a minimum of five samples taken over not more than a 30 day period, fecal coliform bacteria shall not exceed a geometric mean of 200 per 100 mL, nor shall more than 10% of the samples during any 30 day period exceed 400 per 100 mL. For fecal coliform TMDLs in the Upper Big Muddy River watershed, the target is conservatively set at the water quality criterion of 200 colony forming units (cfu)/100 mL.

3.1.6 Total Suspended Solids (TSS)

When appropriate numeric standards do not exist, surrogate parameters must be selected to represent protection of the designated use. For all streams and rivers in the Upper Big Muddy River watershed, IEPA has developed a LRS target of 32.2 mg/L TSS (IEPA, 2016). This target is based on an average of validated, real-world data (1999-2013) for the nearby Upper Kaskaskia watershed, which contains several streams that are in full support of aquatic life.

Based on an average of validated, real-world data for these streams over a period from 1999 to 2013, the load reduction targets for all streams in this watershed are as follows:

- Total Suspended Solids: 32.2 milligrams/liter

For all lakes in the watershed, the load reduction targets are as follows:

- Total Suspended Solids: 23 milligrams/liter

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4 Development of Water Quality Models

Water quality models are used to define the relationship between pollutant loading and the resulting water quality. This section describes the modeling to support TMDL and LRS development, and is divided into the following sections:

- QUAL2E modeling for dissolved oxygen TMDL
- Load Duration Curve approach for fecal coliform, sulfate, iron, manganese, and chloride TMDLs
- BATHTUB modeling for total phosphorus TMDLs for reservoirs.

The remainder of this section describes the TSS modeling to support the TSS LRS.

4.1 QUAL2E Model for the Dissolved Oxygen TMDLs

The QUAL2E water quality model was used to define the relationship between external oxygen-demanding loads and the resulting concentrations of dissolved oxygen in the Lake Cr. (IL_NGA-02) stream segment in the Upper Big Muddy River watershed.

In addition, QUAL2E to was used to model the the dissolved oxygen in Pond Creek (IL_) and Andy Creek (IL_NZN-) to determine if the observed low dissolved oxygen was based on pollutant loads, or low flow conditions. Based on the results of those models, no TMDLs were developed for those stream segments.

QUAL2E is a one-dimensional stream water quality model applicable to dendritic, well-mixed streams. It assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the main direction of flow. The model allows for multiple waste discharges, water withdrawals, tributary flows, and incremental inflows and outflows.

4.1.1 Model Selection

A discussion of the model selection process for the Upper Big Muddy River watershed is provided in the Stage 1 report (Attachment 1).

The QUAL2E model (Brown and Barnwell, 1987) was selected to address dissolved oxygen impairments in the Upper Big Muddy River watershed. QUAL2E is the most commonly used water quality model for addressing low flow conditions.

4.1.2 Modeling Approach

The approach selected for the dissolved oxygen TMDL consists of using data collected during 2015 low flow season surveys to define the current water quality of the river, and using the QUAL2E model to define the extent to which loads must be reduced to meet water quality standards. This is the recommended approach presented in the Stage 1 report.

4.1.3 QUAL2E Model Inputs

This section gives an overview of the model inputs required for QUAL2E application, and how they were derived. The following categories of inputs are required for QUAL2E:

- Model options (title data)
- Model segmentation



- Hydraulic characteristics
- Reach kinetic coefficients
- Initial conditions
- Incremental inflow conditions
- Headwater characteristics
- Point source flows and loads

4.1.3.a Model Options

This portion of the model input parameters defines the specific water quality constituents to be simulated. QUAL2E was set up to simulate temperature, biochemical oxygen demand, the nitrogen series, phosphorus, algae and dissolved oxygen.

4.1.4 Andy Cr. (IL_NZN-13) QUAL2E Model Application

This sections described the application of the QUAL2E model to the above noted stream segment.

4.1.4.a Model Segmentation

The QUAL2E model divides the river being simulated into discrete segments (called "reaches") that are considered to have constant channel geometry and hydraulic characteristics. Reaches are further divided into "computational elements", which define the interval at which results are provided. Andy Creek QUAL2E model consists of two reaches, which are comprised of a varying number of computational elements. Computational elements were specified to have a fixed length of 0.20 miles. Reaches are defined with respect to water quality monitoring stations and tributaries. Model segmentation is presented below in Table 4-1 and Figure 4-1.

Table 4-1. Andy Creek QUAL2E Segmentation

Reach	River miles	Number of computational elements	Other features
1	8.25 – 5.0	13	NZN-12, Valier STP, NZN-15
2	5.0 – 0.0	20	NZN-10

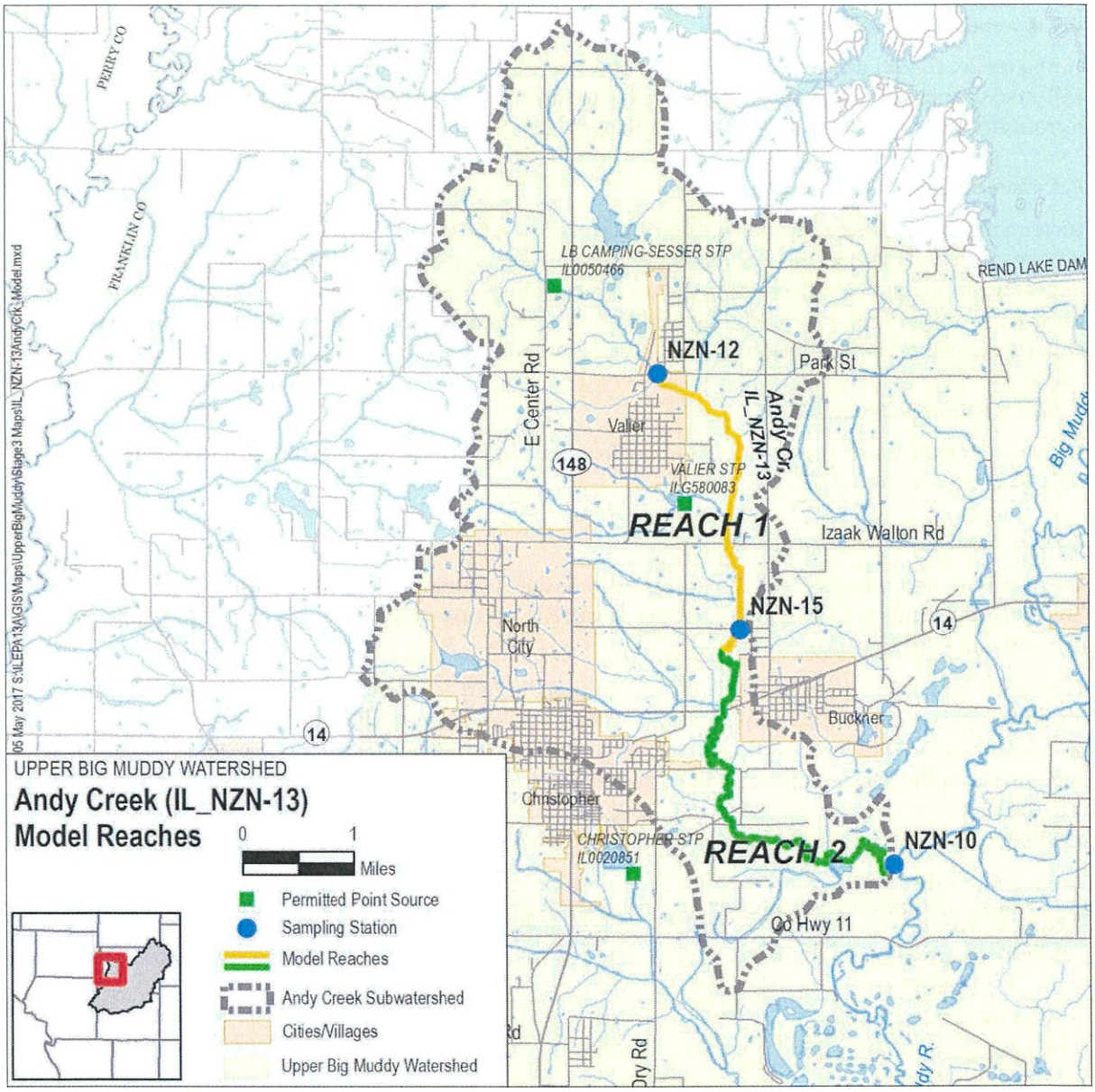


Figure 4-1. Andy Creek QUAL2E Segmentation

4.1.4.b Hydraulic characteristics

A functional representation was used to describe the hydraulic characteristics of the system. For each reach, velocity and depth were specified, based on measurements taken during the September 23, 2015 field survey.

4.1.4.c Reach Kinetic Coefficients

Kinetic coefficients were initially set at values commonly used in past QUAL2E applications from Illinois. The appropriateness of these initial values were assessed during the model calibration process, where these coefficients were refined as necessary (within accepted ranges taken from the scientific literature) to allow model results to best describe observed water quality data.

4.1.4.d Initial Conditions

Initial model conditions were based on field observations, flow measurements, and water quality data collected during 2015. Specifically, observed concentrations of ammonia, phosphorus, organic nitrogen, nitrate and chlorophyll a were used to specify initial conditions.

4.1.4.e Incremental Inflow Conditions

Incremental inflows were calculated using a drainage area ratio and field measured flows. Increases in flows were added to each reach incrementally to represent non-monitored tributaries (flows were increasing from upstream to downstream). Concentrations for these incremental inflows were considered to have concentrations at typical background levels, and temperatures consistent with the mainstem. Other flows came from the headwater and point sources.

4.1.4.f Headwater Characteristics

Headwater characteristics were based on the flow/water quality measurements collected at the more upstream IEPA station (NZN-12).

4.1.4.g Point Source Flows and Loads

There are two permitted NPDES discharges from sewage treatment plants in the Andy Creek watershed. The NPDES permits are for the LB Camping Sesser STP (IL0050466) and the Valier STP (ILG580083). (Attachment 1, Section 2.9).

The model considers one permitted point source that discharges to Andy Creek via a small tributary. The upsrtream point source (LB Camping Sesser STP) is assumed to contribute no load or small loads (based on discharge monitoring report (DMR) data and some assumptions where data was not available), and any impacts on the DO impairments to Andy Creek at the downstream stations would be incorporated into the model by using the sampling data collected at station NZN-12 as the upstream boundary conditions. See Table 4-2 for details of when data were used, and when assumptions were made.

Table 4-2. Andy Creek (IL_NZN-13) Concentrations of QUAL2E model inputs

Model input point	Flow (cfs)	Temp. (Deg F)	DO (mg/L)	CBOD5 (mg/L)	Ammonia (mg/L)	Source
Headwater	0.10	63.7	4.47	1	0.05	Data collected at NZN-12
Valier STP discharge to Reach 1	0.06	70	8.70	10.90	5.80	DMR data (flow, CBOD5, DO, Ammonia)
Incremental inflow to Reach 1	0.145	65.0	4.5	1	0.00	Calculated from flow balance. Water quality specified based on typical background levels.

4.1.4.h QUAL2E Model Calibration

QUAL2E model calibration consisted of:

- Applying the model with all inputs specified as above
- Comparing model results to observed dissolved oxygen, BOD, ammonia, and chlorophyll data
- Adjusting model coefficients to provide the best comparison between model predictions and observed dissolved oxygen data.

The QUAL2E dissolved oxygen calibration for Andy Creek is discussed below. The model was initially applied with the model inputs as specified above. Observed data for the low flow survey conducted on September 23, 2015 was used for calibration purposes.



QUAL2E was calibrated to match the observed average dissolved oxygen concentrations measured at two locations (NZN-15 and NZN-10) on the mainstem of the creek. The data collected at NZN-12 was used to define the upstream boundary conditions. The initial BOD calibration was deemed successful, albeit not totally conclusive, as the majority of observed data (as well as model predictions) for both parameters were below laboratory detection limits. Similarly, the initial coefficients used to describe chlorophyll a correctly replicated observed low observed field concentrations and confirmed that algal productivity was not an important component of the dissolved oxygen budget.

Model results initially over-predicted observed dissolved oxygen data. Model calibration was attained by adjusting reach-specific sediment oxygen demand, with calibration values ranging from 0.054 to 0.065 mg/sq. ft./day. Those values were initially based on the SOD measurement taken at NZN-15 of 0.065 mg/sq. ft./day. The resulting dissolved oxygen predictions compared well to the measured concentrations as shown in Figure 4-2. The QUAL2E model output files from the calibration runs are included in Attachment 3.

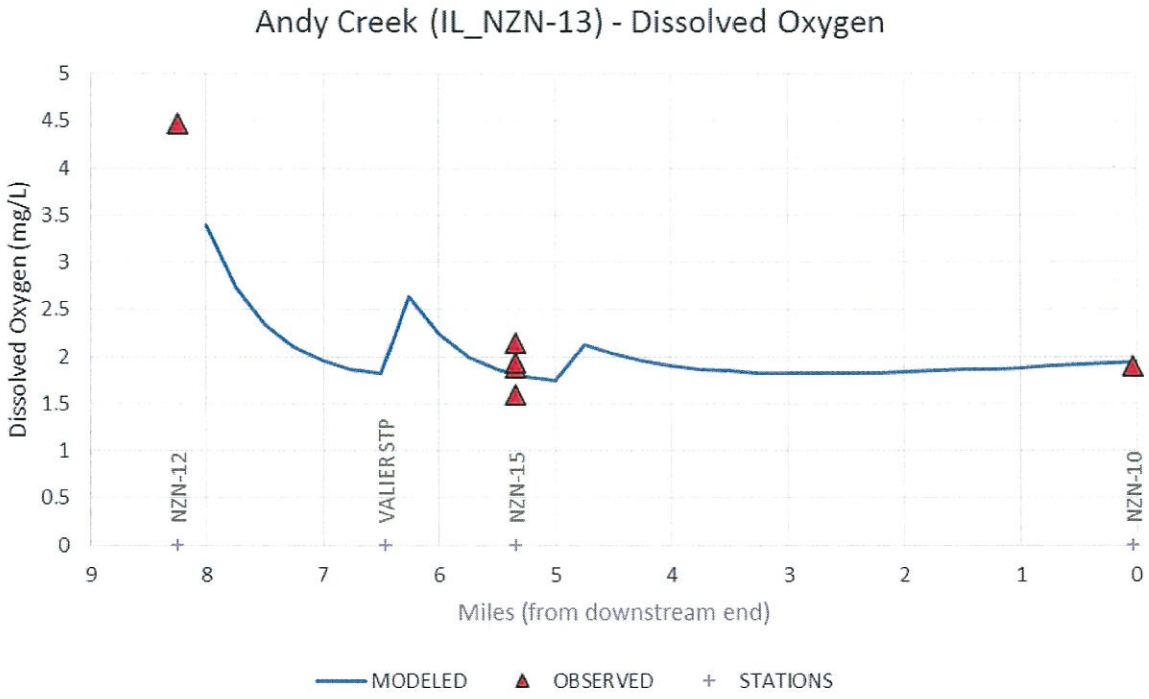


Figure 4-2. QUAL2E DO Calibration for Andy Creek for 9/23/2015 Sampling Survey

4.1.5 Lake Cr. (IL_NGA-02) QUAL2E Model Application

This sections described the application of the QUAL2E model to the above noted stream segment.

4.1.5.a Model Segmentation

The QUAL2E model divides the river being simulated into discrete segments (called "reaches") that are considered to have constant channel geometry and hydraulic characteristics. Reaches are further divided into "computational elements", which define the interval at which results are provided. The Lake Creek QUAL2E model consists of two reaches, which are comprised of a varying number of computational elements. Computational elements were specified to have a fixed length of 0.25 miles. Reaches are defined with respect to water quality monitoring stations and tributaries. Model segmentation is

presented below in Table 4-3 and Figure 4-3. The division between reaches 1 and 2 was determined based on the location of additional tributaries that contribute additional flow to the stream which would be expected to change the hydraulic characteristics of the reach.

Table 4-3. Lake Creek QUAL2E Segmentation

Reach	River miles	Number of computational elements	Other features
1	3.25 – 5.25	8	NGA-02, Johnston City STP, NGA-JC-C1
2	0 – 3.25	14	NGA-01

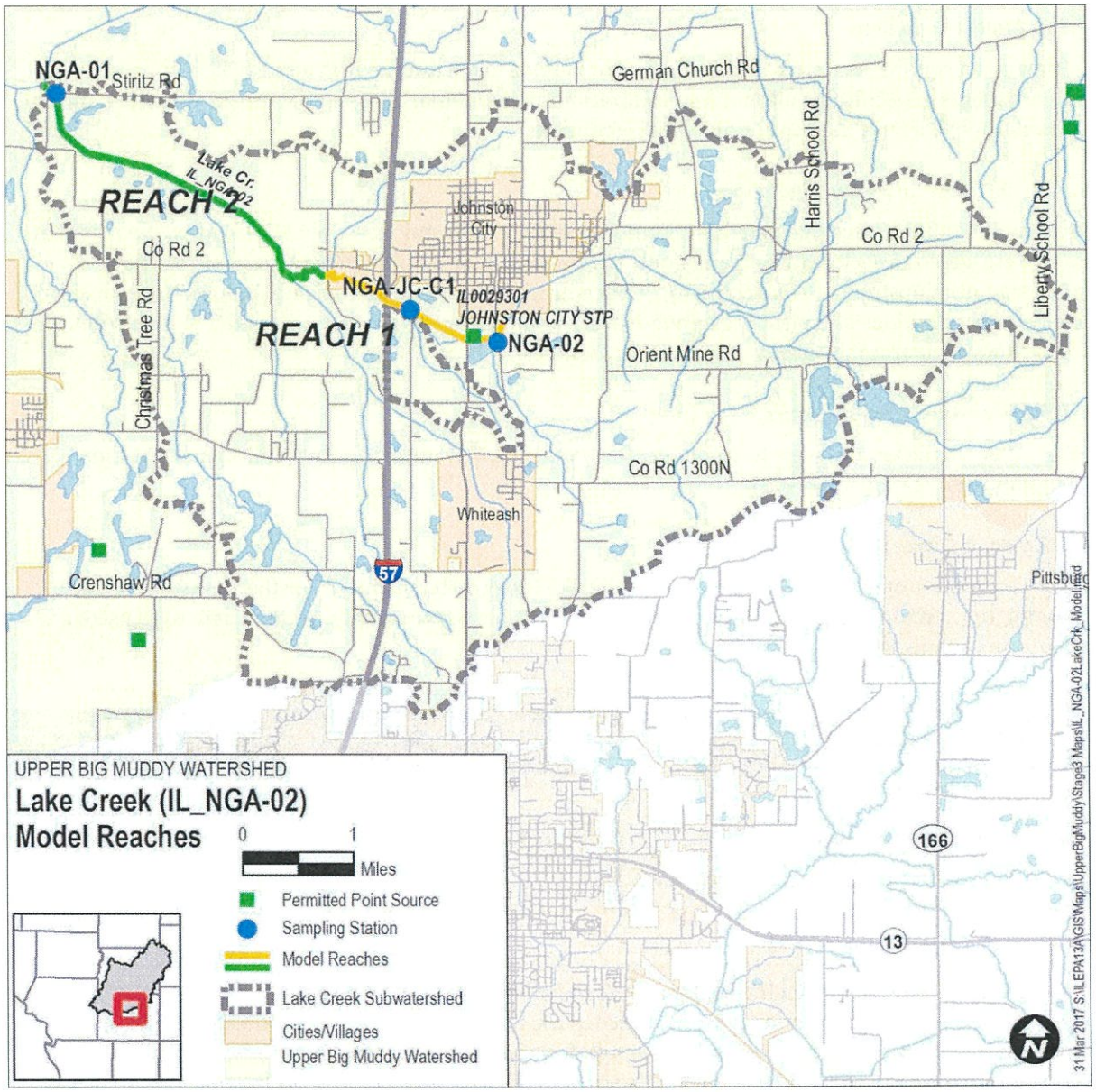


Figure 4-3. Lake Creek (IL_NGA-02) QUAL2E Model Segmentation

4.1.5.b Hydraulic characteristics

A functional representation was used to describe the hydraulic characteristics of the system. For each reach, velocity and depth were specified, based on measurements taken during the August, September and October 2015 field surveys.

4.1.5.c Reach Kinetic Coefficients

Kinetic coefficients were initially set at values commonly used in past QUAL2E applications from Illinois. The appropriateness of these initial values were assessed during the model calibration process, where these coefficients were refined as necessary (within accepted ranges taken from the scientific literature) to allow model results to best describe observed water quality data.

4.1.5.d Initial Conditions

Initial model conditions were based on field observations taken during 2015 and USGS flow measurements. Specifically, observed concentrations of ammonia, phosphorus, organic nitrogen, nitrate and chlorophyll a were used to specify initial conditions.

4.1.5.e Incremental Inflow Conditions

Incremental inflows were calculated using a drainage area ratio and measured USGS flows. Increases in flows were added to each reach incrementally to represent non-monitored tributaries (flows were increasing from upstream to downstream). Concentrations for these incremental inflows were considered to have concentrations at typical background levels, and temperatures consistent with the mainstem. Other flows came from the headwater and point sources.

4.1.5.f Headwater Characteristics

Headwater characteristics were based on the flow/water quality measurements collected at the more upstream IEPA station (NGA-02).

4.1.5.g Point Source Flows and Loads

There is one permitted NPDES discharges in the Lake Creek watershed. It is for the Johnston City STP (IL0029301), a municipal sewage treatment plant. See Table 4-4 for details of when data were used, and when assumptions were made.

Table 4-4. Lake Creek (IL_NGA-02) Concentrations of QUAL2e model inputs

Model input point	Flow (cfs)	Temp. (Deg F)	DO (mg/L)	$CBOD_5$ (mg/L)	Ammonia (mg/L)	Source
Headwater	0.10	63.7	4.47	1	0.05	Data collected at NGA-02, or calculated from flow balance.
Johnston City STP discharge to Reach 1	0.75	70	7.6	14.2	8.90	DMR data (flow, CBOD5, DO), data from NGA-JC-C1 (Ammonia).
Incremental inflow to Reach 2	4.69	65.0	9.0	1	0.00	Calculated from flow balance. Water quality specified based on typical background levels.

It is noted that DMR data from the September 2015 for Johnston City STP indicate that the monthly average CBOD5 concentration (14.2 mg/l) exceeded the permit limit of 10 mg/L, along with effluent violations of daily maximum and monthly average ammonia nitrogen concentrations, although it is uncertain whether the effluent limit violations were occurring specifically during the time of the survey. The of $CBOD_5$ in the Johnston City STP were based on the September 2015 DMR for that facility. The $CBOD_5$ and DO concentrations used to characterize the point load in the QUAL2E model were the monthly averages. The daily maximum $CBOD_5$ was 17 mg/L, but there is no information on whether that occurred on the date of the sampling. The ammonia nitrogen concentration used in the model to characterize the point load was based on the observed concentration at station NGA-JC-C1, which is higher than the reported daily maximum value for ammonia nitrogen in the DMR. The effluent sampling frequency for ammonia nitrogen required in the NPDES permit for the Johnston City STP is only two days per month, so it is possible that higher concentrations could occur between samples. The flow used was the daily average flow for the month reported in the DMR of 0.488 MGD, which is lower than the design average flow for the facility of 0.55 MGD.

4.1.5.h QUAL2E Model Calibration

QUAL2E model calibration consisted of:

- Applying the model with all inputs specified as above
- Comparing model results to observed dissolved oxygen, BOD, ammonia, and chlorophyll data
- Adjusting model coefficients to provide the best comparison between model predictions and observed dissolved oxygen data.

The QUAL2E dissolved oxygen calibration for Lake Creek (IL_NGA-02) is discussed below. The model was initially applied with the model inputs as specified above. Observed data for the low flow survey conducted in 2015 was used for calibration purposes.

QUAL2E was calibrated to match the observed average dissolved oxygen concentrations measured at two locations (NGA-01, and NGA-JC-C1) on the mainstem of the creek. Data collected at station NGA-02 was used to characterize the upstream boundary conditions. The initial DO and ammonia calibration was deemed successful. Similarly, the initial coefficients used to describe chlorophyll a correctly replicated observed low observed field concentrations and confirmed that algal productivity was not an important component of the dissolved oxygen budget in the area downstream of the Johnston City STP discharge.

The reach-specific sediment oxygen demand values entered in the model for Reach 1 of 0.079 g/sq. ft./day was based on an SOD test run at NGA-02. The sediment oxygen demand values entered in the model for Reach 2 of 0.06 g/sq. ft./day was adjusted to match the observed downstream data. The resulting dissolved oxygen predictions compared well to the measured concentrations during the survey, as shown in Figure 4-4. The QUAL2E model output files from the calibration runs are included in Attachment 3.

Based on the components of dissolved oxygen mass balance in the QUAL2E model output files, the largest components of the oxygen deficit in the stream immediately downstream of the Johnston City STP were due to the sediment oxygen demand, and the oxygen consumed for nitrification of ammonia and nitrite. Although SOD is one of the dominant sources of the oxygen deficit, the true cause is a lack of base flow (which greatly exacerbates the effect of SOD).

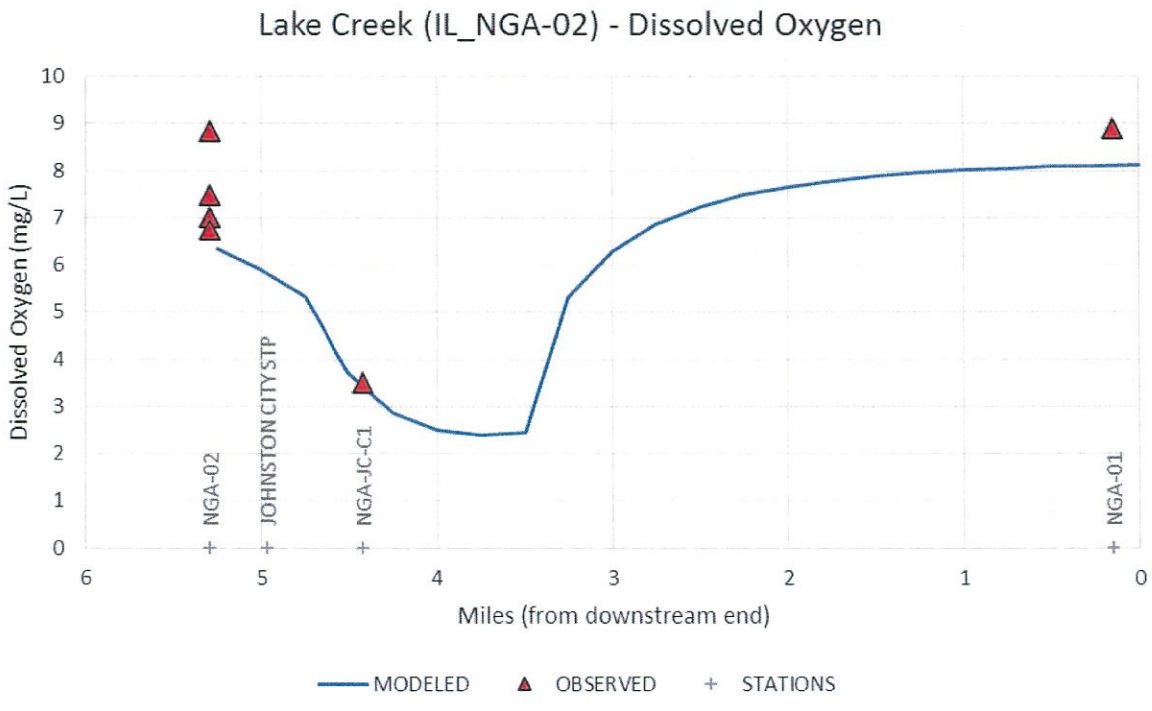


Figure 4-4. QUAL2E DO Calibration for Lake Creek for 9/24/2015 Sampling Survey

4.2 Load Duration Curve Approach

A load duration curve approach was used in the fecal coliform, sulfate, iron, chloride, and manganese analyses for streams in the Upper Big Muddy watershed. A load-duration curve is a graphical representation of observed pollutant load compared to maximum allowable load over the entire range of flow conditions. The load duration curve provides information to:

- Help identify the issues surrounding the problem and differentiate between point and nonpoint source problems, as discussed immediately below;
- Address frequency of deviations (how many samples lie above the curve vs. those that plot below); and
- Aid in establishing the level of implementation needed, by showing the magnitude by which existing loads exceed standards for different flow conditions.

4.2.1 Model Selection

A detailed discussion of the model selection process for TMDL development in the Upper Big Muddy River watershed is provided in the Stage 1 Report. The load-duration curve approach was selected because it is a simpler approach that can be supported with the available data and still support the selected level of TMDL implementation for this TMDL. The load-duration curve approach identifies broad categories of pollutant sources and the extent of control required from these source categories to attain water quality standards.

4.2.2 Approach

The load duration curve approach uses stream flows for the period of record to gain insight into the flow conditions under which exceedances of the water quality standard occur. A load-duration curve is developed by: 1) ranking the daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results; 2) translating the flow duration curve (produced in step 1) into a load duration curve by multiplying the flows by the water quality standard; and 3) plotting observed pollutant loads (measured concentrations times stream flow) on the same graph. Observed loads that fall above the load duration curve exceed the maximum allowable load, while those that fall on or below the line do not exceed the maximum allowable load. An analysis of the observed loads relative to the load duration curve provides information on whether the pollutant source is point or nonpoint in nature. A more complete description of the load duration curve approach is provided in the Stage 1 Report.

4.2.3 Big Muddy R. / IL_N-11 – Fecal Coliform Load Duration Curve

This section describes the flow and water quality data used to support development of the load duration curve for fecal coliform bacteria on the above noted stream segment.

4.2.3.a Flow Data

Segment IL_N-11 of the Big Muddy River is located downstream of Rend Lake, so the flows in the river at that point are impacted by the reservoir storage and dam operations. When developing the load-duration curve, the reservoir storage can reduce the peak flows, and maintain a higher baseflow, making distinction between dry and wet weather related sources difficult to distinguish. To remedy that problem, daily flow measurements were used from the USGS gage on Casey Fork near Mount Vernon, IL (USGS gage number 05595820) for the period from 1999 through 2015.

Casey Fork is a tributary to the Big Muddy River upstream of Rend Lake, so flows at that location are not impacted by the reservior. This gage is located approximately 28.6 miles north of station N-11, where the water quality data was collected. This gage has a drainage area of 76.9 square miles, so all flow data from



the gage are adjusted based on the drainage area ratio (DAR) to the stream segment under consideration. The drainage area within the Upper Big Muddy River watershed for segment IL-N-11 is 312.3 square miles, which does not include areas upstream of Rend Lake. The Casey Fork gage was selected based on the proximity to the stream segment under consideration, and that it is located within the same watershed, the fact that it is upstream of Rend Lake, so it is not impacted by the reservoir.

4.2.3.b Water Quality Data

Fecal coliform data collected at station N-11 by IEPA between 1999 and 2010 were used in the analysis. The data were collected as part of IEPA's ambient water quality monitoring program. Only data for the months of May-October were used because the water quality standard applies only during this period.

4.2.3.c Analysis

A flow duration curve was generated by ranking daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results. The load duration curve for fecal coliform were generated by multiplying the flows in the duration curve by the water quality standard of 200 cfu/100 mL for fecal coliform bacteria. The load duration curve for fecal coliform is shown with a solid line in Figure 4-5. Observed pollutant loads of fecal coliform were calculated using available concentration data paired with corresponding flows, and were plotted on the same graph. The fecal coliform data used only measurements collected between May and October, since that is the period specified under Section 302.209 of Title 35.

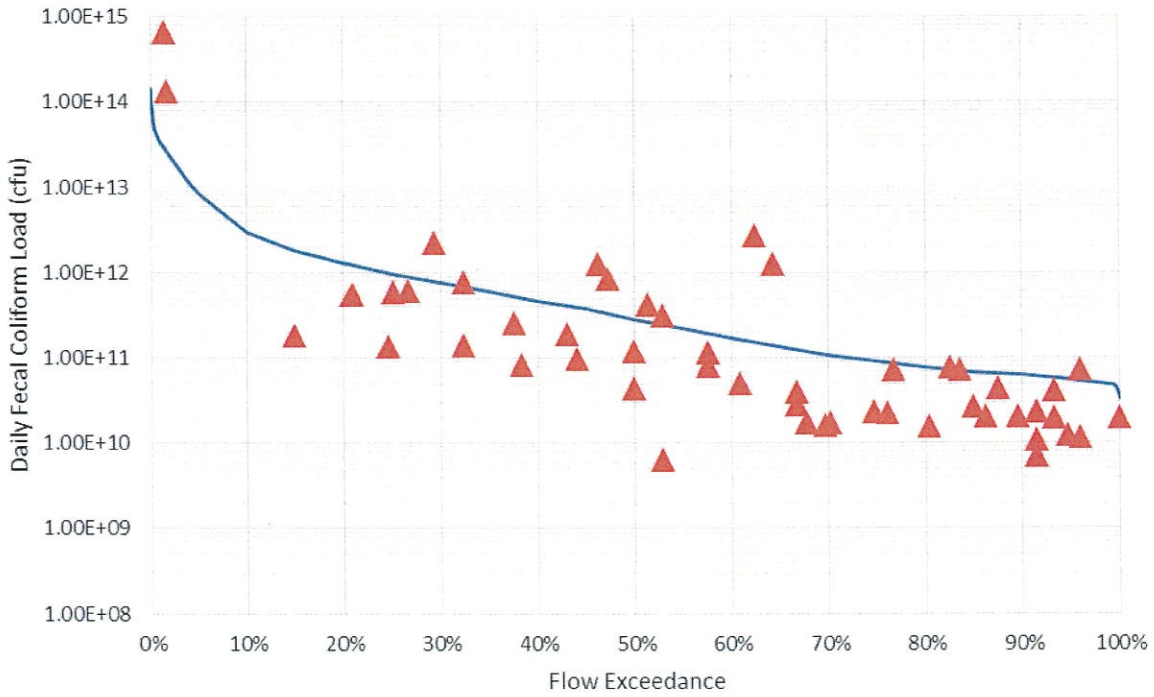


Figure 4-5. Fecal Coliform Load Duration Curve for Upper Big Muddy River (IL_N-11) with Observed Loads (triangles)

In Figure 4-5, the data show exceedances of the fecal coliform target occur over all ranges of flows, but with more exceedances (as a fraction of the samples) occuring in the higher range of flows. This indicates that wet weather sources contribute to the observed violations of the water quality standard.

4.2.4 Andy Cr. / IL_NZN-13 – Iron Load Duration Curve

This section describes the flow and water quality data used to support development of the load duration curve for dissolved iron on the above noted stream segment.

4.2.4.a Flow Data

There is no stream gage on Andy Creek that can be used to estimate the daily flows and loadings. Daily flow measurements are available for the USGS gage on Crab Orchard Creek near Marion, IL (USGS gage number 05597500) for the period from 1999 through 2015. This gage is located approximately 20.2 miles southeast of the Andy Creek watershed. This gage has a drainage area of 31.7 square miles, so all flow data from the gage are adjusted based on the drainage area ratio (DAR) to the stream segment under consideration. The stream segment under consideration has a drainage area of 20.4 square miles at its outlet. The Crab Orchard Creek gage was selected for consideration based on the drainage areas being similar in size, the proximity to the stream segment under consideration, with similar watershed land uses and topography.

4.2.4.b Water Quality Data

Dissolved iron data collected by IEPA in 2008 were used in the analysis. The data were collected as part of IEPA's ambient water quality monitoring program. There were three samples analyzed, and all three exceeded the water quality standards.

4.2.4.c Analysis

A flow duration curve was generated by ranking daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results. A load duration curve for iron was generated by multiplying the flows in the duration curve by the water quality standard of 1.0 mg/L for dissolved iron. The load duration curve for iron is shown with a solid line in Figure 4-6. Observed pollutant loads of dissolved iron were calculated using available concentration data paired with corresponding flows, and were plotted on the same graph.

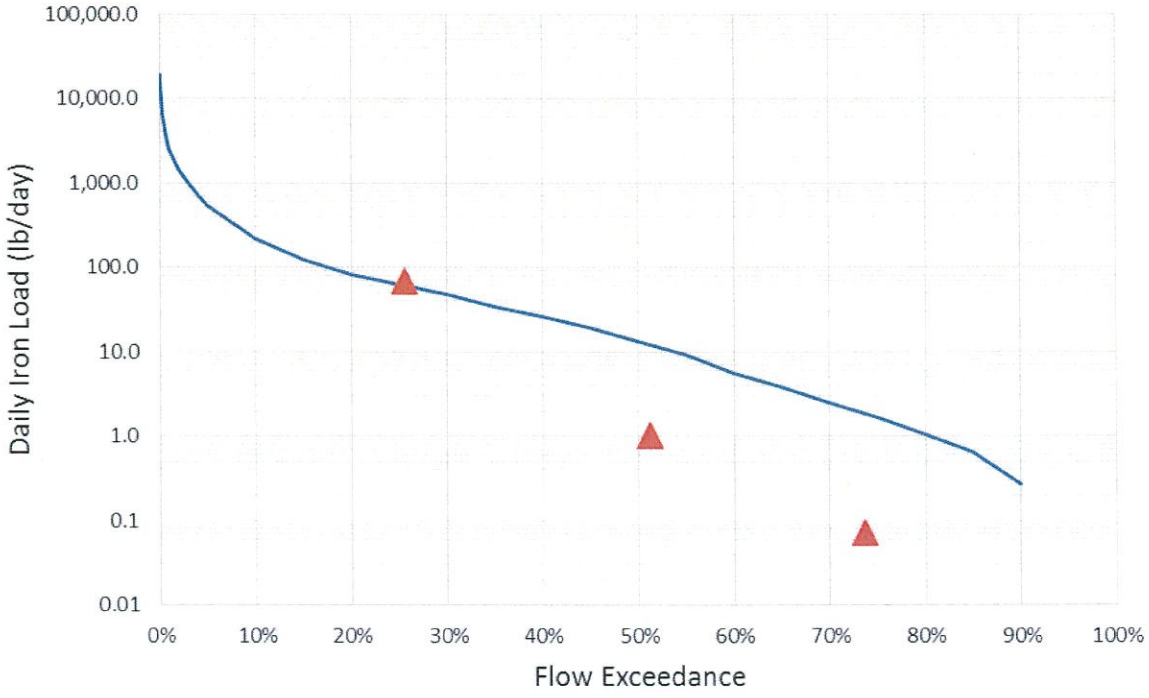


Figure 4-6: Dissolved Iron Load Duration Curve for Andy Creek (IL_NZN-13) with Observed Loads (triangles)

In Figure 4-6, the data show that the sampled data points only exceeded the dissolved iron target at the highest sampled flow. This indicates that wet weather sources or runoff contribute to the observed violation of the water quality standard.

4.2.5 Pond Cr. / IL_NG-02 – Chloride Load Duration Curve

This section describes the flow and water quality data used to support development of the load duration curve for fecal coliform bacteria on the above noted stream segment.

4.2.5.a Flow Data

Daily flow measurements are available for the USGS gage on Crab Orchard Creek near Marion, IL (USGS gage number 05597500) for the period from 1999 through 2015. This gage has a drainage area of 31.7 square miles, so all flow data from the gage are adjusted based on the drainage area ratio (DAR) to the stream segment under consideration.

4.2.5.b Water Quality Data

Fecal coliform data collected by IEPA between 1999 and 2006 were used in the analysis. The data were collected as part of IEPA's ambient water quality monitoring program. Only data for the months of May-October were used because the water quality standard applies only during this period.

4.2.5.c Analysis

A flow duration curve was generated by ranking daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results. The load duration curve for chloride was generated by multiplying the flows in the duration curve by the water quality standard 500 mg/L for chloride. The load duration curve for chloride is shown with a solid line in Figure 4-7. Observed pollutant loads of chloride were calculated using available concentration data paired with corresponding flows, and were plotted on the same graph.

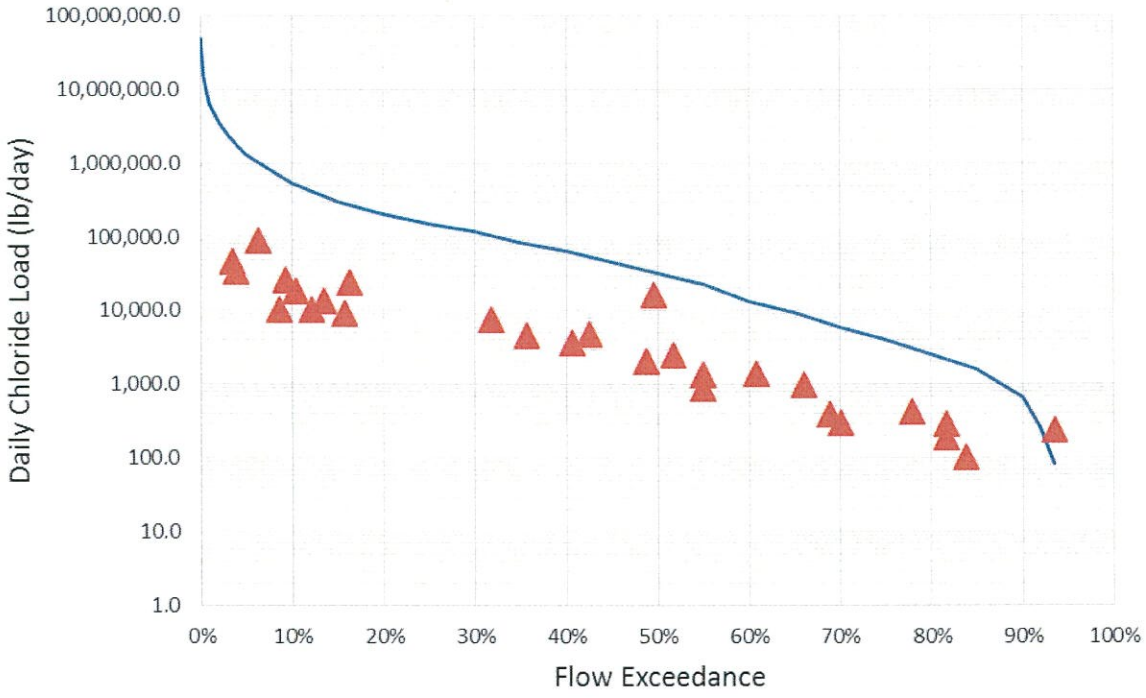


Figure 4-7: Chloride Load Duration Curve for Pond Creek (IL_NG-02) with Observed Loads (triangles)

In Figure 4-7, the data show that the single exceedance of the chloride target occurs at the lowest sampled flow. This indicates that wet weather sources do not contribute to the observed violation of the water quality standard. With the single data point showing an exceedance of the water quality standard for Chloride occurring at the very lowest flows, this indicates that the impairment may be flow related. Before implementing a TMDL for this stream segment, additional monitoring is recommended to confirm that the impairment is related to a pollutant load source, and is not only related to very low flow conditions in the stream. Additional monitoring recommendations are contained in the Watershed Implementation Plan to achieve the TMDLs and Load Reduction Strategy in the Upper Big Muddy River watershed.

4.2.6 Beaver Cr. / IL_NGAZ-JC-D1 – Manganese Load Duration Curve

This section describes the flow and water quality data used to support development of the load duration curve for manganese on the above noted stream segment.

4.2.6.a Flow Data

Daily flow measurements are available for the USGS gage on Crab Orchard Creek near Marion, IL (USGS gage number 05597500) for the period from 1999 through 2015. This gage has a drainage area of 31.7 square miles, so all flow data from the gage are adjusted based on the drainage area ratio (DAR) to the stream segment under consideration.

The stream gage data shows that there are periods where there is no flow in the stream, This does not necessarily mean that the stream dries up, but the flows are below the threshold for stream measurement. This causes the load-duration curve to be equal to zero during these time periods.

4.2.6.b Water Quality Data

Manganese data collected by IEPA in 2008 were used in the analysis. There is only a single data point available for this analysis.

4.2.6.c Analysis

A flow duration curve was generated by ranking daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results. The load duration curve for manganese was generated by multiplying the flows in the duration curve by the chronic water quality standard of 4.85 mg/L, which was calculated based on a hardness measurement of 383 mg/L that was field measured at the same time at the manganese measurement in this stream segment. The load duration curve for manganese is shown with a solid line in Figure 4-8. Observed pollutant loads were calculated using available concentration data paired with corresponding flows, and were plotted on the same graph.

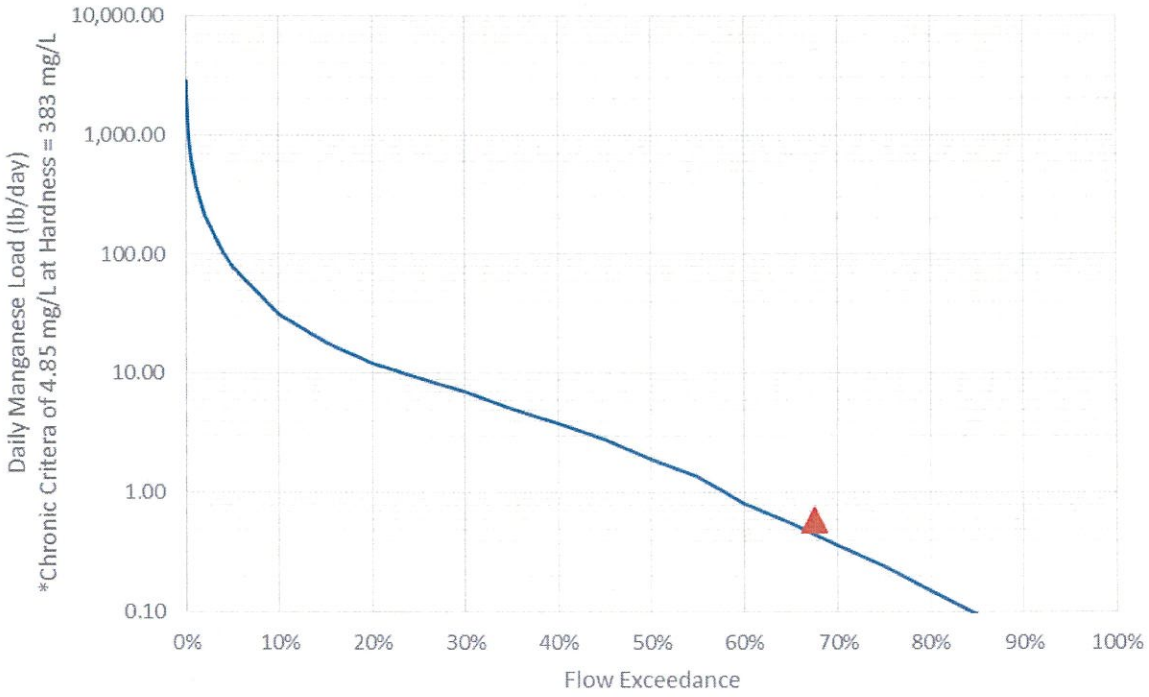


Figure 4-8: Manganese Load Duration Curve for Beaver Creek (IL_NGAZ-JC-D1 with Observed Loads (triangles)

In Figure 4-8, the data show that the single exceedance of the manganese target occurs at the lower end of the normally encountered flows (30% to 70%).

4.2.7 M. Fk. Big Muddy / IL_NH-06 – Fecal Coliform Load Duration Curve

This section describes the flow and water quality data used to support development of the load duration curve for fecal coliform bacteria on the above noted stream segment.

4.2.7.a Flow Data

There is no stream gage on this segment of the Middle Fork of the Big Muddy River that can be used to estimate the daily flows and loadings. Daily flow measurements are available for the USGS gage on Casey Fork near Mount Vernon, IL (USGS gage number 05595820) for the period from 1999 through 2015. Casey Fork is a tributary to the Big Muddy River upstream of Rend Lake, so flows at that location are not impacted by the reservoir storage and dam operations. This gage is located approximately 23.3 miles north of station NH-06, where the water quality data was collected. This gage has a drainage area of 76.9 square miles, so all flow data from the gage are adjusted based on the drainage area ratio (DAR) to the

stream segment under consideration. The stream segment under consideration has a drainage area of 160.6 square miles at its outlet.

4.2.7.b Water Quality Data

Fecal coliform data collected at station NH-06 by IEPA between 1999 and 2010 were used in the analysis. The data were collected as part of IEPA's ambient water quality monitoring program. Only data for the months of May-October were used because the water quality standard applies only during this period.

4.2.7.c Analysis

A flow duration curve was generated by ranking daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results. The load duration curve for fecal coliform were generated by multiplying the flows in the duration curve by the water quality standard of 200 cfu/100 mL for fecal coliform bacteria. The load duration curve for fecal coliform is shown with a solid line in Figure 4-9. Observed pollutant loads of fecal coliform were calculated using available concentration data paired with corresponding flows, and were plotted on the same graph. The fecal coliform data used only measurements collected between May and October, since that is the period specified under Section 302.209 of Title 35.

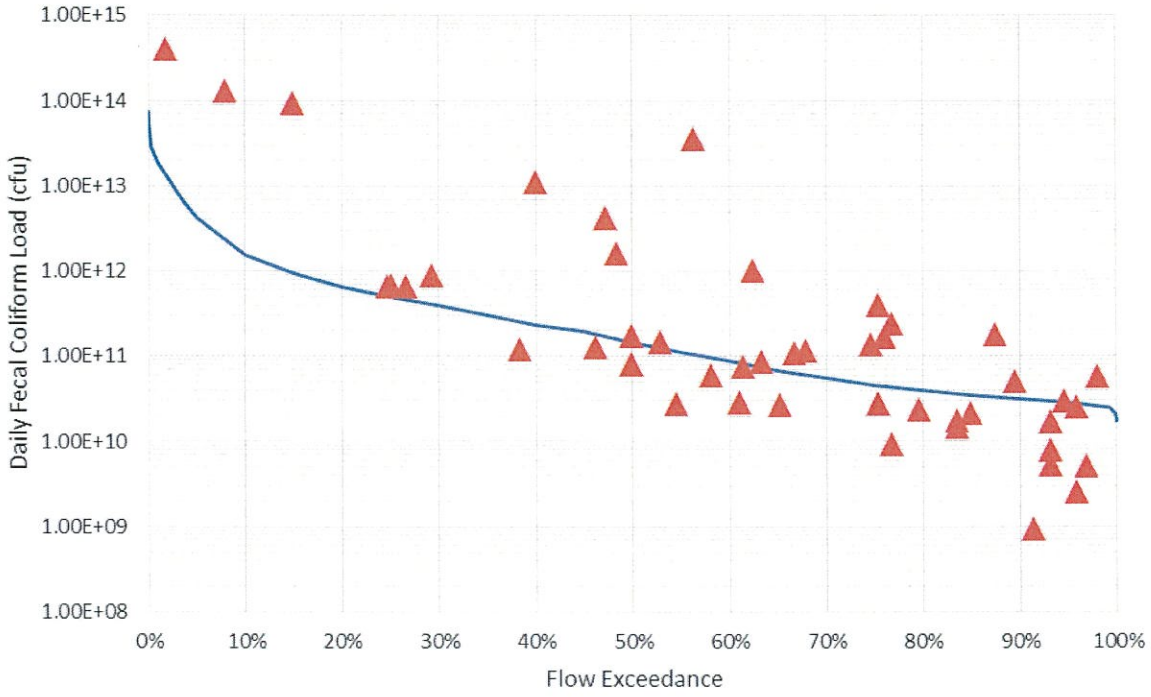


Figure 4-9. Fecal Coliform Load Duration Curve for Middle Fork Big Muddy River (IL_N-11) with Observed Loads (triangles)

In Figure 4-9, exceedances of the fecal coliform target occur over all ranges of flows, but with more exceedances in the higher range of flows. This indicates that wet weather sources are a contributing factor to the observed violations of the water quality standard, but that significant dry weather reductions are necessary as well.

4.3 BATHTUB Model

The BATHTUB model (Walker, 1986) was selected as the tool to define load reduction necessary to attain phosphorus targets in the following lakes/reservoirs located in the Upper Big Muddy River watershed:

- Herrin Old / IL_RNZD
- Johnston City / IL_RNZE
- Arrowhead (Williamson) / IL_RNZX
- West Frankfort Old / IL_RNP
- West Frankfort New/ IL_RNQ

4.3.1 Model Selection

A detailed discussion of the model selection process is provided in the Stage 1 report (Attachment 1). BATHTUB is a simple modeling tool that can predict the relationship between phosphorus load and resulting in-lake phosphorus concentrations. The BATHTUB model was selected because it does not have extensive data requirements (and can therefore be applied with existing data), yet still provides the capability for calibration to observed lake data. BATHTUB has been used previously for several reservoir TMDLs in Illinois, and has been cited as an effective tool for lake and reservoir water quality assessment and management, particularly where data are limited (Ernst et al., 1994).

BATHTUB is a software program for predicting the lake/reservoir response to nutrient loading. Because reservoir ecosystems typically have different characteristics than many natural lakes, BATHTUB was developed to specifically account for some of these differences, including the effects of non-algal turbidity on transparency and algae responses to phosphorus.

BATHTUB contains a number of empirical regression equations that have been calibrated using a wide range of lake and reservoir data sets. It can treat the lake or reservoir as a continuously stirred, mixed reactor, or it can predict longitudinal gradients in trophic state variables in a reservoir or narrow lake. These trophic state variables include in-lake total and ortho-phosphorus, organic nitrogen, hypolimnetic dissolved oxygen, metalimnetic dissolved oxygen, chlorophyll concentrations, and Secchi depth (transparency). Both tabular and graphical displays are available from the program.

4.3.2 Modeling Approach

The approach taken for the total phosphorus TMDLs consisted of using existing empirical data to define current loads to each of the lakes, and using the BATHTUB model to define the extent to which these loads must be reduced to meet water quality standards. This approach was taken because phosphorus concentrations exceed the water quality standards, often by significant amounts. Phosphorus loads will need to be reduced to a fraction of existing load in order to attain water quality standards.

4.3.3 BATHTUB Model Inputs

This section gives an overview of the model inputs required for BATHTUB application, and how they were derived for application to the reservoirs on this project. The following categories of inputs are required for BATHTUB:

- Model Options
- Global Variables
- Reservoir Segmentation
- Tributary Loads

  The model options and global variables applied universally across the 5 lakes that were modeled in BATHTUB for this this project. Those are discussed below, with the descriptions of the reservoir segmentation and tributary loads in each model contained in separate sections of this report.



4.3.3.a Model Options

BATHTUB provides a multitude of model options to estimate nutrient concentrations in a reservoir. Model options were entered as shown in Table 4-5, and the rationale for these options discussed below. No conservative substance was being simulated, so this option was not needed. The Canfield and Bachman phosphorus option was selected for phosphorus, as this is a commonly used formulation for Midwestern phosphorus TMDLs (e.g. MPCA, 2007; https://www.pca.state.mn.us/sites/default/files/wq-iw8-03e.pdf) Nitrogen was not simulated because phosphorus is the nutrient of concern.

Chlorophyll a and transparency were not simulated because the water quality target is specified as total phosphorus. The Fischer numeric dispersion model was selected, which is the default approach in BATHTUB for defining mixing between lake segments. Phosphorus calibrations were based on lake concentrations. No nitrogen calibration was required. The use of availability factors was not required and estimated concentrations were used to generate mass balance Tables.

Table 4-5. BATHTUB Model Options

Model	Model Option
Conservative substance	Not computed
Total phosphorus	Canfield and Bachman
Total nitrogen	Not computed
Chlorophyll-a	Not computed
Transparency	Not computed
Longitudinal dispersion	Fischer-numeric
Phosphorus calibration	Concentrations
Nitrogen calibration	None
Error analysis	Model and Data
Availability factors	Ignored
Mass-balance Tables	Use estimated concentrations

4.3.3.b Global Variables

The global variables required by BATHTUB consist of:

- The averaging period for the analysis
- Precipitation, evaporation, and change in lake levels
- Atmospheric phosphorus loads

BATHTUB is a steady state model, whose predictions represent concentrations averaged over a period of time. One decision in the application of BATHTUB is the selection of length of time over which inputs and outputs should be modeled. An annual averaging period was used for all lakes in the Upper Big Muddy watershed, consistent with the fact that tributary loading estimates represented annual average conditions.

There was no assumed increase in storage during the modeling period, to represent steady state conditions. The values selected for precipitation and change in lake levels have little influence on model predictions. Atmospheric phosphorus loads were specified using default values provided by BATHTUB.

4.3.3.c Reservoir Segmentation

BATHTUB provides the capability to divide the reservoir under study into a number of individual segments, allowing prediction of the change in phosphorus concentrations over the length of each segment. The segmentation scheme selected for the lakes modeled was designed to provide at least two



segments per lake, to include segment representing the deeper conditions near the dam, and at least one upstream segment, depending on the lake and the conficuration of the primary lake sampling stations.

Table 4-6. BATHTUB Model Segmentation

Lake / Reservoir	Total Size (ac)	Model Segments
Herrin Old / IL_RNZD	51.3	2
Johnston City / IL_RNZE	64	2
Arrowhead (Williamson) / IL_RNZX	30	3
West Frankfort Old / IL_RNP	146	2
West Frankfort New/ IL_RNQ	214	3

The areas of the segments and the watersheds for the segments were determined by Geographic Information System (GIS), and maps are provided for each of the lakes provided below.

BATHTUB requires that a range of inputs be specified for each segment. These include segment surface area, length, total water depth, and depth of thermocline and mixed layer. Segment-specific values for segment depths (total, thermocline and mixed layer) were calculated from the lake monitoring data, while segment lengths and surface areas were calculated via GIS.

4.3.3.d Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Tributary and direct drainage flows to each segment were estimated using observed flows at the USGS gaging station at on Crab Orchard Creek near Marion, IL (USGS gage number 05597500), adjusted through the use of drainage area ratios as follows:

Flow into segment = Flow at USGS gage * Segment-specific drainage area ratio

Drainage area ratio = Drainage area of watershed contributing to model segment

Drainage area of watershed contributing to USGS gage

Segment-specific drainage area ratios were calculated via GIS information.

Total phosphorus concentrations for each tributary and direct drainage inflow were estimated by dividing the watershed phosphorus load (calculated based on land use and literature phosphorus loading rates) by the tributary flow.

Average total phosphorus concentrations = Annual watershed phosphorus loads / Annual tributary flow

A complete listing of all segment-specific flows and tributary concentrations is provided in Attachment 4.

4.3.4 BATHTUB Calibration

BATHTUB model calibration consists of:

1. Applying the model with all inputs specified as above
2. Comparing model results to observed phosphorus data
3. Adjusting model coefficients to provide the best comparison between model predictions and observed phosphorus data.

Additional site-sprecific information on the calibration of the BATHTUB model application for each reservoir in the Upper Big Muddy River watershed is given in the sections below.



4.3.5 Herrin Old / IL_RNZD BATHTUB Model Application

Herrin Old Reservoir is a 51 acre lake located in Williamson County, Illinois. It is approximately 21 feet deep at its deepest point near the dam at the downstream side of the lake. Herrin Old Lake requires a TMDL for total phosphorus.

The listing and recommendation of a TMDL for total phosphorus in the Stage 1 report was based on a single water quality sample taken in 2011 that exceeded the water quality standard of 0.05 mg/L. Additional data from 2012 and 2013 was provided by IEPA for the modeling and TMDL preparation. The new data shows that the water quality sampled at the upstream stations (RNZD02 & RNZD-3) all met the water quality standards. These were all sampled at a depth of 1 ft. The only samples taken during this period that exceeded the water quality standard we taken at station RNZD-1 at depths near the bottom of the reservoir. This indicates that the internal phosphorus loading from sedimants is the primary source contributing to the impairment of the water body.

4.3.5.a Reservoir Segmentation

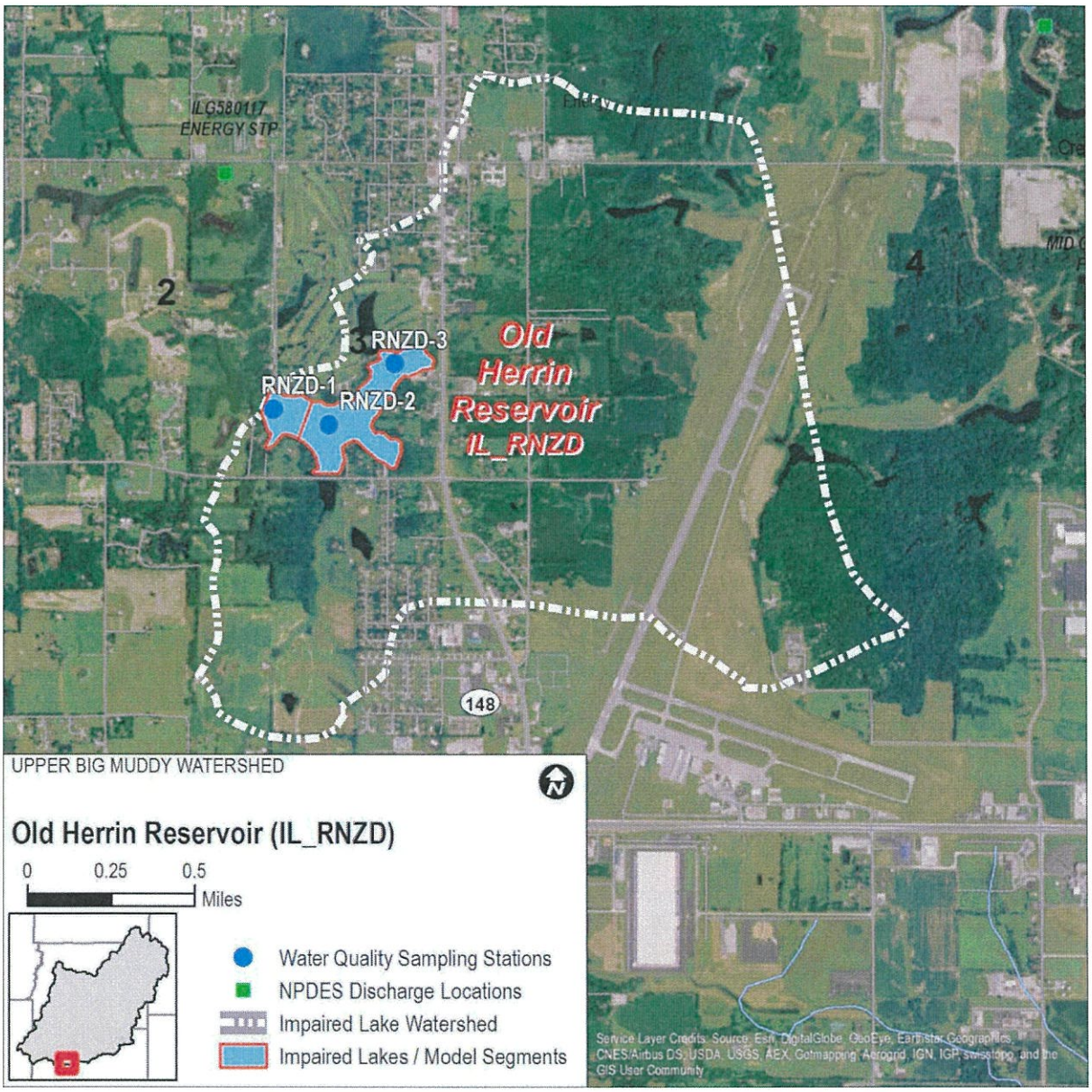


Figure 4-10. Old Herrin Reservoir (IL_RNZD) Segmentation Used in BATHTUB Model

4.3.5.b Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Tributary and direct drainage flows to each segment were estimated using observed flows at the USGS gaging station at on Crab Orchard Creek near Marion, IL (USGS gage number 05597500), adjusted through the use of drainage area ratios as described in section 4.3.3.d above.

Annual average flow from the contributing watershed calculated using the above method was 3.2 cfs, and the annual average total phosphorus concentrations (calculated based on land use and literature phosphorus loading rates) 0.029 mg/L. This correlated well with the observed total phosphorus

concentrations at the upstream sampling stations (RNZD-2 and RNZD-3). The total estimated annual watershed load is 84.3 kg/yr of total phosphorus.

A complete listing of all segment-specific flows and tributary concentrations is provided in Attachment 4.

4.3.5.c BATHTUB Calibration

The BATHTUB model was initially applied with the model inputs as specified above. Observed lake data for the year 2012 were used for calibration purposes.

BATHTUB was calibrated to match the observed reservoir-average phosphorus concentrations. Model results using default model parameters initially under-predicted the observed phosphorus, i.e. model predictions were lower than observed concentrations. Phosphorus loss rates in BATHTUB reflect a typical "net settling rate" (i.e. settling minus sediment release) observed in a range of reservoirs. Under-prediction of observed phosphorus concentrations can occur in cases of elevated phosphorus release from lake sediments. The mismatch between model and data was corrected via the addition of an internal phosphorus load of 12 mg/m²/day in the downstream model segment (Segment 1). This internal load estimate was adjusted during the model calibration to match th observed data. The resulting modeled and observed total phosphorus concentrations are shown in Figure 4-11. BATHTUB output files are provided in Attachment 4.

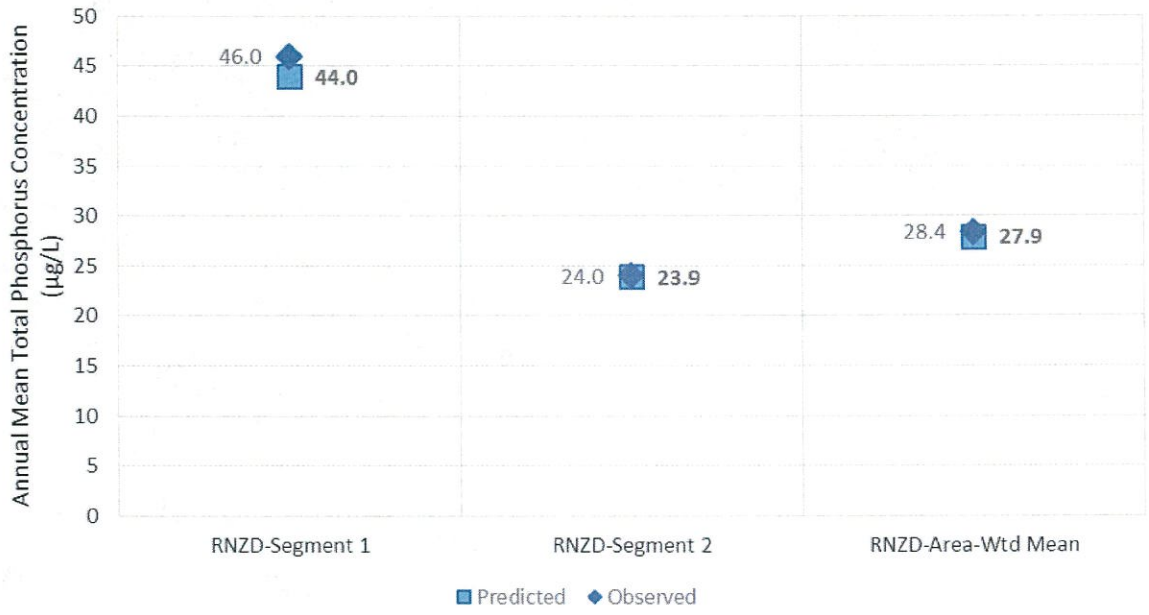


Figure 4-11. Herrin Old (IL_RNZD) BATHTUB Segment Modeled vs. Observed Total Phosphorus Concentration

4.3.6 Johnston City / IL_RNZE BATHTUB Model Application

Johnston City Lake / IL_RNZE is an impoundment of Lake Creek; it is just east of Freeman No. 4 Mine. The lake requires a TMDL for total phosphoru. The most recent water quality data for Johnston City Lake is from 2002. There are three sampling stations located within the lake, as shown in Figure 4-12 below.

4.3.6.a Reservoir Segmentation

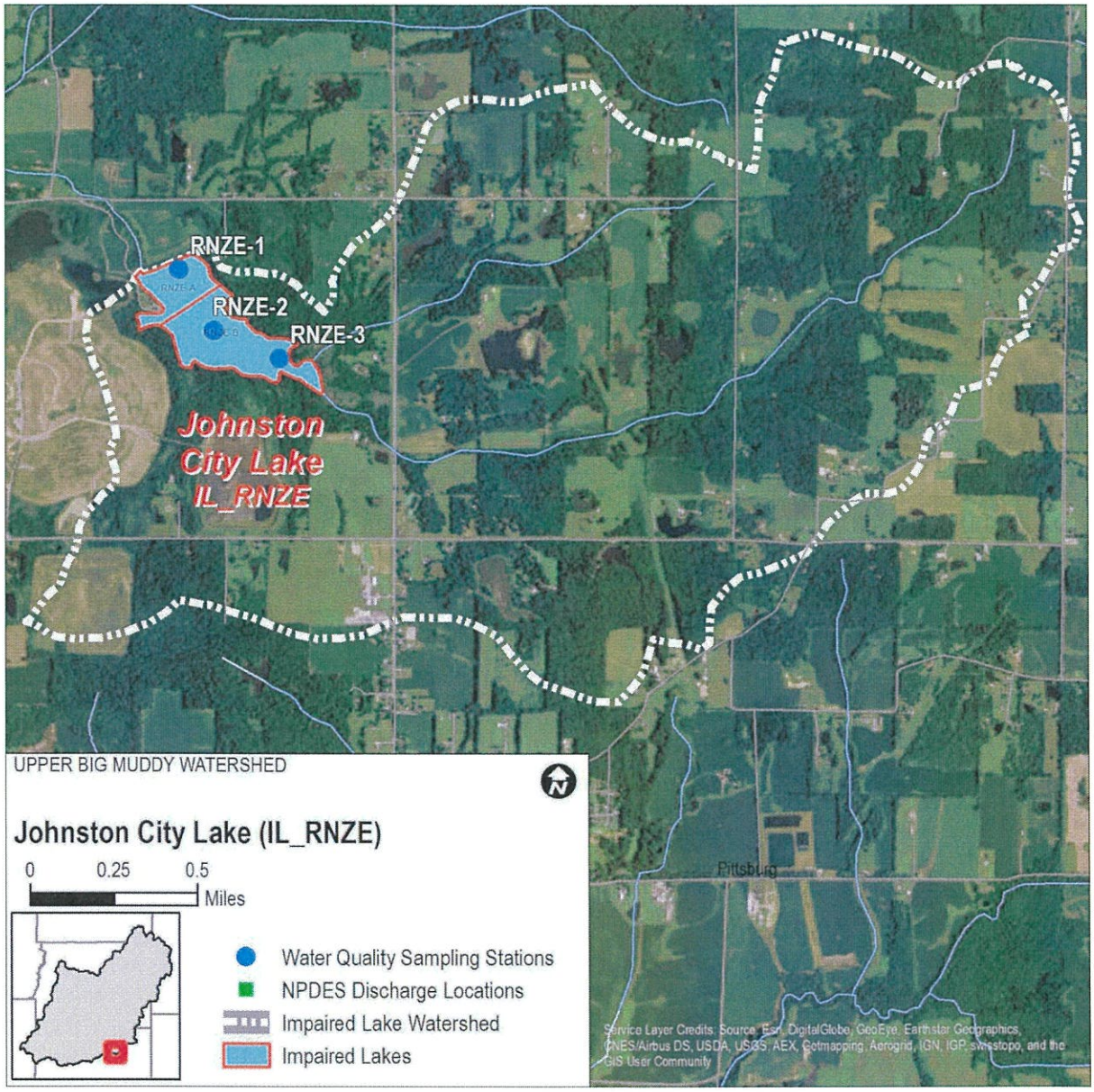


Figure 4-12. Johnston City Lake (IL_RNZE) Segmentation Used in BATHTUB Model

4.3.6.b Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Tributary and direct drainage flows to each segment were estimated using observed flows at the USGS gaging station at on Crab Orchard Creek near Marion, IL (USGS gage number 05597500), adjusted through the use of drainage area ratios as described in section 4.3.3.d above.

Annual average flow from the contributing watershed calculated using the above method was 4.9 cfs, and the annual average total phosphorus concentrations (calculated based on land use and literature phosphorus loading rates) 0.040 mg/L. The total estimated annual watershed load is 175.5 kg/yr of total phosphorus.

A complete listing of all segment-specific flows and tributary concentrations is provided in Attachment 4.

4.3.6.c BATHTUB Calibration

The BATHTUB model was initially applied with the model inputs as specified above. Observed lake data for the year 2002 were used for calibration purposes.

BATHTUB was calibrated to match the observed reservoir average phosphorus concentrations. Model results using default model parameters initially under-predicted the observed phosphorus, i.e. model predictions were lower than observed concentrations. Phosphorus loss rates in BATHTUB reflect a typical "net settling rate" (i.e. settling minus sediment release) observed in a range of reservoirs. Under-prediction of observed phosphorus concentrations can occur in cases of elevated phosphorus release from lake sediments. The mismatch between model and data was corrected via the addition of an internal phosphorus load of 2 mg/m²/day in the upstream model segment (Segment 2). The resulting modeled and observed total phosphorus concentrations are shown in Figure 4-13. BATHTUB output files are provided in Attachment 4.

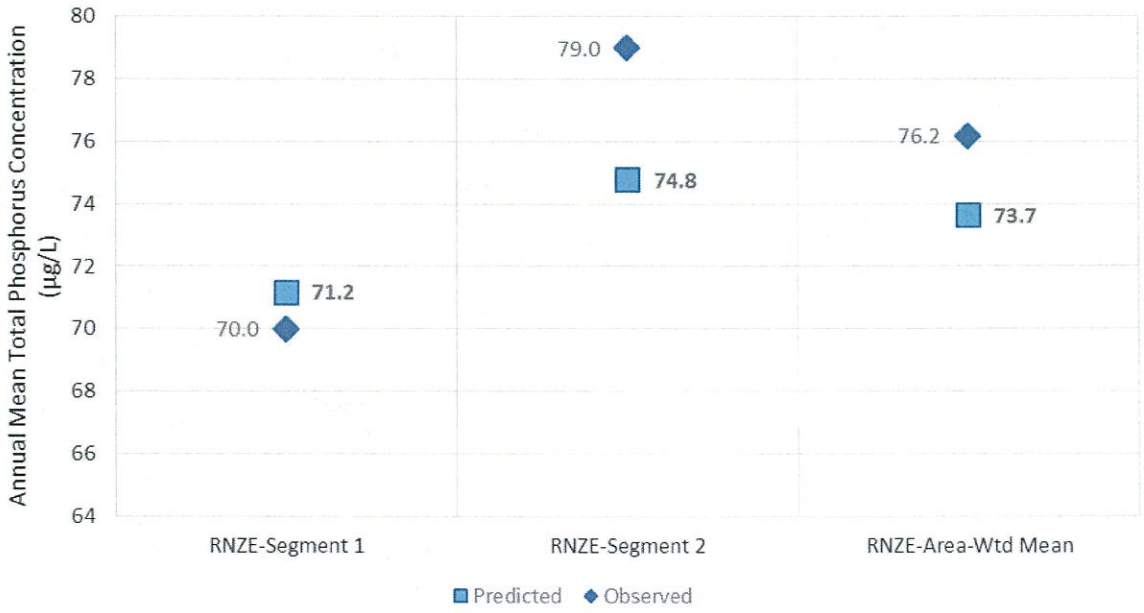


Figure 4-13. Johnston City Lake (IL_RNZE) BATHTUB Segment Modeled vs. Observed Total Phosphorus Concentration

4.3.7 Arrowhead (Williamson) / IL_RNZX BATHTUB Model Application

Arrowhead Lake (Williamson) / IL_RNZX is located just northeast of Johnston City, near Shakerag, IL. Arrowhead requires a TMDL for total phosphorus.

4.3.7.a Reservoir Segmentation

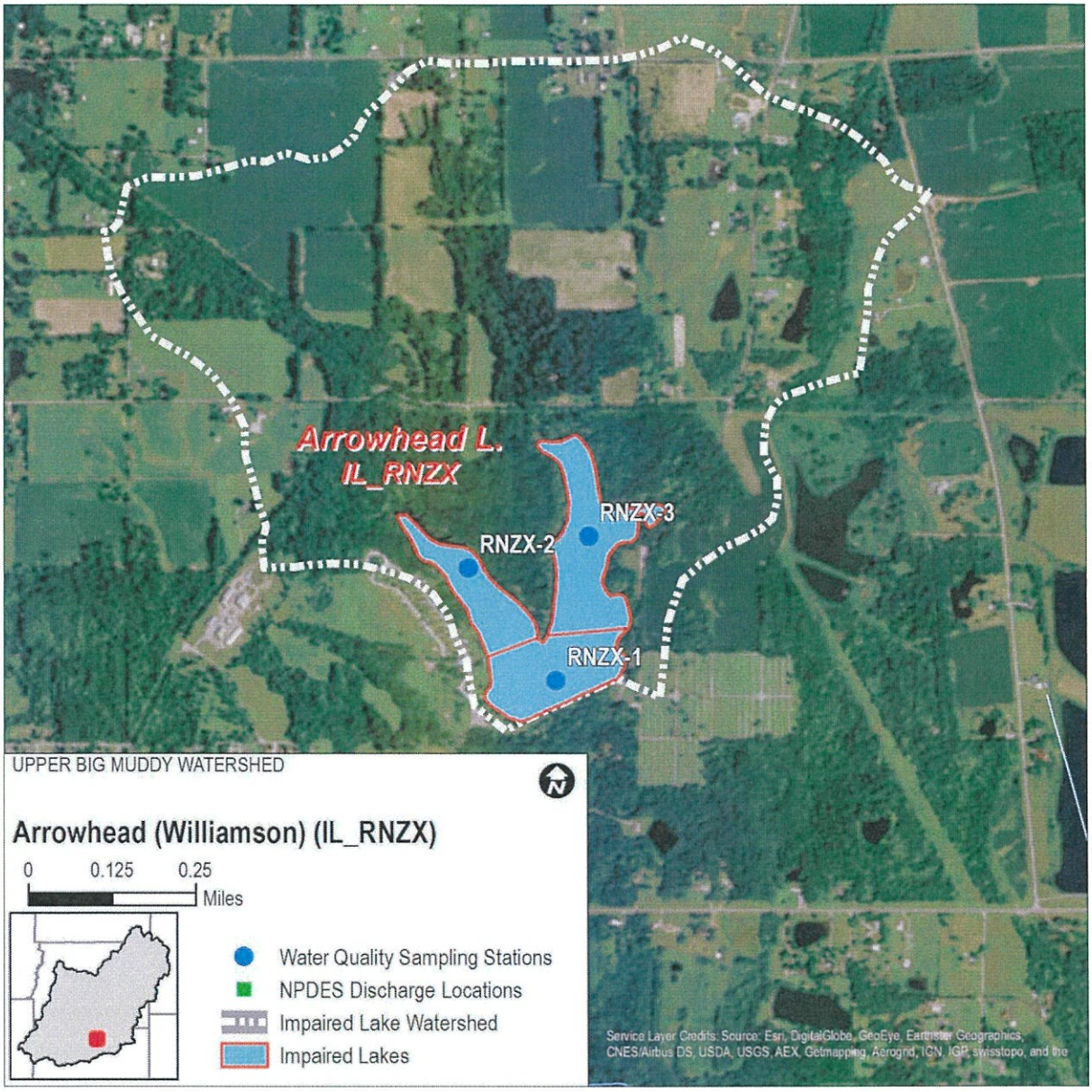


Figure 4-14. Arrowhead (Williamson) (IL_RNZX) Segmentation Used in BATHTUB Model

4.3.7.b Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Tributary and direct drainage flows to each segment were estimated using observed flows at the USGS gaging station at on Crab Orchard Creek near Marion, IL (USGS gage number 05597500), adjusted through the use of drainage area ratios as described in section 4.3.3.d above.

Annual average flow from the contributing watershed calculated using the above method was 1.0 cfs, and the annual average total phosphorus concentration (calculated based on land use and literature

phosphorus loading rates) was 0.046 mg/L. The total estimated annual watershed load is 39.7 kg/yr of total phosphorus.

A complete listing of all segment-specific flows and tributary concentrations is provided in Attachment 4.

4.3.7.c BATHTUB Calibration

The BATHTUB model was initially applied with the model inputs as specified above. Observed lake data for the year 2013 were used for calibration purposes.

BATHTUB was calibrated to match the observed reservoir-average phosphorus concentrations. Model results using default model parameters initially under-predicted the observed phosphorus, i.e. model predictions were lower than observed concentrations. Phosphorus loss rates in BATHTUB reflect a typical "net settling rate" (i.e. settling minus sediment release) observed in a range of reservoirs. Under-prediction of observed phosphorus concentrations can occur in cases of elevated phosphorus release from lake sediments. The mismatch between model and data was corrected via the addition of an internal phosphorus load of 12 mg/m²/day. The resulting modeled and observed total phosphorus concentrations are shown in Figure 4-15. BATHTUB output files are provided in Attachment 4.

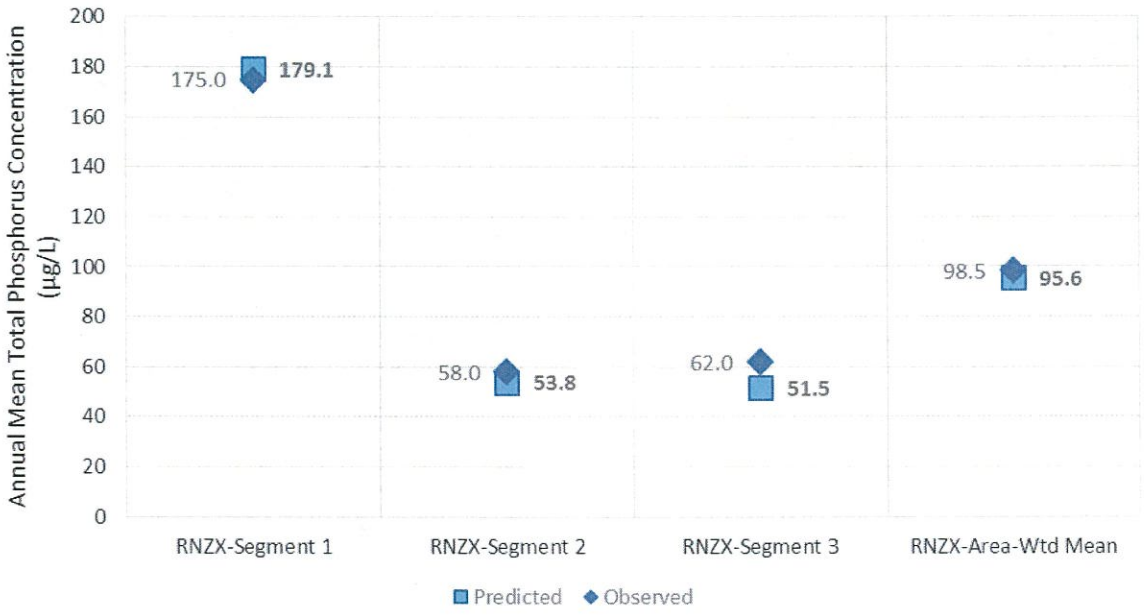


Figure 4-15. Arrowhead (Williamson) (IL_RNZX) BATHTUB Segment Modeled vs. Observed Total Phosphorus Concentration

4.3.8 West Frankfort Old / IL_RNP BATHTUB Model Application

West Frankfort Old City Lake is a 147 acre impoundment located approcimately 6 miles east of the West Frankfort in Franklin County that requires a TMDL for total phosphorus. The water quality data used to develop the BATHTUB model was collected in 2008 and 2013.

4.3.8.a Reservoir Segmentation

The BATHTUB model for the West Franklin Old Reservior, was developed with two model segments as shown in Figure 4-16, one representing the upstream monitoring stations (RNP-2 & RNP-3), and one representing the downstream station at the deepest portion of the lake (RNP-1).

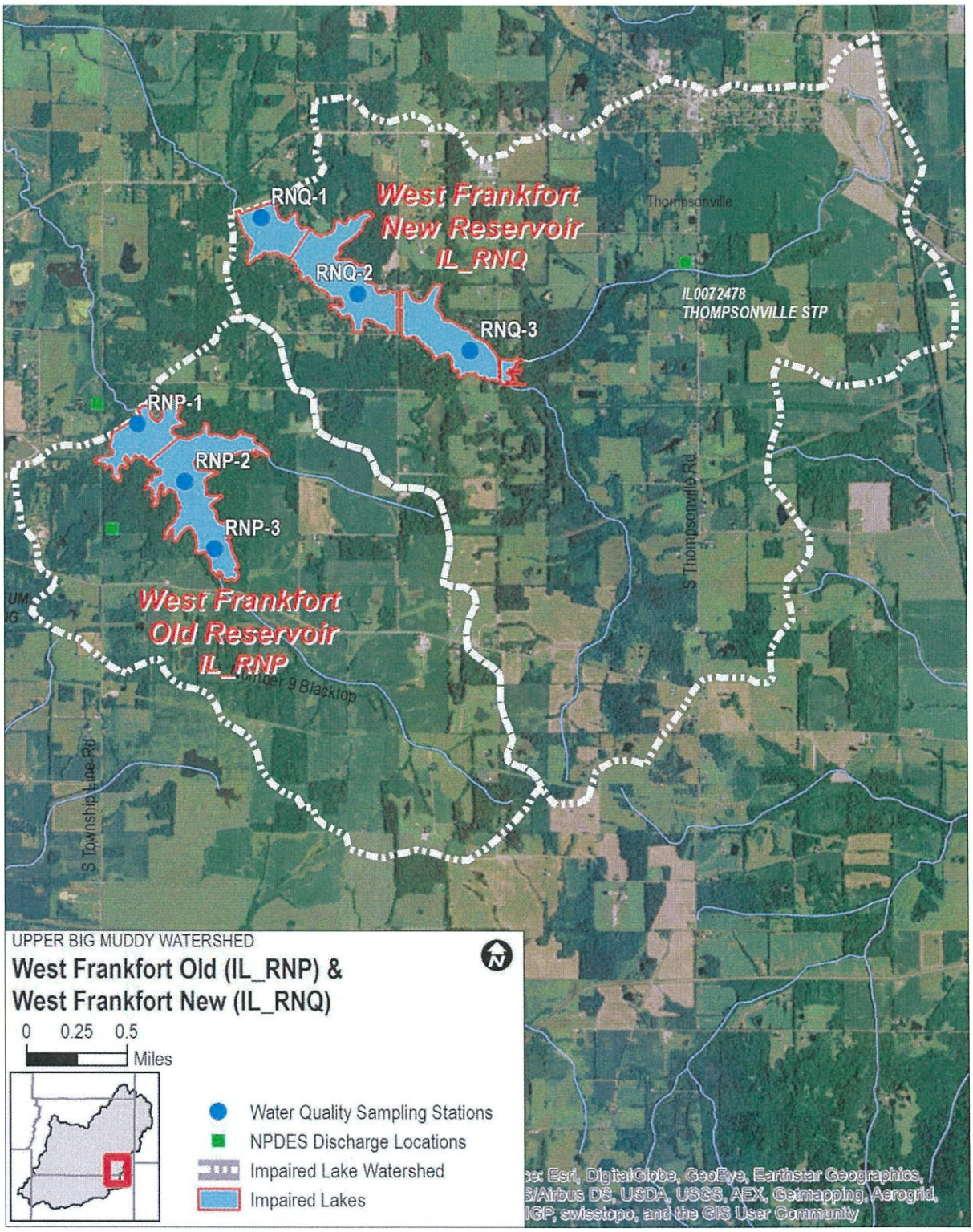


Figure 4-16. West Frankfort Old (IL_RNP) and West Frankfort New (IL_RNQ) Lake Segmentation Used in BATHTUB

4.3.8.b Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Tributary and direct drainage flows to each segment were estimated using observed flows at the USGS gaging station at on Crab Orchard Creek near Marion, IL (USGS gage number 05597500), adjusted through the use of drainage area ratios as described in section 4.3.3.d above.

Annual average flow from the contributing watershed calculated using the above method was 5.0 cfs, and the annual average total phosphorus concentration (calculated based on land use and literature phosphorus loading rates) was 0.164 mg/L. The total estimated annual watershed load is 725.5 kg/yr (1599.5 lb/year) of total phosphorus.

4.3.8.c BATHTUB Calibration

The BATHTUB model was initially applied with the model inputs as specified above. Observed lake data for the years 2008 and 2013 were used for calibration purposes.

BATHTUB was calibrated to match the observed reservoir-average phosphorus concentrations. Model results using default model parameters initially under-predicted the observed phosphorus, i.e. model predictions were lower than observed concentrations. Phosphorus loss rates in BATHTUB reflect a typical "net settling rate" (i.e. settling minus sediment release) observed in a range of reservoirs. Under-prediction of observed phosphorus concentrations can occur in cases of elevated phosphorus release from lake sediments. The mismatch between model and data was corrected via the addition of an internal phosphorus load of 40 mg/m²/day in the downstream segment (Segment 1). The resulting modeled and observed total phosphorus concentrations are shown in Figure 4-17. BATHTUB output files are provided in Attachment 4.



Figure 4-17. West Frankfort Old (IL_RNP) BATHTUB Segment Modeled vs. Observed Total Phosphorus Concentration

4.3.9 West Frankfort New/ IL_RNQ BATHTUB Model Application

4.3.9.a Reservoir Segmentation

West Frankfort New reservoir is located northeast of West Franklin Old Reservior, as shown in Figure 4-16. The BATHTUB model was developed with three model segments, one for each of the primary monitoring station in the lake.

4.3.9.b Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Tributary and direct drainage flows to each segment were estimated using observed flows at the USGS gaging station at on Crab Orchard Creek near Marion, IL (USGS gage number 05597500), adjusted through the use of drainage area ratios as described in section 4.3.3.d above.

Annual average flow from the contributing watershed calculated using the above method was 10.0 cfs, and the annual average total phosphorus concentration (calculated based on land use and literature phosphorus loading rates) was 0.101 mg/L. The total estimated annual watershed load is 906.2 kg/yr of total phosphorus.

In addition to the watershed loads, there is a point source load from the Thompsonville STP (IL0072478). The design average flow (DAF) for the facility is 0.08 million gallons per day (MGD) and the design maximum flow (DMF) for the facility is 0.20 MGD. Treatment consists of two cell aerated lagoon and rock filter.

The average daily flows from this STP reported in the DMRs from 2008 through 2016 0.087 MGD. There is no water quality data for total phosphorus from this point source to use for model calibration. The total phosphorus concentration in the STP effluent was assumed to be 3.66 mg/L. With the monthly average flows reported on the DMRs for that facility, the annual average loading is 437.4 kg/yr.

Based on the combined flow and loads from the sources identified above, the total annual average concentration into the reservoir is 0.148 mg/L, with a total annual loading of 1343.6 kg/yr.

4.3.9.c BATHTUB Calibration

The BATHTUB model was initially applied with the model inputs as specified above. Observed lake data for the year 2013 were used for calibration purposes.

BATHTUB was calibrated to match the observed reservoir-average phosphorus concentrations. Model results using default model parameters initially under-predicted the observed phosphorus, i.e. model predictions were lower than observed concentrations. Phosphorus loss rates in BATHTUB reflect a typical "net settling rate" (i.e. settling minus sediment release) observed in a range of reservoirs. Under-prediction of observed phosphorus concentrations can occur in cases of elevated phosphorus release from lake sediments. The mismatch between model and data was corrected via the addition of internal phosphorus loads of 25 mg/m^2/day in Segment 3 (upstream), 35 mg/m^2/day in Segment 2, and 90 mg/m^2/day in Segment 1 (downstream). The resulting modeled and observed total phosphorus concentrations are shown in Figure 4-18. BATHTUB output files are provided in Attachment 4.



Figure 4-18. West Frankfort New (IL_RNQ) BATHTUB Segment Modeled vs. Observed Total Phosphorus Concentration

4.4 Total Suspended Solids Model for Load Reduction Strategy Development

This section describes the model selection and modeling approach for the total suspended solids load reduction strategy for the following waterbodies in the Upper Big Muddy River watershed, identified by IEPA as being impaired due to elevated total suspended solids concentrations:

- Herrin Old / IL_RNZD
- Johnston City / IL_RNZE
- West Frankfort Old / IL_RNP
- West Frankfort New/ IL_RNQ
- Big Muddy R. / IL_N-06
- Big Muddy R. / IL_N-11
- Big Muddy R. / IL_N-17
- Hurricane Creek / IL_NF-01
- Pond Cr. / IL_NG-02
- M. Fk. Big Muddy / IL_NH-07

4.4.1 Modeling Approach

The total suspended solids load reduction strategy is based on a simple empirical model using the average of all available TSS data on each waterbody, and comparing it with the LRS endpoint concentration identified in Section 3.1.

The load reduction target concentration for TSS for all streams in this watershed is 27.75 mg/L. For all lakes in the watershed, the load reduction targets concentration is 23 mg/L.

After reviewing the water quality data available, it was found that the following waterbodies have average TSS concentrations already below the target for the watershed, and therefore will not have LRSs prepared.

- Herrin Old / IL_RNZD
- Johnston City / IL_RNZE
- West Frankfort Old / IL_RNP
- West Frankfort New/ IL_RNQ
- Hurricane Creek / IL_NF-01

5 TMDL Development for the Upper Big Muddy River Watershed

This section presents the development of the TMDLs for the following waterbodies in the Upper Big Muddy River watershed:

- Upper Big Muddy River (IL_N-11) for fecal coliform
- Andy Cr. (IL_NZN-13) for iron.
- Lake Cr. (IL_NGA-02) for dissolved oxygen.
- Beaver Cr. (IL_NGAZ-JC-D1) for manganese.
- Middle Fork Big Muddy (IL_NH-06) for fecal coliform.
- Arrowhead (Williamson) (IL_RNZX) for total phosphorus.
- Herrin Old (IL_RNZD) for total phosphorus.
- Johnston City (IL_RNZE) for total phosphorus.
- West Frankfort Old (IL_RNP) for total phosphorus.
- West Frankfort New (IL_RNQ) for total phosphorus.

In addition, a dissolved oxygen TMDL was planned for Andy Creek (IL_NZN-13), but after reviewing the field data and developing the QUAL2E model, it was determined that the low flows and high sediment oxygen demand were the primary causes of the low dissolved oxygen in this stream, not external pollutant loadings.

5.1 Andy Creek (IL_NZN-13) Dissolved Oxygen TMDL

A dissolved oxygen assessment was conducted for Andy Creek segment IL_NZN-13. The result of this assessment indicates that low stream flows preclude attainment of dissolved oxygen standards, even in the complete absence of external pollutant loads. For this reason, a TMDL is not being developed for dissolved oxygen. Details of the assessments are discussed below.

Two lines of assessment were used to make the determination that it is low stream flows, rather than external pollutant loads, that precludes attainment of dissolved oxygen standards:

1. Sediment oxygen demand is the dominant component of the dissolved oxygen mass balance provided by QUAL2E.
2. Setting all external loading sources to zero in the QUAL2E model does not result in attainment in dissolved oxygen standards.
3. Leaving all external loads at currently specified values, but increasing base stream flow, does result in attainment with dissolved oxygen standards.

5.1.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards.

The first step in determining the loading capacity was to reduce external sources of oxygen-demanding substances to determine whether these reductions would result in the river attaining the dissolved oxygen target.

QUAL2E simulations showed that, even with incremental inflow and permitted BOD loads set to zero, compliance with the dissolved oxygen standards was not attained. Examination of model results showed that sediment oxygen demand was the dominant source of the oxygen deficit, and that DO standards could only be attained during critical periods via reduction of SOD[1].

5.2 Lake Creek (IL_NGA-02) Dissolved Oxygen TMDL

A dissolved oxygen assessment was conducted for Lake Creek segment IL_NGA-02 utilizing the data collected in September 2015 and a QUAL2E model. The QUAL2E model was calibrated to the data available, which occurred during a month when there were effluent limit violations from the Johnston City STP for both CBOD5 and ammonia nitrogen.

To determine if the effluent violations were causing the observed DO impairments, the QUAL2E model was run with modifying the input loads from the Johnston City STP to the current permit limits of 10 mg/L $CBOD_5$ (monthly average effluent limit) and 1.5 mg/L ammonia nitrogen (monthly average effluent limit), and 6.0 mg/L of dissolved oxygen (monthly average minimum) at the design average flow for the facility of 0.55 MGD.

The result of this assessment shows that if the Johnston City STP effluent meets the above noted limits. The dissolved oxygen concentration in the stream reaches a minimum level of 5.37 mg/L, which is above the 5.0 mg/L endpoint selected for the TMDL based on the State of Illinois water quality standards.

5.2.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards.

The first step in determining the loading capacity was to reduce external sources of oxygen-demanding substances to determine whether these reductions would result in the river attaining the dissolved oxygen target.

QUAL2E simulations showed that with the point load $CBOD_5$ and ammonia nitrogen loads set to zero, compliance with the dissolved oxygen standards was attained with a minimum dissolved oxygen concentration of 5.38 mg/L.

Further QUAL2E simulations with adjusted BOD, dissolved oxygen, and ammonia nitrogen loads from the Johnston City STP were performed to determine the loading capacity. As noted above, QUAL2E model simulations with the input loads from the Johnston City STP set ther current permit limits of 10 mg/L $CBOD_5$ (monthly average effluent limit) and 1.5 mg/L ammonia nitrogen (monthly average effluent limit), and 6.0 mg/L of dissolved oxygen (monthly average minimum) at the design average flow for the facility of 0.55 MGD resulted in a minimum dissolved oxygen concentration of 5.37 mg/L, which is above the 5.0 mg/L endpoint selected for the TMDL based on the State of Illinois water quality standards.

Additional QUAL2E simulations were performed with the input loads from the Johnston City STP adjusted until the minimum dissolved oxygen concentration was 5.0 mg/L to determine the maximum loading capacity of the stream. The loading capacity of the stream for ammonia nitrogen was determined

[1] Although SOD is the dominant source of the oxygen deficit, the true cause of low dissolved oxygen is a lack of base flow (which greatly exacerbates the effect of SOD). Because TMDLs cannot be written to control flow, no TMDL was developed for this stream segment.

to be 1.80 mg/L, with a $CBOD_5$ load of 11 mg/L, and 5.45 mg/L of dissolved oxygen at the design average flow for the facility. The total loading capacity for Lake Creek segment IL_NGA-02 for ammonia nitrogen is 8.25 lb/day.

5.2.2 Allocation

A TMDL consists of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

The WLA for the Johnston City STP into Lake Creek segment IL_NGA-02 was calculated based on the permitted design average flow for the facility, and the current NPDES effluent limit concentration for ammonia nitrogen of 1.5 mg/L (monthly average limitation). The WLA for Lake Creek is presented in Table 5-1.

Table 5-1. Lake Creek Segment IL_NGA-02 Watershed Permitted Dischargers and WLAs

NPDES ID	Facility Name	Ammonia Nitrogen Effluent Concentration (mg/L)	Design average flow (MGD)	WLA (lb/day)
ILG0029301	Johnston City STP	1.50	0.55	6.88

The remaining loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The load allocation for nonpoint sources is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall phosphorus load. Given a total loading capacity of 8.25 lbs/day of ammonia nitrogen, a WLA for the Johnston City STP of 6.88 lbs/day, and an explicit margin of safety of 10% (discussed below), the load allocation for Lake Creek segment IL_NGA-02 is 0.54 lbs/day.

5.2.3 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The QUAL2E model and the sampling were performed during a low flow period, which is critical for determining loads associated with low dissolved oxygen.

5.2.4 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the QUAL2E water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the stream, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit total ammonia nitrogen load allocated to the margin of safety is 0.825 lbs/day for Lake Creek.

5.2.5 Reserve Capacity

Lake Creek is located in Williamson County, the population of which has increased by 8.3% between 2000 and 2010 (Stage 1 Report Section 2.6). In 2010, the U.S. Census Bureau estimated the Franklin County population at 66,357.



The Illinois Department of Public Health population projections (Shahidullah 2015) for Williamson County shows a slight population increase to 69,246 in the year 2025. Further, the Greater Egypt Regional Planning and Development Commission, referencing US Census Bureau projections, states that the population in the Greater Egypt 5-county area which includes Williamson County will be relatively steady (or slightly declining) through 2030 (GERPDC 2010).

A reserve capacity is not needed, due to the slight projected increase in population, and because, at this time IEPA is not aware of any increases in discharges from the existing point sources, or the establishment of future municipal or industrial point sources.

5.2.6 TMDL Summary

The dissolced oxygen (ammonia) TMDL for Lake Creek segment IL_NGA-02, is presented in Table 5-2.

Table 5-2. Lake Creek IL_NGA-02 TMDL Summary

Allocation	Total Ammonia Nitrogen Load (lbs/day)
Load Capacity (LC)	8.25
Wasteload Allocation (WLA)	6.88
Load Allocation (LA)	0.54
Margin of safety (10% of LC)	0.83

5.3 Upper Big Muddy River (IL_N-11) Fecal Coliform TMDL

A load capacity calculation approach was applied to support development of a fecal coliform TMDL for Upper Big Muddy River segment IL_N-11.

5.3.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards.

The loading capacity for Upper Big Muddy River segment IL_N-11 was defined over a range of specified flows based on expected Upper Big Muddy River flows at the mouth of the creek. The allowable loading capacity was computed by multiplying flow by the TMDL target (200 cfu/100 mL). The fecal coliform loading capacity for IL_N-11 is presented in Table 5-3.

Table 5-3. Fecal Coliform Load Capacity (IL_N-11)

Flow Exceedance Percentile from the LDC	Upper Big Muddy River Flow (cfs)	Allowable Load (cfu/day)
99%	9.7	4.8E+10
95%	11	5.6E+10
90%	13	6.2E+10
80%	16	7.7E+10
70%	22	1.1E+11
60%	35	1.7E+11
50%	57	2.8E+11
40%	93	4.6E+11
30%	150	7.6E+11
20%	260	1.3E+12
10%	610	3.0E+12
5%	1700	8.3E+12
1%	7200	3.5E+13

The maximum fecal coliform concentrations recorded between May and October were examined for each flow duration interval, as shown in Table 5-4, in order to estimate the percent reduction in existing loads required to meet the 200 cfu/100 mL target. As shown in Table 5-4, a greater reduction is needed at higher river flows to meet the target. During these higher flow periods, fecal coliform measurements were observed to exceed 200 cfu/100 mL more frequently.

Table 5-4. Required Reductions in Existing Loads under Different Flow Conditions (IL_N-11)

Flow Percentile Interval	Upper Big Muddy River Flow (cfs)	# samples > 200/ # samples (May-Oct)	Maximum fecal coliform concentration (cfu/100 ml)	Percent Reduction to Meet Target
0 - 30	28,875 - 154	3 / 8	4,500	95.6%
30 - 70	154 - 21.9	7 / 22	3,600	94.4%
70 - 100	21.9 - 6.9	1 / 15	210	4.8%

5.3.2 Allocation

A TMDL consists of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

The WLA for the 10 permitted sewage treatment plant discharges in the Upper Big Muddy River segment IL_N-11 watershed was calculated based on the permitted design average flow for these dischargers and a fecal coliform concentration that is consistent with meeting the TMDL target (200 cfu/100mL). Eight of the ten NPDES-permitted dischargers have disinfection exemptions, therefore, the WLA is based on the

dischargers meeting 200 cfu/100 mL at the downstream end of their exempted reach. WLAs are presented in Table 5-5.

Table 5-5. Segment IL_N-11 Watershed Permitted Dischargers and WLAs

NPDES ID	Facility Name	Disinfection exemption?	Design average flow (MGD)	WLA (cfu/day)
ILG580083	VALIER STP	Yes, year-round	0.08	6.06E+08
ILG580215	WEST CITY STP	Yes, year-round	0.1	7.57E+08
ILG580221	HANAFORD STP	Yes, year-round	0.042	3.18E+08
ILG580272	ORIENT STP	Yes, year-round	0.0752	5.69E+08
IL0050466	LB CAMPING-SESSER STP	No (400 cfu / 100 mL Daily Max)	0.0051	3.86E+07
IL0061760	HILL CITY APARTMENTS-BENTON	Yes, year-round	0.004	3.03E+07
IL0065111	REND LAKE CONS. DIST. STP	Yes, year-round	0.5	3.79E+09
IL0020851	CHRISTOPHER STP	Yes, year-round	0.768	5.81E+09
IL0022365	BENTON NORTHWEST STP	No (400 cfu / 100 mL Daily Max)	1.01	7.65E+09
IL0031704	WEST FRANKFORT STP	Yes, year-round	1.4	1.06E+10

The total WLA for the ten (10) point source dischargers in the IL_N-11 watershed is 3.02E+10 cfu/day. This does not include any dischargers in the areas upstream of Rend Lake. The significant retention time and settling capacity in the reservior are assumed to reduce fecal coliform loads from the upstream areas to be below the water quality standards.

The remainder of the loading capacity is given to the load allocation for nonpoint sources as an implicit MOS was used in this TMDL (Table 5-6). The load allocations are not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall fecal coliform load.



Table 5-6. Fecal Coliform TMDL for Segment IL_N-11 Upper Big Muddy River[1]

Upper Big Muddy River Flow (cfs)	Allowable Load (cfu/day)	Wasteload Allocation (WLA) (cfu/day)	Load Allocation (LA) (cfu/day)
12.6	6.16E+10	3.02E+10	3.14E+10
15.8	7.75E+10	3.02E+10	4.73E+10
21.9	1.07E+11	3.02E+10	7.71E+10
34.9	1.71E+11	3.02E+10	1.41E+11
56.9	2.78E+11	3.02E+10	2.48E+11
93.4	4.57E+11	3.02E+10	4.27E+11
154	7.55E+11	3.02E+10	7.25E+11
260	1.27E+12	3.02E+10	1.24E+12
609	2.98E+12	3.02E+10	2.95E+12
7226	3.54E+13	3.02E+10	3.53E+13

[1]This TMDL has an implicit Margin of Safety, so MOS is not included in this table.

5.3.3 Critical Condition

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Figure 4-5 provides a graphical depiction of the data compared to the load capacity, showing that exceedances of the TMDL target occur over the full range of flow conditions. TMDL development utilizing the load-duration approach applies to the full range of flow conditions; therefore critical conditions were addressed during TMDL development.

5.3.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The load capacity calculation approach used for the TMDL evaluated seasonal loads because only May through October water quality data were used in the analysis, consistent with the specification that the standard only applies during this period. The fecal coliform standard will be met regardless of flow conditions in the applicable season because the load capacity calculations specify target loads for the entire range of flow conditions that are possible to occur in any given point in the season where the standard applies.

5.3.5 Margin of Safety

Total maximum daily loads are required to contain a Margin of Safety (MOS) to account for any uncertainty concerning the relationship between pollutant loading and receiving water quality. The MOS can be either implicit (e.g., incorporated into the TMDL analysis through conservative assumptions), or explicit (e.g., expressed in the TMDL as a portion of the loading), or expressed as a combination of both. The fecal coliform TMDL contains an implicit margin of safety, through the use of multiple conservative assumptions. First, the TMDL target (no more than 200 cfu/100 mL at any point in time) is more conservative than the more restrictive portion of the fecal coliform water quality standard (geometric mean of 200 cfu/100 mL for all samples collected May through October). An additional implicit Margin of Safety is provided via the use of a conservative model to define load capacity. The model assumes no decay of bacteria that enter the river, and therefore represents an upper bound of expected concentrations for a given pollutant load. This margin of safety can be reviewed in the future as new data are developed.



5.4 Middle Fork Big Muddy (IL_NH-06) Fecal Coliform TMDL

A load capacity calculation approach was applied to support development of a fecal coliform TMDL for Middle Fork Big Muddy River segment IL_NH-06.

5.4.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards.

The loading capacity for the Middle Fork Big Muddy River segment IL_NH-06 was defined over a range of specified flows based on expected flows at the outlet of the segment. The allowable loading capacity was computed by multiplying flow by the TMDL target (200 cfu/100 mL). The fecal coliform loading capacity for IL_NH-06 is presented in Table 5-7.

Table 5-7. Fecal Coliform Load Capacity (IL_NH-06)

Flow Exceedance Percentile from the LDC	Middle Fork Big Muddy River Flow (cfs)	Allowable Load (cfu/day)
99%	5.0	2.5E+10
95%	5.8	2.9E+10
90%	6.5	3.2E+10
80%	8.1	4.0E+10
70%	11	5.5E+10
60%	18	8.8E+10
50%	29	1.4E+11
40%	48	2.4E+11
30%	79	3.9E+11
20%	130	6.5E+11
10%	310	1.5E+12
5%	870	4.2E+12
1%	3700	1.8E+13

The maximum fecal coliform concentrations recorded between May and October were examined for each flow duration interval, as shown in Table 5-8, in order to estimate the percent reduction in existing loads required to meet the 200 cfu/100 mL target. As shown in Table 5-8, the greatest reduction is needed at normally encountered river flows to meet the target. During these higher flow periods, fecal coliform measurements were observed to exceed 200 cfu/100 mL more frequently (as a fraction of the samples taken).

Table 5-8. Required Reductions in Existing Loads under Different Flow Conditions (IL_NH-06)

Flow Percentile Interval	Upper Big Muddy River Flow (cfs)	# samples > 200/ # samples (May-Oct)	Maximum fecal coliform concentration (cfu/100 ml)	Percent Reduction to Meet Target
0 - 30	14,849 - 79	7 / 7	20,000	99.0%
30 - 70	79 - 11.3	10 / 18	63,600	99.7%
70 - 100	11.3 - 3.55	7 / 21	1,760	88.6%

5.4.2 Allocation

A TMDL consists of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

The WLA for the 3 permitted sewage treatment plant discharges in the Middle Fork Big Muddy River segment IL_NH-06 watershed was calculated based on the permitted design average flow for these dischargers and a fecal coliform concentration that is consistent with meeting the TMDL target (200 cfu/100mL). All three of these NPDES-permitted dischargers have disinfection exemptions, therefore, the WLA is based on the dischargers meeting 200 cfu/100 mL at the downstream end of their exempted reach. WLAs are presented in Table 5-9.

Table 5-9. Segment IL_NH-06 Permitted Dischargers and WLAs

NPDES ID	Facility Name	Disinfection exemption?	Design average flow (MGD)	WLA (cfu/day)
ILG580221	HANAFORD STP	Yes, year-round	0.042	3.18E+08
IL0061760	HILL CITY APARTMENTS-BENTON	Yes, year-round	0.004	3.03E+07
IL0065111	REND LAKE CONS. DIST. STP	Yes, year-round	0.5	3.79E+09

The total WLA for the three (3) point source dischargers in the IL_NH-06 watershed is 4.13E+09 cfu/day.

The remainder of the loading capacity is given to the load allocation for nonpoint sources as an implicit MOS was used in this TMDL (Table 5-10). The load allocations are not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall fecal coliform load.

Table 5-10. Fecal Coliform TMDL for Segment IL_NH-06 Upper Big Muddy River[1]

Upper Big Muddy River Flow (cfs)	Allowable Load (cfu/day)	Wasteload Allocation (WLA) (cfu/day)	Load Allocation (LA) (cfu/day)
6.5	3.17E+10	4.13E+09	2.75E+10
8.1	3.99E+10	4.13E+09	3.57E+10
11.3	5.52E+10	4.13E+09	5.10E+10
18.0	8.79E+10	4.13E+09	8.38E+10
29.2	1.43E+11	4.13E+09	1.39E+11
48.0	2.35E+11	4.13E+09	2.31E+11
79.4	3.88E+11	4.13E+09	3.84E+11
134	6.54E+11	4.13E+09	6.50E+11
313	1.53E+12	4.13E+09	1.53E+12
3716	1.82E+13	4.13E+09	1.82E+13

[1]This TMDL has an implicit Margin of Safety, so MOS is not included in this table.

5.4.3 Critical Condition

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Figure 4-9 provides a graphical depiction of the data compared to the load capacity, showing that exceedances of the TMDL target occur over the full range of flow conditions. TMDL development utilizing the load-duration approach applies to the full range of flow conditions; therefore critical conditions were addressed during TMDL development.

5.4.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The load capacity calculation approach used for the TMDL evaluated seasonal loads because only May through October water quality data were used in the analysis, consistent with the specification that the standard only applies during this period. The fecal coliform standard will be met regardless of flow conditions in the applicable season because the load capacity calculations specify target loads for the entire range of flow conditions that are possible to occur in any given point in the season where the standard applies.

5.4.5 Margin of Safety

Total maximum daily loads are required to contain a Margin of Safety (MOS) to account for any uncertainty concerning the relationship between pollutant loading and receiving water quality. The MOS can be either implicit (e.g., incorporated into the TMDL analysis through conservative assumptions), or explicit (e.g., expressed in the TMDL as a portion of the loading), or expressed as a combination of both. The fecal coliform TMDL contains an implicit margin of safety, through the use of multiple conservative assumptions. First, the TMDL target (no more than 200 cfu/100 mL at any point in time) is more conservative than the more restrictive portion of the fecal coliform water quality standard (geometric mean of 200 cfu/100 mL for all samples collected May through October). An additional implicit Margin of Safety is provided via the use of a conservative model to define load capacity. The model assumes no decay of bacteria that enter the river, and therefore represents an upper bound of expected concentrations for a given pollutant load. This margin of safety can be reviewed in the future as new data are developed.



5.5 Andy Creek (IL_NZN-13) Iron TMDL

A load capacity calculation approach was applied to support development of dissolved iron TMDL for Andy Creek segment IL_NZN-13.

5.5.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards. The loading capacity was defined over a range of specified flows based on expected flows. The allowable loading capacity was computed by multiplying the estimated flow in Andy Creek by the TMDL target concentration of 1 mg/l (Table 5-11).

Table 5-11. Iron Load Capacity (IL_NZN-13)

Flow Exceedance Percentile from the LDC	Stream Flow (cfs)	Allowable Load (lbs/day)
90%	0.1	0.27
80%	0.2	1.0
70%	0	2.5
60%	1	5.5
50%	2	1.3
40%	5	2.6
30%	9	4.8
20%	15	8.3
10%	40	2.1
5%	99	5.4

The maximum dissolved iron concentrations were examined for each flow duration interval, as shown in Table 5-12, in order to estimate the percent reduction in existing loads required to meet the 1 mg/l target. Reductions of up to 9.9% in current loads are needed at higher river flows to meet the target. No reductions are needed at lower flows.

Table 5-12. Required Reductions in Existing Loads under Different Flow Conditions (IL_NZN-13)

Flow Percentile Interval	Stream Flow (cfs)	# samples > 1 mg/L / # samples	Maximum Dissolved Iron concentration (mg/L)	Percent Reduction to Meet Target
0 - 30	3,572 - 9	1 / 1	1.11	9.9%
30 - 70	9 - 0.46	0 / 1	0.081	-
70 - 100	0.46 - 0	0 / 1	0.038	-

5.5.2 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There are no permitted dischargers of iron in the Andy Creek segment IL_NZN-13 watershed, and therefore the wasteload allocation did not need to be calculated.

The remainder of the loading capacity is given to the load allocation for nonpoint sources and the MOS (Table 5-13). The load allocations are not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall iron load.

Table 5-13. Iron TMDL for Andy Creek (Segment IL_NZN-13)

Stream Flow (cfs)	Allowable Load (lbs/day)	MOS (10%) (lbs/day)	Wasteload Allocation (WLA) (lbs/day)	Load Allocation (LA) (lbs/day)
0.05	0.27	0.03	0	0.24
0.19	1.04	0.10	0	0.94
0.46	2.46	0.25	0	2.2
1.0	5.54	0.55	0	5.0
2.4	13.2	1.3	0	11.9
4.8	26.0	2.6	0	23.4
9.0	48.5	4.9	0	43.7
15	83.1	8.3	0	74.8
40	215	22	0	194
472	2541	254	0	2287

5.5.3 Critical Condition

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Figure 4-6 provides a graphical depiction of the data compared to the load capacity, showing that the TMDL target is exceeded during higher flow conditions. TMDL development utilizing the load-duration approach applies to the full range of flow conditions, including high flows; therefore critical conditions were addressed during TMDL development.

5.5.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The iron standard will be met regardless of flow conditions in any season because the load capacity calculations specify target loads for the entire range of flow conditions that are possible to occur in the stream.

5.5.5 Margin of Safety

Total maximum daily loads are required to contain a Margin of Safety (MOS) to account for any uncertainty concerning the relationship between pollutant loading and receiving water quality. The iron TMDL contains an explicit margin of safety of 10%. This 10% margin of safety was included to address potential uncertainty in the effectiveness of load reduction alternatives. This margin of safety can be reviewed in the future as new data are developed.

5.6 Beaver Creek (IL_NGAZ-JC-D1) Manganese TMDL

A load capacity calculation approach was applied to support development of an atrazine TMDL for Beaver Creek segment IL_NGAZ-JC-D1.

5.6.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards. The loading capacity was defined over a range of specified flows based on expected flows. The allowable loading capacity was computed by multiplying the estimated Beaver Creek flow by the TMDL target concentration of 4.85 mg/l (Table 5-14).

Table 5-14. Manganese Load Capacity (IL_NGAZ-JC-D1)

Flow Exceedance Percentile from the LDC	Beaver Creek Flow (cfs)	Allowable Load (lbs/day)
80%	0.006	0.15
70%	0.01	0.36
60%	0.03	0.81
50%	0.07	1.93
40%	0.15	3.80
30%	0.27	7.10
20%	0.47	12.16
10%	1.2	31.42
5%	3.0	78.36
1%	14	371.98

The maximum manganese concentrations were examined for each flow duration interval, as shown in Table 5-15, in order to estimate the percent reduction in existing loads required to meet the 4.85 mg/L target. Reductions of 24.4% of current loads are needed based on the single water quality sample data point sampled in the normally occurring flows interval. No reductions are are able to be calculated at lower or higher flows based on the data available.

Table 5-15. Required Reductions in Existing Loads under Different Flow Conditions (IL_NGAZ-JC-D1)

Flow Percentile Interval	Beaver Creek Flow (cfs)	# samples > 4.85 mg/l samples	Maximum Manganese concentration (mg/L)	Percent Reduction to Meet Target
0 - 30	108 - 0.27	0 / 0	-	-
30 - 70	0.27 - 0.01	1 / 1	6.41	24.4%
70 - 100	0.01 - 0	0 / 0	-	-

5.6.2 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There are no permitted dischargers of manganese in the Beaver Creer segment IL_NGAZ-JC-D1 watershed, and therefore the wasteload allocation did not need to be calculated.

The remainder of the loading capacity is given to the load allocation for nonpoint sources and the MOS (Table 5-16). The load allocations are not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall manganese load.



Table 5-16. Manganese TMDL for Beaver Creek (Segment IL_NGAZ-JC-D1)

Flow (cfs)	Allowable Load (lbs/day)	MOS (10%) (lbs/day)	Wasteload Allocation (WLA) (lbs/day)	Load Allocation (LA) (lbs/day)
0.01	0.36	0.04	0	0.32
0.03	0.81	0.08	0	0.73
0.07	1.9	0.2	0	1.7
0.15	3.8	0.4	0	3.4
0.27	7.1	0.7	0	6.4
0.5	12.2	1.2	0	11.0
1.2	31.3	3.1	0	28.2

5.6.3 Critical Condition

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Figure 4-8 provides a graphical depiction of the data compared to the load capacity, showing that the TMDL target is exceeded during higher flow conditions. TMDL development utilizing the load-duration approach applies to the full range of flow conditions, including high flows; therefore critical conditions were addressed during TMDL development.

5.6.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The atrazine standard will be met regardless of flow conditions in any season because the load capacity calculations specify target loads for the entire range of flow conditions that are possible to occur in the river.

5.6.5 Margin of Safety

Total maximum daily loads are required to contain a Margin of Safety (MOS) to account for any uncertainty concerning the relationship between pollutant loading and receiving water quality. The manganese TMDL contains an explicit margin of safety of 10%. This 10% margin of safety was included to address potential uncertainty in the effectiveness of load reduction alternatives. This margin of safety can be reviewed in the future as new data are developed.

5.7 Herrin Old (IL_RNZD) Total Phosphorus TMDL

5.7.1 Calculation of the Loading Capacity

The loading capacity for Herrin Old Reservoir was determined by running the BATHTUB model repeatedly, reducing the tributary nutrient concentrations and/or internal phosphorus loadings for each simulation until model results demonstrated attainment of the water quality objective.

The maximum tributary concentration that results in compliance with water quality standards was used as the basis for determining the loading capacity. The tributary concentration was then converted into a loading rate through multiplication with the tributary flow.

The initial BATHTUB simulations and the sampling data from 2013 indicated that Herrin Old Reservoir phosphorus concentrations would meet the the water quality standards using the lake-averaged



phosphorus concentrations. The sampling data indicated that the only exceedances of the water quality standard were at the deepest parts of the lake, which indicates that the internal phosphorus source needs to be reduced by either capping the sediments (e.g. alum treatment or similar), or by dredging any organic sediments from the lake. The resulting load, with calibrated tributary concentrations and no additional sediment phosphorus load yields an average phosphorus load of 0.23 kg/day (0.51 lbs/day) and a concentration of 0.029 mg/L. This is below the phosphorus target of 0.05 mg/L, so reductions in the tributary loads are not necessary.

5.7.2 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There are no point sources in the watershed, and therefore there is no wasteload allocation given for Herrin Old Reservoir. The entire loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The loading capacity is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall phosphorus load. Given a loading capacity of 0.23 kg/day (0.51 lbs/day), and an explicit margin of safety of 10% (discussed below), the load allocation for Herrin Old Reservoir of 0.21 kg/day (0.46 lbs/day).

5.7.3 Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events can transport significant quantities of nonpoint source loads to lake. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. This TMDL is based upon an annual period that takes into account both spring loads and summer water quality in order to effectively consider these critical conditions.

5.7.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The BATHTUB model used for this TMDL is designed to evaluate loads over a seasonal to annual averaging period. The annual loading analysis that was used is appropriate due to the facts that:

1. The analysis demonstrated that the TMDL could only attain water quality targets if a significant reduction was achieved in sediment phosphorus release.
2. There is a long response time between phosphorus loading and sediment response, typically on the order of several years (e.g. Chapra and Canale, 1991).

5.7.5 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the BATHTUB water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the watershed, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit total phosphorus load allocated to the margin of safety is 0.02 kg/day (0.04 lbs/day) for Herrin Old Reservoir.

5.7.6 Reserve Capacity

This watershed is located in Williamson County, the population of which has increased by 8.3% between 2000 and 2010 (Stage 1 Report Section 2.6). In 2010, the U.S. Census Bureau estimated the Franklin County population at 66,357.

The Illinois Department of Public Health population projections (Shahidullah 2015) for Williamson County shows a slight population increase to 69,246 in the year 2025. Further, the Greater Egypt Regional Planning and Development Commission, referencing US Census Bureau projections, states that the population in the Greater Egypt 5-county area which includes Williamson County will be relatively steady (or slightly declining) through 2030 (GERPDC 2010).

A reserve capacity is not needed, due to the slight projected increase in population, and because, at this time IEPA is not aware of any increases in discharges from the existing point sources, or the establishment of future municipal or industrial point sources.

5.7.7 TMDL Summary

The total phosphorus TMDL for Herrin Old Reservoir, segment IL_RNZD, is presented in Table 5-17.

Table 5-17. Herrin Old Reservior IL_RNZD TMDL Summary

Allocation	Total Phosphorus Load kg/day (lbs/day)
Load Capacity (LC)	0.23 (0.51)
Wasteload Allocation (WLA)	Not applicable. There are no permitted dischargers in this watershed
Load Allocation (LA)	0.21 (0.46)
Margin of safety (10% of LC)	0.02 (0.05)

5.8 Johnston City (IL_RNZE) Total Phosphorus TMDL

5.8.1 Calculation of the Loading Capacity

The loading capacity for Johnston City Reservoir was determined by running the BATHTUB model repeatedly, reducing the tributary nutrient concentrations for each simulation until model results demonstrated attainment of the water quality objective. The maximum tributary concentration that results in compliance with water quality standards was used as the basis for determining the loading

capacity. The tributary concentration was then converted into a loading rate through multiplication with the tributary flow.

Initial BATHTUB load reduction simulations indicated that Johnston City Reservoir phosphorus concentrations would exceed the water quality standard regardless of the level of tributary load reduction, due to the elevated internal phosphorus loads from lake sediments. This internal phosphorus flux is expected to decrease in the future in response to external phosphorus load reductions, or in response to management actions to remove organic sediments from the lake, reverting back to more typical conditions. This reduction in future sediment phosphorus release was represented in the model by eliminating the additional internal sediment phosphorus source for future scenarios. The resulting load, with calibrated tributary concentrations and no additional sediment phosphorus load yields an average phosphorus load of 0.43 kg/day (0.95 lbs/day) and a concentration of 0.048 mg/L. This meets the phosphorus target of 0.05 mg/L, so reductions in the tributary loads are not necessary. Therefore, the loading capacity is equal to the current incoming loads of 0.43 kg/day (0.95 lbs/day).

5.8.2 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There are no point sources in the watershed, and therefore there is no wasteload allocation given for Johnston City Reservoir. The entire loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The loading capacity is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall phosphorus load. Given a loading capacity of 0.2 kg/day (0.44 lbs/day), and an explicit margin of safety of 10% (discussed below), the load allocation for Johnston City Reservoir of 0.18 kg/day (0.40 lbs/day).

5.8.3 Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events can transport significant quantities of nonpoint source loads to lake. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. This TMDL is based upon an annual period that takes into account both spring loads and summer water quality in order to effectively consider these critical conditions.

5.8.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The BATHTUB model used for this TMDL is designed to evaluate loads over a seasonal to annual averaging period. The annual loading analysis that was used is appropriate due to the facts that:

1. The analysis demonstrated that the TMDL could only attain water quality targets if a significant reduction was achieved in sediment phosphorus release.
2. There is a long response time between phosphorus loading and sediment response, typically on the order of several years (e.g. Chapra and Canale, 1991).

5.8.5 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the BATHTUB water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the watershed, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit total phosphorus load allocated to the margin of safety is 0.02 kg/day (0.04 lbs/day) for Johnston City Lake.

5.8.6 Reserve Capacity

This watershed is located in Williamson County, the population of which has increased by 8.3% between 2000 and 2010 (Stage 1 Report Section 2.6). In 2010, the U.S. Census Bureau estimated the Franklin County population at 66,357.

The Illinois Department of Public Health population projections (Shahidullah 2015) for Williamson County shows a slight population increase to 69,246 in the year 2025. Further, the Greater Egypt Regional Planning and Development Commission, referencing US Census Bureau projections, states that the population in the Greater Egypt 5-county area which includes Williamson County will be relatively steady (or slightly declining) through 2030 (GERPDC 2010).

A reserve capacity is not needed, due to the slight projected increase in population, and because, at this time IEPA is not aware of any increases in discharges from the existing point sources, or the establishment of future municipal or industrial point sources.

5.8.7 TMDL Summary

The total phosphorus TMDL for Johnston City Lake, segment IL_RNZE, is presented in Table 5-18.

Table 5-18. Johnston City Lake IL_RNZE TMDL Summary

Allocation	Total Phosphorus Load kg/day (lbs/day)
Load Capacity (LC)	0.48 (1.06)
Wasteload Allocation (WLA)	Not applicable. There are no permitted dischargers in this watershed
Load Allocation (LA)	0.43 (0.95)
Margin of safety (10% of LC)	0.05 (0.11)

5.9 Arrowhead (Williamson) (IL_RNZX) Total Phosphorus TMDL

5.9.1 Calculation of the Loading Capacity

The loading capacity for the Arrowhead (Williamson) Reservoir was determined by running the BATHTUB model repeatedly, reducing the tributary nutrient concentrations for each simulation until model results demonstrated attainment of the water quality objective. The maximum tributary concentration that results in compliance with water quality standards was used as the basis for determining the loading capacity. The tributary concentration was then converted into a loading rate through multiplication with the tributary flow.

Initial BATHTUB load reduction simulations indicated that Arrowhead (Williamson) Reservoir phosphorus concentrations would exceed the water quality standard regardless of the level of tributary load reduction, due to the elevated internal phosphorus loads from lake sediments. This internal phosphorus flux is expected to decrease in the future in response to external phosphorus load reductions and/or potential management actions (e.g. dredging organic sediments, alum treatment), reverting back to more typical conditions. This reduction in future sediment phosphorus release was represented in the model by eliminating the additional internal sediment phosphorus source for future scenarios. The resulting load, with calibrated tributary concentrations and no additional sediment phosphorus load yields an average phosphorus load of 0.11 kg/day (0.24 lbs/day) and a lake-wide average concentration of 0.049 mg/L. The predicted lake concentrations in the upstream model segments (Segment 2 and Segment 3) are 0.05 and 0.06 mg/l respectively. Therefore reductions in the tributary loads are necessary to meets the phosphorus target of 0.05 mg/L across the entire waterbody. The loading capacity was an average of 0.085 kg/day (0.19 lbs/day). This allowable load corresponds to an approximately 30% reduction from existing tributary loads.

5.9.2 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There are no point sources in the watershed, and therefore there is no wasteload allocation given for Arrowhead (Williamson) Reservoir. The entire loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The loading capacity is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall phosphorus load. Given a loading capacity of 0.085 kg/day (0.19 lbs/day), and an explicit margin of safety of 10% (discussed below), the load allocation for Arrowhead (Williamson) Reservoir of 0.076 kg/day (0.17 lbs/day).

5.9.3 Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events can transport significant quantities of nonpoint source loads to lake. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. This TMDL is based upon an annual period that takes into account both spring loads and summer water quality in order to effectively consider these critical conditions.



5.9.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The BATHTUB model used for this TMDL is designed to evaluate loads over a seasonal to annual averaging period. The annual loading analysis that was used is appropriate due to the facts that:

3. The analysis demonstrated that the TMDL could only attain water quality targets if a significant reduction was achieved in sediment phosphorus release.
4. There is a long response time between phosphorus loading and sediment response, typically on the order of several years (e.g. Chapra and Canale, 1991).

5.9.5 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the BATHTUB water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the watershed, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit total phosphorus load allocated to the margin of safety is 0.008 kg/day (0.02 lbs/day) for Arrowhead (Williamson) Reservoir.

5.9.6 Reserve Capacity

The Arrowhead (Williamson) Reservoir watershed is located in Williamson County, the population of which has increased by 8.3% between 2000 and 2010 (Stage 1 Report Section 2.6). In 2010, the U.S. Census Bureau estimated the Franklin County population at 66,357.

The Illinois Department of Public Health population projections (Shahidullah 2015) for Williamson County shows a slight population increase to 69,246 in the year 2025. Further, the Greater Egypt Regional Planning and Development Commission, referencing US Census Bureau projections, states that the population in the Greater Egypt 5-county area which includes Williamson County will be relatively steady (or slightly declining) through 2030 (GERPDC 2010).

A reserve capacity is not needed, due to the slight projected increase in population, and because, at this time IEPA is not aware of any increases in discharges from the existing point sources, or the establishment of future municipal or industrial point sources.

5.9.7 TMDL Summary

The total phosphorus TMDL for Arrowhead (Williamson) Reservoir, segment IL_RNZX, is presented in Table 5-19.

Table 5-19. Arrowhead (Williamson) IL_RNZX TMDL Summary

Allocation	Total Phosphorus Load kg/day (lbs/day)
Load Capacity (LC)	0.085 (0.19)
Wasteload Allocation (WLA)	Not applicable. There are no permitted dischargers in this watershed
Load Allocation (LA)	0.076 (0.17)
Margin of safety (10% of LC)	0.008 (0.02)

5.10 West Frankfort Old (IL_RNP) Total Phosphorus TMDL

Calculation of the Loading Capacity

The loading capacity for West Frankfort Old Reservoir was determined by running the BATHTUB model repeatedly, reducing the tributary nutrient concentrations for each simulation until model results demonstrated attainment of the water quality objective. The maximum tributary concentration that results in compliance with water quality standards was used as the basis for determining the loading capacity. The tributary concentration was then converted into a loading rate through multiplication with the tributary flow.

Initial BATHTUB load reduction simulations indicated that West Frankfort Old Reservoir phosphorus concentrations would exceed the water quality standard regardless of the level of tributary load reduction, due to the elevated internal phosphorus loads from lake sediments. This internal phosphorus flux is expected to decrease in the future in response to external phosphorus load reductions, reverting back to more typical conditions. This reduction in future sediment phosphorus release was represented in the model by eliminating the additional internal sediment phosphorus source for future scenarios. The resulting load, with calibrated tributary concentrations and no additional sediment phosphorus load yields an average phosphorus load of 1.99 kg/day (4.37 lbs/day) and a concentration of 0.11 mg/L. This exceeds the phosphorus target of 0.05 mg/L, so reductions in the tributary loads are necessary. The loading capacity was an average of 0.50 kg/day (1.09 lbs/day). This allowable load corresponds to an approximately 75% reduction from existing tributary loads.

5.10.1 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There are no point sources in the watershed, and therefore there is no wasteload allocation given for West Frankfort Old Reservoir. The entire loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The loading capacity is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall phosphorus load. Given a loading capacity of 0.50 kg/day (1.09 lbs/day), and an explicit margin of safety of 10% (discussed below), the load allocation for West Frankfort Old Reservoir of 0.45 kg/day (0.98 lbs/day).

5.10.2 Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events can transport significant quantities of nonpoint source loads to lake. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. This TMDL is based upon an annual period that takes into account both spring loads and summer water quality in order to effectively consider these critical conditions.



5.10.3 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The BATHTUB model used for this TMDL is designed to evaluate loads over a seasonal to annual averaging period. The annual loading analysis that was used is appropriate due to the facts that:

1. The analysis demonstrated that the TMDL could only attain water quality targets if a significant reduction was achieved in sediment phosphorus release.
2. There is a long response time between phosphorus loading and sediment response, typically on the order of several years (e.g. Chapra and Canale, 1991).

5.10.4 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the BATHTUB water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the watershed, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit total phosphorus load allocated to the margin of safety is 0.05 kg/day (0.11 lbs/day) for West Frankfort Old Reservoir.

5.10.5 Reserve Capacity

The West Frankfort Old Reservoir watershed is located in Franklin County, the population of which has increased by 1.4% between 2000 and 2010 (Stage 1 Report Section 2.6). In 2010, the U.S. Census Bureau estimated the Franklin County population at 39,570.

The Illinois Department of Public Health population projections (Shahidullah 2015) for Franklin County shows a slight population decline to 37,958 in the year 2025. Further, the Greater Egypt Regional Planning and Development Commission, referencing US Census Bureau projections, states that the population in the Greater Egypt 5-county area which includes Franklin County will be relatively steady (or slightly declining) through 2030 (GERPDC 2010).

A reserve capacity is not needed, due to the slight projected decrease in population, and because, at this time IEPA is not aware of any increases in discharges from the existing point sources, or the establishment of future municipal or industrial point sources.

5.10.6 TMDL Summary

The total phosphorus TMDL for West Frankfort Old Reservoir, segment IL_RNP, is presented in Table 5-20.

Table 5-20. West Frankfort Old IL_RNP TMDL Summary

Allocation	Total Phosphorus Load kg/day (lbs/day)
Load Capacity (LC)	0.50 (1.09)
Wasteload Allocation (WLA)	Not applicable. There are no permitted dischargers in this watershed
Load Allocation (LA)	0.45 (0.98)
Margin of safety (10% of LC)	0.05 (0.11)

5.11 West Frankfort New (IL_RNQ) Total Phosphorus TMDL

5.11.1 Calculation of the Loading Capacity

The loading capacity for West Frankfort New Reservoir was determined by running the BATHTUB model repeatedly, reducing the tributary nutrient concentrations for each simulation until model results demonstrated attainment of the water quality objective. The maximum tributary concentration that results in compliance with water quality standards was used as the basis for determining the loading capacity. The tributary concentration was then converted into a loading rate through multiplication with the tributary flow.

Initial BATHTUB load reduction simulations indicated that West Frankfort New Reservoir phosphorus concentrations would exceed the water quality standard regardless of the level of tributary load reduction, due to the elevated internal phosphorus loads from lake sediments. This internal phosphorus flux is expected to decrease in the future in response to external phosphorus load reductions or lake management actions, reverting back to more typical conditions. This reduction in future sediment phosphorus release was represented in the model by eliminating the additional internal sediment phosphorus source for future scenarios. The resulting load, with calibrated tributary and Thompsonville STP concentrations and no additional sediment phosphorus load yields an average phosphorus load of 3.63 kg/day (7.99 lbs/day) and a concentration of 0.104 mg/L. This exceeds the phosphorus target of 0.05 mg/L, so reductions in the tributary loads are necessary. The loading capacity calculated was an average of 0.91 kg/day (2.0 lbs/day). This allowable load corresponds to an approximately 75% reduction from existing loads, estimated as 3.68 kg/day (8.11 lbs/day).

5.11.2 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There is a single point sources in the watershed from the Thompsonville STP (IL0072478). The current treatment at this facility consists of two cell aerated lagoon and a rock filter. These treatment processes are not capable of removing significant amount of total phosphorus from the effluent. The design average flow (DAF) for the facility is 0.08 million gallons per day (MGD) and the design maximum flow (DMF) for the facility is 0.20 MGD.

The average daily flows from this STP reported in the DMRs from 2008 through 2016 0.087 MGD. There is no water quality data for total phosphorus from this point source to use for model calibration. In estimating the existing phosphorus load from this facility, a total phosphorus concentration in the STP effluent was assumed to be 3.66 mg/L. The resulting average load from the Thompsonville STP is 1.20 kg/day (2.64 lb/day). This load along is higher than the loading capacity of the reservoir, so reductions will be necessary to meet the water quality standards. The WLA for this facility was developed based on the DAF, and a target effluent concentration of 1.0 mg/L. This results in an average WLA of 0.30 kg/day (0.67 lb/day), which represents a 74.6% reduction from the estimated current load.

The remaining loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The load allocation for nonpoint sources is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the



contributions of specific sources to the overall phosphorus load. Given a total loading capacity of 0.91 kg/day (2.0 lbs/day), a WLA for the Thompsonville STP of 0.30 kg/day (0.72 lb/day), and an explicit margin of safety of 10% (discussed below), the load allocation for West Frankfort New Reservoir is 0.52 kg/day (1.15 lbs/day). This represents a reduction of approximately 79% of the watershed nonpoint sources from the existing loads.

5.11.3 Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events can transport significant quantities of nonpoint source loads to lake. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. This TMDL is based upon an annual period that takes into account both spring loads and summer water quality in order to effectively consider these critical conditions.

5.11.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The BATHTUB model used for this TMDL is designed to evaluate loads over a seasonal to annual averaging period. The annual loading analysis that was used is appropriate due to the facts that:

1. The analysis demonstrated that the TMDL could only attain water quality targets if a significant reduction was achieved in sediment phosphorus release.
2. There is a long response time between phosphorus loading and sediment response, typically on the order of several years (e.g. Chapra and Canale, 1991).

5.11.5 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the BATHTUB water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the watershed, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit total phosphorus load allocated to the margin of safety is 0.09 kg/day (0.2 lbs/day) for West Frankfort New Reservoir.

5.11.6 Reserve Capacity

This watershed is located in Franklin County, the population of which has increased by 1.4% between 2000 and 2010 (Stage 1 Report Section 2.6). In 2010, the U.S. Census Bureau estimated the Franklin County population at 39,570.

The Illinois Department of Public Health population projections (Shahidullah 2015) for Franklin County shows a slight population decline to 37,958 in the year 2025. Further, the Greater Egypt Regional Planning and Development Commission, referencing US Census Bureau projections, states that the population in the Greater Egypt 5-county area which includes Franklin County will be relatively steady (or slightly declining) through 2030 (GERPDC 2010).

A reserve capacity is not needed, due to the slight projected decrease in population, and because, at this time IEPA is not aware of any increases in discharges from the existing point sources, or the establishment of future municipal or industrial point sources.



5.11.7 TMDL Summary

The total phosphorus TMDL for West Frankfort New Reservoir, segment IL_RNQ, is presented in Table 5-21.

Table 5-21. West Frankfort New Reservoir IL_RNQ TMDL Summary

Allocation	Total Phosphorus Load kg/day (lbs/day)
Load Capacity (LC)	0.91 (2.01)
Wasteload Allocation (WLA)	0.30 (0.67)
Load Allocation (LA)	0.52 (1.15)
Margin of safety (10% of LC)	0.09 (0.20)

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6 LRS Development

This section presents the development of the total suspended solids Load Reduction Strategy for 5 streams in the Upper Big Muddy River watershed. IEPA requires a LRS to identify the load capacity, and the percentage reduction needed.

6.1 TSS Load Reduction Strategy - Streams

The load capacity was calculated by multiplying the total suspended solids concentration of 32.2 mg/L by the average annual 2015 Upper Big Muddy River flows estimated using a drainage area ratio approach and USGS measured flows for Upper Big Muddy River at Browns, IL (Gage 03378000). The percent reduction was calculated by comparing the average TSS concentrations for the monitoring stations located on the segment calculated from the full record of measured total suspended solids concentrations (Attachment 1 and Attachment 2) to the LRS target concentration.

Table 6-1 presents the TSS LRSs for all of the waterbodies in the Upper Big Muddy River watershed.

Table 6-1. Total Suspended Solids LRS

Stream (Segment ID)	Monitoring Station(s)	Target (mg/L)	Average Concentration (mg/L)	Current load (lbs/day)	Load capacity (lbs/day)	Percent Reduction
Big Muddy R. (IL_N-06)	N-06	32.2	43.7	16,148	11,910	26.2%
Big Muddy R. (IL_N-11)	N-11	32.2	53.0	31,932	19,395	39.3%
Big Muddy R. (IL_N-17)	N-17	32.2	110.3	27,108	7,911	70.8%
Pond Cr. (IL_NG-02)	NG-02	32.2	86.3	39,449	14,721	62.7%
M. Fk. Big Muddy (IL_NH-07)	NH-07, NH-08, NH-21	32.2	72.3	53,894	23,992	55.5%

7 Reasonable Assurances

Documenting adequate reasonable assurance increases the probability that regulatory and voluntary mechanisms will achieve pollution reduction levels specified in the TMDL and that the applicable WQS are attained.

The Illinois EPA NPDES regulatory program and the issuance of an NPDES permit provide the reasonable assurance that the WLAs in the TMDL will be achieved. That is because federal regulations implementing the CWA require that effluent limits in permits be consistent with "the assumptions and requirements of any available [WLA]" in an approved TMDL [40 CFR 122.44(d)(1)(vii)(B)]. For point sources, Illinois EPA administers the NPDES permitting program for wastewater treatment plants, MS4s and CAFOs. Wasteload allocations in the TMDL report will be included in the appropriate NPDES permits when permits are renewed.

For TMDLs for waters impaired by both point and nonpoint sources, determinations of reasonable assurance that the TMDLs load allocations will be achieved include whether practices capable of reducing the specified pollutant load exist, are technically feasible, and have a high likelihood of implementation. The nonpoint source load reductions can and will be achieved when there are good management practices and programs (technical and funding mechanisms) to assist in achieving good management practices. The Watershed Implementation Plan for the TMDLs contained in this report identifies practices that are capable of reducing the pollutant loads to the TMDL endpoints, and potential funding mechanisms for implementation.

For nonpoint sources, the primary strategy for reduction for attaining water quality standards in the Upper Big Muddy River watershed is to implement BMPs to reduce and treat agricultural and urban stormwater runoff, along with the use of in-stream restoration practices. This strategy relies on voluntary actions that includes accountability. Educational efforts and cost sharing programs are intended to achieve participation levels sufficient to attain water quality standards and meet the designated uses. An important key to the success of a TMDL program, in terms of engaging the public, is building linkages to other programs, such as nonpoint source management practices.

In rural areas many homes, businesses, and schools do not have access to central sewage disposal systems. County and local health departments operate sewage and water programs to assure that sewage and water systems are designed according to code so that neither the public health nor the environment is jeopardized. The counties and local health departments issue licenses and provide training to contractors, inspect and license pumper trucks, review sewage system applications, issue construction permits, assist in the design of sewage disposal systems, inspect new sewage disposal systems, investigate complaints, and carry out enforcement activities based upon county ordinances. These activities help to eliminate the discharge of raw sewage and reduce the bacterial contamination within the Upper Big Muddy River watershed.

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8 Public Participation and Involvement

[This section will be filled in following the public meeting]

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Attachment 1: Stage 1 Report



Attachment 3:

QUAL2E Model Files

Calibration input

Calibration output

Attachment 4: BATHTUB Model Files

Herrin Old / IL_RNZD
- Calibration input
- Calibration output

Johnston City / IL_RNZE
- Calibration input
- Calibration output

Arrowhead (Williamson) / IL_RNZX
- Calibration input
- Calibration output

West Frankfort Old / IL_RNP
- Calibration input
- Calibration output

West Frankfort New/ IL_RNQ
- Calibration input
- Calibration output

Attachment 5: Load Duration Curve Analysis

IL_N-11 Fecal Coliform LDC

IL_NZN-13 Iron LDC

IL_NG-02 Chloride LDC

IL_NGAZ-JC-D1 Manganese LDC

IL_NH-06 Fecal Coliform LDC

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Big Muddy Fish Data

Water body		Total	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date			1975JUL28	1964JUL02	1975JUL28	1988AUG17	1995AUG01
Station code			N-04	N-11	N-11	N-11	N-11
Species		50	18	15	21	15	19
Non-native proportion		0.06	0.17	0.06	0.36	0.36	0.11
Total fish		1612	199	384	107	83	117
Electrode minutes			60		60	60	60
Paddlefish	Polyodon spathula	1	1				
Shortnose gar	Lepisosteus platostomus	23			4	1	1
Longnose gar	Lepisosteus osseus	6			1		
Spotted gar	Lepisosteus oculatus	8	2			1	
Bowfin	Amia calva	6			4	1	
Gizzard shad	Dorosoma cepedianum	299	102	7	28	4	35
Goldeye	Hiodon alosoides	14	7		1		1
Grass pickerel	Esox americanus	2			1		
Silver carp	Hypophthalmichthys molitrix	3					
Carp	Cyprinus carpio	157	33	10	39	30	13
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)	148		148			
Silvery minnow	Hybognathus nuchalis	3					1
Redfin shiner	Lythrurus umbratilus	1			1		
Ribbon shiner	Lythrurus fumeus	5					
Red shiner	Cyprinella lutrensis	172	1		1		20
Bluntnose minnow	Pimephales notatus	4					
Bullhead minnow	Pimephales vigilax	21					1
Emerald shiner	Notropis atherinoides	10					
Sand shiner	Notropis ludibundus	1					
Bigmouth buffalo	Ictiobus cyprinellus	18	8		5		
Smallmouth buffalo	Ictiobus bubalus	111	1		4	3	6
Black buffalo	Ictiobus niger	5					
River carpsucker	Carpiodes carpio	14	1			1	
Creek chubsucker	Erimyzon oblongus	1					
River redhorse *T*	Moxostoma carinatum	1				1	
Shorthead redhorse	Moxostoma macrolepidotum	3				1	1
Channel catfish	Ictalurus punctatus	34	1	7	2	7	3
Blue catfish	Ictalurus furcatus	1					
Yellow bullhead	Ameiurus natalis	4		4			
Black bullhead	Ameiurus melas	3					
Flathead catfish	Pylodictis olivaris	8					2
Madtom spp.	Noturus spp.	61		61			
Pirate perch	Aphredoderus sayanus	5		4			
Blackstripe topminnow	Fundulus notatus	5					
Blackspotted topminnow	Fundulus olivaceus	1					
Mosquitofish	Gambusia affinis	1					
Brook silverside	Labidesthes sicculus	17			1		
White bass	Morone chrysops	5			1		1
Yellow bass	Morone mississippiensis	10					
Black crappie	Pomoxis nigromaculatus	32	5	14	3		
White crappie	Pomoxis annularis	34	5	7	1	3	4
Largemouth bass	Micropterus salmoides	16	6	1	2		4
Spotted bass	Micropterus punctulatus	19					7
Warmouth	Lepomis gulosus	26	9	7	2	2	
Green sunfish	Lepomis cyanellus	5		3			1
Bluegill	Lepomis macrochirus	49	6	11	3	8	1
Redear sunfish	Lepomis microlophus	1	1				
Longear sunfish	Lepomis megalotis	110	7	55	2	6	9
Orangespotted sunfish	Lepomis humilis	47		40	1		
Walleye	Stizostedion vitreum	1		1			
River darter	Percina shumardi	1					
Freshwater drum	Aplodinotus grunniens	79	3	4		14	6
	Total		199	384	107	83	117

Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
2000SEP06	2003JUL29	2008AUG20	2018JUL25
N-11	N-11	N-11	N-11
17	32	27	17
0.07	0.06	0.02	0.05
158	172	296	96
90	60	60	60
1	9	1	6
			5
		3	2
	1		
32	20	62	9
1	4		
		1	
		3	
11	11	4	6
	2		
	5		
53	39	54	4
4			
	5	13	2
2		6	2
	1		
3	1		1
19	12	33	33
		2	3
		2	10
	1		
	1		
	6	4	4
	1		
	3		
1	1	3	1
		1	
	2	3	
	1		
	1		
13	1	2	
2	1		
1		9	
1	1	8	
	2	12	
	3		
2	8	2	
	1	5	
		1	
3	2	14	1
	5	25	1
		6	
	1		
9	20	17	6
158	172	296	96

Water body		Total	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date			1975JUL28	1995JUL26	2000JUL17	2003JUL07
Station code			N-04	N-05	N-05	N-05
Species		92	18	21	16	20
Non-native proportion		0.04	0.17	0.01	0.04	
Total fish		42758	199	150	77	121
Electrode minutes			60	28	35.9	25.1
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula	47	1			
Shortnose gar	Lepisosteus platostomus	352				
Longnose gar	Lepisosteus osseus	99				
Spotted gar	Lepisosteus oculatus	84	2			
Bowfin	Amia calva	150				
Skipjack herring	Alosa chrysochloris	3				
Shad spp.	Dorosoma spp.	120				
Gizzard shad	Dorosoma cepedianum	4208	102			
Threadfin shad	Dorosoma petenense	44				
Goldeye	Hiodon alosoides	61	7			
Mooneye	Hiodon tergisus	1				
Grass pickerel	Esox americanus	332		9		
Grass carp	Ctenopharyngodon idella	25				
Bighead carp	Aristichthys nobilis	5				
Silver carp	Hypophthalmichthys molitrix	345				
Goldfish	Carassius auratus	4				
Carp	Cyprinus carpio	2392	33	2	3	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)	2744				
Golden shiner	Notemigonus crysoleucas	220		1	1	3
Creek chub	Semotilus atromaculatus	753				6
Central stoneroller	Campostoma anomalum	402				
Suckermouth minnow	Phenacobius mirabilis	29				
Blacknose dace	Rhinichthys atratulus	163				
Silver chub	Macrhybopsis storeriana	1				
Silvery minnow	Hybognathus nuchalis	416				
Redfin shiner	Lythrurus umbratilus	715		4		6
Ribbon shiner	Lythrurus fumeus	41				
Spotfin shiner	Cyprinella spiloptera	1				
Blacktail shiner	Cyprinella venusta	2				
Red shiner	Cyprinella lutrensis	1260	1			3
Pugnose minnow	Opsopoeodus emiliae	5				
Fathead minnow	Pimephales promelas	142				
Bluntnose minnow	Pimephales notatus	1933		32	1	4
Bullhead minnow	Pimephales vigilax	155				
Emerald shiner	Notropis atherinoides	219				
River shiner	Notropis blennius	1				
Sand shiner	Notropis ludibundus	464				
Mimic shiner	Notropis volucellus	35				
Channel shiner	Notropis wickliffi	51				
Bigmouth buffalo	Ictiobus cyprinellus	641	8			
Smallmouth buffalo	Ictiobus bubalus	721	1			
Black buffalo	Ictiobus niger	87				
Unidentified Carpsucker	Carpiodes sp.	2				
Quillback	Carpiodes cyprinus	9				
River carpsucker	Carpiodes carpio	107	1			
Highfin carpsucker	Carpiodes velifer	1				
White sucker	Catostomus commersoni	480		1		1
Spotted sucker	Minytrema melanops	104				
Creek chubsucker	Erimyzon oblongus	666		5	4	2
River redhorse *T*	Moxostoma carinatum	1				
Shorthead redhorse	Moxostoma macrolepidotum	7				
Golden redhorse	Moxostoma erythrurum	35				
Channel catfish	Ictalurus punctatus	717	1			
Blue catfish	Ictalurus furcatus	15				
Yellow bullhead	Ameiurus natalis	420				2
Black bullhead	Ameiurus melas	24				
Brown bullhead	Ameiurus nebulosus	1				
Flathead catfish	Pylodictis olivaris	194				
Madtom spp.	Noturus spp.	317				
Tadpole madtom	Noturus gyrinus	84		1	1	1
Freckled madtom	Noturus nocturnus	7				
Pirate perch	Aphredoderus sayanus	828			12	9
Blackstripe topminnow	Fundulus notatus	979		1	1	2
Blackspotted topminnow	Fundulus olivaceus	532		17	10	5
Mosquitofish	Gambusia affinis	896				
Brook silverside	Labidesthes sicculus	252				
Inland silversides	Menidia beryllina	14				
Mississippi silversides	Menidia beryllina	1				
Striped bass	Morone saxatilis	1				
White bass	Morone chrysops	154				

Water body		Total	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date			1975JUL28	1995JUL26	2000JUL17	2003JUL07
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops	3				
Yellow bass	Morone mississippiensis	36				
Flier	Centrarchus macropterus	93				
Black crappie	Pomoxis nigromaculatus	360	5			
Blacknose crappie	Pomoxis migromaculatus	5				
White crappie	Pomoxis annularis	510	5	2		1
Largemouth bass	Micropterus salmoides	1142	6	3	6	5
Spotted bass	Micropterus punctulatus	165				
Warmouth	Lepomis gulosus	590	9	2	1	3
Green sunfish	Lepomis cyanellus	2281		35	18	17
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus	2				
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus	38		1	1	
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus	12				
Bluegill	Lepomis macrochirus	5053	6	14	2	37
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus	1				
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus	4				
Redear sunfish	Lepomis microlophus	102	1			
Longear sunfish	Lepomis megalotis	3378	7	15	5	12
Orangespotted sunfish	Lepomis humilis	796				1
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	106				
Walleye	Stizostedion vitreum	5				
Sauger	Stizostedion canadense	2				
Blackside darter	Percina maculata	19		1	1	
Dusky darter	Percina sciera	2				
River darter	Percina shumardi	2				
Logperch	Percina caprodes	43				
Johnny darter	Etheostoma nigrum	318		1	9	
Bluntnose darter	Etheostoma chlorosomum	26				
Mud darter	Etheostoma asprigene	35		1		
Orangethroat darter	Etheostoma spectabile	90				
Spottail darter	Etheostoma squamiceps	7				
Slough darter	Etheostoma gracile	341		1	1	
Freshwater drum	Aplodinotus grunniens	870	3	1		1

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2008JUN17	2013AUG05	1975JUL24	1978JUL12	1980JUL08
Station code		N-05	N-05	N-06	N-06	N-06
Species		25	18	16	17	18
Non-native proportion		0.01		0.48	0.38	0.24
Total fish		158	76	211	187	171
Electrode minutes		22	26.83	60		60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula			1		
Shortnose gar	Lepisosteus platostomus			1	4	1
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					1
Bowfin	Amia calva			2		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		1	22	38	57
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides			3		1
Mooneye	Hiodon tergisus				1	
Grass pickerel	Esox americanus	3	5			
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	1		102	71	41
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas	10				
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	18				
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	1		4	11	12
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	10				1
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus			29	21	8
Smallmouth buffalo	Ictiobus bubalus	1		5	1	7
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio				3	2
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	2	1			
Spotted sucker	Minytrema melanops	9	2			
Creek chubsucker	Erimyzon oblongus	15				
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					1
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	1	1			
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris				2	
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus	2	1			
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	1	3			
Blackstripe topminnow	Fundulus notatus	11	15			
Blackspotted topminnow	Fundulus olivaceus	11	5			
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus				1	3
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops				1	

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2008JUN17	2013AUG05	1975JUL24	1978JUL12	1980JUL08
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus		1			
Black crappie	Pomoxis nigromaculatus			4	1	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	1		2	4	3
Largemouth bass	Micropterus salmoides	1	8	4	9	9
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	2	3	1		
Green sunfish	Lepomis cyanellus	22	5			
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	8	9	20	10	12
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus	1				
Longear sunfish	Lepomis megalotis	20	12	7	4	5
Orangespotted sunfish	Lepomis humilis	5				6
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum		2			
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	1	1			
Freshwater drum	Aplodinotus grunniens	1		4	5	1

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1988AUG15	1990JUL10	1992JUL17	1994AUG01	1995AUG01
Station code		N-06	N-06	N-06	N-06	N-06
Species		18	16	16	20	22
Non-native proportion		0.22	0.25	0.15	0.18	0.18
Total fish		200	55	40	275	176
Electrode minutes		60	60	60		60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	4	1			2
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus	1				
Bowfin	Amia calva	1				3
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	14	8	2	85	19
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides		1		5	4
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		1			
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	44	14	6	50	31
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	12	12	1		17
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					1
Bullhead minnow	Pimephales vigilax	3				1
Emerald shiner	Notropis atherinoides		1			
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	19		5	13	7
Smallmouth buffalo	Ictiobus bubalus	14	5	3	45	21
Black buffalo	Ictiobus niger		1	3	4	
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio			1		
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	1	1	3	4	1
Blue catfish	Ictalurus furcatus				1	
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	1	1	2	2	
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					
Blackstripe topminnow	Fundulus notatus					1
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus					3
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops			1	2	1

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1988AUG15	1990JUL10	1992JUL17	1994AUG01	1995AUG01
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis		1			
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus				4	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	12	3	2	6	11
Largemouth bass	Micropterus salmoides			1	1	2
Spotted bass	Micropterus punctulatus	6	2	4	10	10
Warmouth	Lepomis gulosus	5			7	2
Green sunfish	Lepomis cyanellus				1	1
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	27		2	6	21
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	27	2	1	23	6
Orangespotted sunfish	Lepomis humilis	1			1	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	8	1	3	5	11

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1998AUG20	2000SEP22	2003JUL10	2008AUG20	1964JUL10
Station code		N-06	N-06	N-06	N-06	N-07
Species		30	25	25	28	9
Non-native proportion		0.24	0.07	0.08	0.04	
Total fish		136	167	203	277	424
Electrode minutes		60	60	60	60	
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1	3	4	2	1
Longnose gar	Lepisosteus osseus	2			1	
Spotted gar	Lepisosteus oculatus	2	2		3	
Bowfin	Amia calva	1	1		2	
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	17	12	33	89	25
Threadfin shad	Dorosoma petenense			6		
Goldeye	Hiodon alosoides	1		1		
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus				1	
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	18	11	10	10	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					243
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	2		5		
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus	3		13		
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta				2	
Red shiner	Cyprinella lutrensis	2	23	21	45	
Pugnose minnow	Opsopoeodus emiliae	1				
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		1			
Bullhead minnow	Pimephales vigilax	1		1		
Emerald shiner	Notropis atherinoides		1		7	
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus	2				
Channel shiner	Notropis wickliffi			13		
Bigmouth buffalo	Ictiobus cyprinellus	4	4	3	2	
Smallmouth buffalo	Ictiobus bubalus	8	32	12	18	
Black buffalo	Ictiobus niger		1	2	5	
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio	3	1		4	
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum			1		
Channel catfish	Ictalurus punctatus	1		1	4	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					2
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris				1	
Madtom spp.	Noturus spp.					5
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus			1		1
Blackstripe topminnow	Fundulus notatus	4	2			
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus	9	38		21	
Inland silversides	Menidia beryllina	14				
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops	1		7	1	

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1998AUG20	2000SEP22	2003JUL10	2008AUG20	1964JUL10
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis	2	1		2	
Flier	Centrarchus macropterus					1
Black crappie	Pomoxis nigromaculatus		1	3	4	1
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	4	1	6	3	2
Largemouth bass	Micropterus salmoides	4	1	5	6	
Spotted bass	Micropterus punctulatus	10	7	13	4	
Warmouth	Lepomis gulosus	1	3		2	
Green sunfish	Lepomis cyanellus	1	5			
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	12	10	34	11	
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	2	3	4	9	
Orangespotted sunfish	Lepomis humilis		2			127
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid			1	1	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera				1	
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene			1		
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	3	1	2	16	16

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1964JUL03	1975JUL24	1964JUL02	1975JUL28	1988AUG17
Station code		N-08	N-10	N-11	N-11	N-11
Species		9	20	15	21	15
Non-native proportion		0.06	0.11	0.06	0.36	0.36
Total fish		158	316	384	107	83
Electrode minutes			60		60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus		2		4	1
Longnose gar	Lepisosteus osseus				1	
Spotted gar	Lepisosteus oculatus					1
Bowfin	Amia calva	1	4		4	1
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		136	7	28	4
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides		4		1	
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus				1	
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus		1			
Carp	Cyprinus carpio	4	35	10	39	30
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)	83		148		
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus				1	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis				1	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		1			
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		20		5	
Smallmouth buffalo	Ictiobus bubalus				4	3
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					1
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	3				
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					1
Shorthead redhorse	Moxostoma macrolepidotum					1
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		1	7	2	7
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis		1	4		
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.	10		61		
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	16		4		
Blackstripe topminnow	Fundulus notatus					
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus				1	
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops		2		1	

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1964JUL03	1975JUL24	1964JUL02	1975JUL28	1988AUG17
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis		1			
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		26	14	3	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	1	22	7	1	3
Largemouth bass	Micropterus salmoides		17	1	2	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	3	2	7	2	2
Green sunfish	Lepomis cyanellus	20		3		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	5	22	11	3	8
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus		3			
Longear sunfish	Lepomis megalotis	12	8	55	2	6
Orangespotted sunfish	Lepomis humilis			40	1	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum			1		
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens		8	4		14

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1995AUG01	2000SEP06	2003JUL29	2008AUG20	1988AUG16
Station code		N-11	N-11	N-11	N-11	N-12
Species		19	17	32	27	20
Non-native proportion		0.11	0.07	0.06	0.02	0.11
Total fish		117	158	172	296	97
Electrode minutes		60	90	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1	1	9	1	3
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus				3	
Bowfin	Amia calva			1		2
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	35	32	20	62	24
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides	1	1	4		
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus				1	2
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix				3	
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	13	11	11	4	11
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	1		2		
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus			5		
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	20	53	39	54	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		4			
Bullhead minnow	Pimephales vigilax	1		5	13	
Emerald shiner	Notropis atherinoides		2		6	
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus			1		
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		3	1		1
Smallmouth buffalo	Ictiobus bubalus	6	19	12	33	1
Black buffalo	Ictiobus niger				2	1
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio				2	2
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus			1		
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum	1		1		
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	3		6	4	8
Blue catfish	Ictalurus furcatus			1		
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas			3		
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	2	1	1	3	4
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus				1	
Blackstripe topminnow	Fundulus notatus			2	3	
Blackspotted topminnow	Fundulus olivaceus			1		
Mosquitofish	Gambusia affinis			1		
Brook silverside	Labidesthes sicculus		13	1	2	1
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops	1	2	1		1

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1995AUG01	2000SEP06	2003JUL29	2008AUG20	1988AUG16
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis		1		9	
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		1	1	8	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	4		2	12	1
Largemouth bass	Micropterus salmoides	4		3		1
Spotted bass	Micropterus punctulatus	7	2	8	2	
Warmouth	Lepomis gulosus			1	5	
Green sunfish	Lepomis cyanellus	1			1	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	1	3	2	14	10
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	9		5	25	6
Orangespotted sunfish	Lepomis humilis				6	11
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					1
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi			1		
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	6	9	20	17	6

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1992AUG17	1994AUG09	1995AUG02	1998SEP08	2000SEP06
Station code		N-12	N-12	N-12	N-12	N-12
Species		11	15	21	17	19
Non-native proportion		0.22	0.21	0.11	0.33	0.14
Total fish		36	76	163	123	136
Electrode minutes		60	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus		4	2	2	4
Longnose gar	Lepisosteus osseus	3	1		3	
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva		7	2	6	1
Skipjack herring	Alosa chrysochloris		1			
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		20	66	36	29
Threadfin shad	Dorosoma petenense				12	
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	8	16	18	28	19
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis			3		10
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					4
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					12
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					1
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	1		2	5	6
Smallmouth buffalo	Ictiobus bubalus	1	9	3	6	6
Black buffalo	Ictiobus niger		1			
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus				1	
River carpsucker	Carpiodes carpio	2	1		3	4
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	8	3		4	6
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	5	3	3	4	6
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					
Blackstripe topminnow	Fundulus notatus			2		1
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis			1		
Brook silverside	Labidesthes sicculus					6
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops		2	2	2	4

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1992AUG17	1994AUG09	1995AUG02	1998SEP08	2000SEP06
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		1	1		
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis			2	1	
Largemouth bass	Micropterus salmoides			12	1	
Spotted bass	Micropterus punctulatus			2		
Warmouth	Lepomis gulosus			1		
Green sunfish	Lepomis cyanellus			1		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	1	5	30	1	2
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	2		3		
Orangespotted sunfish	Lepomis humilis	1		1		2
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	4	2	6	8	13

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2003JUL29	2008AUG26	2011AUG18	2012OCT29	2013AUG06
Station code		N-12	N-12	N-12	N-12	N-12
Species		24	27	26	29	29
Non-native proportion		0.08	0.03	0.06	0.11	0.11
Total fish		143	407	287	249	240
Electrode minutes		60	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	7	1	4	7	24
Longnose gar	Lepisosteus osseus	2		8	1	24
Spotted gar	Lepisosteus oculatus	1	3	2	1	
Bowfin	Amia calva	2	1	1	1	
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	41	170	156	4	19
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides	1		1	2	4
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella				10	1
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix		1	5	3	9
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	11	10	13	15	16
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	8				
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	26	19	1	25	34
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					1
Bullhead minnow	Pimephales vigilax	2	2	1	14	8
Emerald shiner	Notropis atherinoides	4	19		9	7
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus			2		1
Mimic shiner	Notropis volucellus				28	1
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		2	6	21	9
Smallmouth buffalo	Ictiobus bubalus	7	13	11	18	30
Black buffalo	Ictiobus niger	1		2	6	1
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus				1	
River carpsucker	Carpiodes carpio					2
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum	2				
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	8	4	4	25	8
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis		1			
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	1	5	6	1	4
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					
Blackstripe topminnow	Fundulus notatus		14			
Blackspotted topminnow	Fundulus olivaceus				4	
Mosquitofish	Gambusia affinis	1				
Brook silverside	Labidesthes sicculus		20			2
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops	1	7	8	1	2

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2003JUL29	2008AUG26	2011AUG18	2012OCT29	2013AUG06
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		4	5		1
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	1	2	10	5	1
Largemouth bass	Micropterus salmoides	2	9	3	1	
Spotted bass	Micropterus punctulatus			5	1	3
Warmouth	Lepomis gulosus		7		1	
Green sunfish	Lepomis cyanellus		1			1
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	2	23	21	2	2
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus			1		
Longear sunfish	Lepomis megalotis		10	6	36	11
Orangespotted sunfish	Lepomis humilis	1	33	1	1	3
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid		1			
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi	1				
Logperch	Percina caprodes		1			
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	10	24	4	5	11

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2014SEP24	1975AUG06	1975AUG05	1975JUL30	1988AUG16
Station code		N-12	N-13	N-15	N-16	N-16
Species		20	14	18	19	16
Non-native proportion		0.02	0.34	0.34	0.4	0.34
Total fish		180	192	169	148	106
Electrode minutes		60	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	5	5	1		1
Longnose gar	Lepisosteus osseus	1			1	
Spotted gar	Lepisosteus oculatus				1	
Bowfin	Amia calva	1	1	2		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	72	28	26	20	9
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides				3	
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix	3				
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	1	66	57	59	36
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera	1				
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	49				3
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax	5				4
Emerald shiner	Notropis atherinoides	18				
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	2	1	6	4	3
Smallmouth buffalo	Ictiobus bubalus		1	4	1	4
Black buffalo	Ictiobus niger					1
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio	2		2	1	2
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum	1				
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	2	2	7	2	5
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris				2	6
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					
Blackstripe topminnow	Fundulus notatus	5				
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis	1				
Brook silverside	Labidesthes sicculus	1		3		
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops				1	

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2014SEP24	1975AUG06	1975AUG05	1975JUL30	1988AUG16
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis			1	1	
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		6	10	3	
Blacknose crappie	Pomoxis nigromaculatus					
White crappie	Pomoxis annularis		1	11	18	1
Largemouth bass	Micropterus salmoides		23	1	3	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus				4	1
Green sunfish	Lepomis cyanellus			1		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus		20	15	16	12
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus		1			
Longear sunfish	Lepomis megalotis	4	5	12	2	2
Orangespotted sunfish	Lepomis humilis	1		1		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	5	32	9	6	16

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2003JUL17	1975JUL29	1988AUG17	1995AUG03	2003JUL16
Station code		N-16	N-17	N-17	N-17	N-17
Species		25	13	20	17	20
Non-native proportion		0.01	0.26	0.24	0.16	0.03
Total fish		197	147	132	167	76
Electrode minutes		58	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	2		2		3
Longnose gar	Lepisosteus osseus					1
Spotted gar	Lepisosteus oculatus		1	1		1
Bowfin	Amia calva	3	1		1	1
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	54	42	20	75	16
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides		4		1	
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	2	38	32	27	2
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	12				7
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					1
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	48		3	1	24
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax	14			4	2
Emerald shiner	Notropis atherinoides		1			
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi	1				
Bigmouth buffalo	Ictiobus cyprinellus	1	9	2		
Smallmouth buffalo	Ictiobus bubalus			2	7	3
Black buffalo	Ictiobus niger	1				1
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio				1	
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	2	4	3	2	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	5		3	3	
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	2				
Blackstripe topminnow	Fundulus notatus	1		1		
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis	3		1		
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina	1				
Striped bass	Morone saxatilis					
White bass	Morone chrysops	1				2

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2003JUL17	1975JUL29	1988AUG17	1995AUG03	2003JUL16
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops				1	
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus	1	15	1	2	1
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis		19	2	2	1
Largemouth bass	Micropterus salmoides	5	2	2	9	1
Spotted bass	Micropterus punctulatus				1	1
Warmouth	Lepomis gulosus			2	1	1
Green sunfish	Lepomis cyanellus			2		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	10	5	25	19	3
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	2		12		
Orangespotted sunfish	Lepomis humilis	5		1		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes	1				
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene	3				
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	17	6	15	10	4

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1975JUL29	1975JUL25	1975AUG12	1988AUG17	2011SEP20
Station code		N-18	N-20	N-23	N-23	N-23
Species		16	15	17	16	23
Non-native proportion		0.15	0.29	0.34	0.24	0.04
Total fish		137	90	136	87	224
Electrode minutes		60	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula			2		1
Shortnose gar	Lepisosteus platostomus		1	1	6	10
Longnose gar	Lepisosteus osseus			1	1	6
Spotted gar	Lepisosteus oculatus					7
Bowfin	Amia calva	2			1	2
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	14	32	26	5	17
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides	1	4			
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella			1		
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					7
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	20	26	45	21	2
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		5		1	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax				1	
Emerald shiner	Notropis atherinoides		2			
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	12	4	11	9	14
Smallmouth buffalo	Ictiobus bubalus	4		1	1	16
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio	1		3	5	1
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		2	5	7	4
Blue catfish	Ictalurus furcatus					2
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	1	2	3	4	16
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	2				
Blackstripe topminnow	Fundulus notatus					
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus					5
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					4

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1975JUL29	1975JUL25	1975AUG12	1988AUG17	2011SEP20
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus	14	1	3		6
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	15	4	11		10
Largemouth bass	Micropterus salmoides	5	1	6		9
Spotted bass	Micropterus punctulatus				2	
Warmouth	Lepomis gulosus	7		1		2
Green sunfish	Lepomis cyanellus					
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	16	2	13	2	37
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	21	3			9
Orangespotted sunfish	Lepomis humilis				3	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	2	1	3	18	37

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2012OCT26	2013AUG16	1964JUL03	1975AUG12	1975AUG05
Station code		N-23	N-23	N-24	N-25	N-26
Species		20	31	10	14	16
Non-native proportion		0.39	0.36		0.43	0.11
Total fish		333	578	219	209	185
Electrode minutes		60	60		60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	83	32		3	4
Longnose gar	Lepisosteus osseus	1	14			
Spotted gar	Lepisosteus oculatus		5			
Bowfin	Amia calva		1	1	1	
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	7	110	16	56	106
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides		1			1
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella	1	10			
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix	120	168			
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	10	28		89	21
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)			30		
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	6	21			
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax	3	15			
Emerald shiner	Notropis atherinoides	13	51			
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus		16			
Mimic shiner	Notropis volucellus		3			
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	6	7		8	7
Smallmouth buffalo	Ictiobus bubalus	22	26		1	1
Black buffalo	Ictiobus niger	14	4			
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio	7	10		3	1
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni			19		
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	17	11		7	2
Blue catfish	Ictalurus furcatus	3				
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	4	3		1	
Madtom spp.	Noturus spp.			71		
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus			50		
Blackstripe topminnow	Fundulus notatus		2			
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus	1	11			
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops		8			

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2012OCT26	2013AUG16	1964JUL03	1975AUG12	1975AUG05
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus				4	2
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis		1		19	16
Largemouth bass	Micropterus salmoides		2	2	6	1
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus			1		2
Green sunfish	Lepomis cyanellus		1	5		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus		4	3	6	12
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					1
Longear sunfish	Lepomis megalotis	4	1	2		2
Orangespotted sunfish	Lepomis humilis	2		19		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera		1			
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	9	10		5	6

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1975AUG13	1964JUL01	1975AUG13	1978AUG17	1979AUG13
Station code		N-27	N-28	N-99	N-99	N-99
Species		15	13	16	17	16
Non-native proportion		0.33	0.01	0.15	0.15	0.16
Total fish		240	367	130	221	119
Electrode minutes		60		30	90	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula			36		
Shortnose gar	Lepisosteus platostomus			1	2	2
Longnose gar	Lepisosteus osseus	1				
Spotted gar	Lepisosteus oculatus	1		1		
Bowfin	Amia calva	7		2		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.		6		106	8
Gizzard shad	Dorosoma cepedianum	40		26		
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides			1		
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		2			
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	78	2	20	17	18
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)		68			
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	1		2	5	5
Smallmouth buffalo	Ictiobus bubalus	1		1	2	7
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio				2	6
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus				2	
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	30	15	1	2	13
Blue catfish	Ictalurus furcatus					1
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	2			2	3
Madtom spp.	Noturus spp.		75			
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus		16			
Blackstripe topminnow	Fundulus notatus					
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops			1	3	8

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1975AUG13	1964JUL01	1975AUG13	1978AUG17	1979AUG13
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus		1			
Black crappie	Pomoxis nigromaculatus	7	12	1	3	1
Blacknose crappie	Pomoxis nigromaculatus					
White crappie	Pomoxis annularis	15	1	2	7	4
Largemouth bass	Micropterus salmoides	21		8	22	7
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	1	7	2		1
Green sunfish	Lepomis cyanellus		3		1	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	33	78	25	41	28
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis		32		1	1
Orangespotted sunfish	Lepomis humilis		48		1	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	2	1		2	6

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1980JUL29	1986AUG14	1988AUG18	1990SEP26	1992AUG18
Station code		N-99	N-99	N-99	N-99	N-99
Species		15	14	21	12	14
Non-native proportion		0.4	0.12	0.03	0.2	0.01
Total fish		98	93	235	45	67
Electrode minutes		60	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula	1				
Shortnose gar	Lepisosteus platostomus	1		8	2	1
Longnose gar	Lepisosteus osseus	4				1
Spotted gar	Lepisosteus oculatus			3		
Bowfin	Amia calva		5	2		1
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	6	24	35		35
Threadfin shad	Dorosoma petenense	12		2		
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	27	11	4	8	1
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis			1		
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax			2		
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	8	8	2	1	
Smallmouth buffalo	Ictiobus bubalus	7		3		5
Black buffalo	Ictiobus niger			1		
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio		5	3	1	
Highfin carpsucker	Carpiodes velifer					1
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	1	4	13	14	1
Blue catfish	Ictalurus furcatus	1				
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	8	4	1	2	8
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					
Blackstripe topminnow	Fundulus notatus					
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis				1	
White bass	Morone chrysops	7	2		3	3

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1980JUL29	1986AUG14	1988AUG18	1990SEP26	1992AUG18
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		4	1		1
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis		2	1	5	1
Largemouth bass	Micropterus salmoides	2	7	5	4	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	1	1			
Green sunfish	Lepomis cyanellus					
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus		13	44	1	7
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis			8		
Orangespotted sunfish	Lepomis humilis			43		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	12	3	53	3	1

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1994AUG15	1995AUG12	1998SEP08	2000SEP07	2003JUL30
Station code		N-99	N-99	N-99	N-99	N-99
Species		15	11	22	22	23
Non-native proportion		0.06	0.16	0.12	0.19	0.16
Total fish		114	49	141	126	131
Electrode minutes		60	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula			3	2	
Shortnose gar	Lepisosteus platostomus			3	3	9
Longnose gar	Lepisosteus osseus					1
Spotted gar	Lepisosteus oculatus				1	1
Bowfin	Amia calva		3	2	2	1
Skipjack herring	Alosa chrysochloris					1
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	13	6	30	12	37
Threadfin shad	Dorosoma petenense			3		
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis				3	
Silver carp	Hypophthalmichthys molitrix	1				9
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	6	8	14	21	12
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					5
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis				4	3
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides			6	3	2
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	5	6	7	7	10
Smallmouth buffalo	Ictiobus bubalus	19	13	5	17	10
Black buffalo	Ictiobus niger			9	5	
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio	1			1	2
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					1
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	7		17	12	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	7	2	10	2	2
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					
Blackstripe topminnow	Fundulus notatus			1		
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis		1	1		
Brook silverside	Labidesthes sicculus			1	2	1
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops	2		1	1	6

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1994AUG15	1995AUG12	1998SEP08	2000SEP07	2003JUL30
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis	1		4		
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus	6	2		3	1
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	4	1		2	
Largemouth bass	Micropterus salmoides	16	2	2		3
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus			1		
Green sunfish	Lepomis cyanellus				1	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	24	5	15	4	4
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis					1
Orangespotted sunfish	Lepomis humilis			1		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	2		5	18	9

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Cedar Creek
Date		2008AUG26	2010NOV09	2013AUG08	2014SEP25	1964JUL09
Station code		N-99	N-99	N-99	N-99	NA-01
Species		26	20	32	18	9
Non-native proportion		0.08	0.12	0.06	0.05	
Total fish		177	158	416	167	84
Electrode minutes		60	60	60	60	
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	2	1	18	1	
Longnose gar	Lepisosteus osseus		1	12	2	
Spotted gar	Lepisosteus oculatus		3	6		
Bowfin	Amia calva	4		3		
Skipjack herring	Alosa chrysochloris				1	
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	45	18	229	82	
Threadfin shad	Dorosoma petenense	1	1			
Goldeye	Hiodon alosoides			1	1	
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					3
Grass carp	Ctenopharyngodon idella	1		1		
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix	2		5	8	
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	10	18	17	1	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					39
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis			2		
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	2		9	14	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax			2		
Emerald shiner	Notropis atherinoides	7		12	24	
River shiner	Notropis blennius			1		
Sand shiner	Notropis ludibundus				1	
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		10	4	1	
Smallmouth buffalo	Ictiobus bubalus	7	6	19	3	
Black buffalo	Ictiobus niger		1	1		
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio	1		4	5	
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	29	2	12	6	
Blue catfish	Ictalurus furcatus	3		3		
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					1
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	4		4	1	
Madtom spp.	Noturus spp.					11
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					17
Blackstripe topminnow	Fundulus notatus	1		1		
Blackspotted topminnow	Fundulus olivaceus			1		
Mosquitofish	Gambusia affinis			1		
Brook silverside	Labidesthes sicculus	10				
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops	7	31	5	2	

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Cedar Creek
Date		2008AUG26	2010NOV09	2013AUG08	2014SEP25	1964JUL09
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops		1			
Yellow bass	Morone mississippiensis	2				
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus	1	2	2		
Blacknose crappie	Pomoxis nigromaculatus					
White crappie	Pomoxis annularis	3	2	1		
Largemouth bass	Micropterus salmoides	3	34			2
Spotted bass	Micropterus punctulatus					2
Warmouth	Lepomis gulosus		1	7		3
Green sunfish	Lepomis cyanellus					2
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					1
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	6	14	14		1
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis		4	5		2
Orangespotted sunfish	Lepomis humilis	3	1	3	2	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum	1				
Sauger	Stizostedion canadense	1	1			
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	21	6	11	12	

Water body		Cedar Creek	Cedar Creek	Cedar Creek	Cedar Creek	Cave Creek
Date		1995JUL28	2003JUL23	2003JUL22	2008JUL29	1995JUL24
Station code		NA-01	NA-02	NA-03	NA-03	NAC-01
Species		12	13	17	27	11
Non-native proportion		0.07	0.04			
Total fish		32	52	75	176	85
Electrode minutes		25.36	35	26.05	38	27
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus		4	1		
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus			1		
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	10	13	2	3	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	2	2			
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas	3			3	
Creek chub	Semotilus atromaculatus				2	17
Central stoneroller	Campostoma anomalum					7
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis			8		
Redfin shiner	Lythrurus umbratilus				16	
Ribbon shiner	Lythrurus fumeus	1				
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					6
Pugnose minnow	Opsopoeodus emiliae			1		
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus			2	1	3
Bullhead minnow	Pimephales vigilax			1		
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi			21		
Bigmouth buffalo	Ictiobus cyprinellus	1		1	4	
Smallmouth buffalo	Ictiobus bubalus				4	
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni				2	22
Spotted sucker	Minytrema melanops		2	5	4	
Creek chubsucker	Erimyzon oblongus				1	14
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum				1	
Channel catfish	Ictalurus punctatus		1			
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis				1	
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus		1	1		
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	3	2			1
Blackstripe topminnow	Fundulus notatus		2	5	16	
Blackspotted topminnow	Fundulus olivaceus	1		2	7	2
Mosquitofish	Gambusia affinis				2	
Brook silverside	Labidesthes sicculus				1	
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Cedar Creek	Cedar Creek	Cedar Creek	Cedar Creek	Cave Creek
Date		1995JUL28	2003JUL23	2003JUL22	2008JUL29	1995JUL24
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus				3	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	2	2	2	7	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus				2	
Green sunfish	Lepomis cyanellus	3	1		11	8
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					1
Bluegill	Lepomis macrochirus	1	5	8	35	
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus	2				
Redear sunfish	Lepomis microlophus				6	
Longear sunfish	Lepomis megalotis	2	13	13	21	1
Orangespotted sunfish	Lepomis humilis				13	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid				1	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum			1	2	3
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	1			3	
Freshwater drum	Aplodinotus grunniens		4		4	

Water body		Cave Creek	Kinkaid Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek
Date		2008JUN09	1964JUL09	1995JUL20	1998AUG20	2000AUG16
Station code		NAC-02	NB-01	NC-03	NC-03	NC-03
Species		15	13	16	10	20
Non-native proportion			0.04	0.44	0.22	0.17
Total fish		130	892	57	37	111
Electrode minutes		42		30	60	70
Seine hauls						1
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus		1			1
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					1
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum			3	10	26
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio		7	25	8	19
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)		705			
Golden shiner	Notemigonus crysoleucas	1		1		
Creek chub	Semotilus atromaculatus	1				
Central stoneroller	Campostoma anomalum	10				
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	13				
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis			4		5
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	25				
Bullhead minnow	Pimephales vigilax			1		
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					1
Smallmouth buffalo	Ictiobus bubalus					3
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					1
River carpsucker	Carpiodes carpio				1	1
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni		2			
Spotted sucker	Minytrema melanops		9			
Creek chubsucker	Erimyzon oblongus	22				
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum		29			
Channel catfish	Ictalurus punctatus			1	8	7
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	2	25			
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris			2		1
Madtom spp.	Noturus spp.		3			
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	1	1	1		
Blackstripe topminnow	Fundulus notatus	8		1		1
Blackspotted topminnow	Fundulus olivaceus	4		1		
Mosquitofish	Gambusia affinis			4		
Brook silverside	Labidesthes sicculus				2	2
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Cave Creek	Kinkaid Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek
Date		2008JUN09	1964JUL09	1995JUL20	1998AUG20	2000AUG16
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis		3			7
Largemouth bass	Micropterus salmoides	1	2	1	2	8
Spotted bass	Micropterus punctulatus		36			
Warmouth	Lepomis gulosus			1		1
Green sunfish	Lepomis cyanellus	17	26	1		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	6	6	5	1	8
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	17	37	5	2	10
Orangespotted sunfish	Lepomis humilis				1	3
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	2				
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens				2	4

Water body		Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek
Date		2003JUL15	1964JUL09	1964JUL14	1995JUL20	2000JUL24
Station code		NC-03	NC-07	NC-08	NC-09	NC-09
Species		19	4	12	30	20
Non-native proportion		0.16			0.11	0.07
Total fish		79	74	197	232	204
Electrode minutes		60			35	33.2
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva	1				
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	17		1	16	20
Threadfin shad	Dorosoma petenense				7	
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		6			
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	13			19	14
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)		29	110		
Golden shiner	Notemigonus crysoleucas				4	
Creek chub	Semotilus atromaculatus					1
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storerlana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	1			2	
Pugnose minnow	Opsopoeodus emiliae				1	
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					2
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	3				
Smallmouth buffalo	Ictiobus bubalus				1	
Black buffalo	Ictiobus niger	1				
Unidentified Carpsucker	Carpiodes sp.			1		
Quillback	Carpiodes cyprinus	1				
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni			11	1	29
Spotted sucker	Minytrema melanops			5	5	1
Creek chubsucker	Erimyzon oblongus				3	5
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	2			2	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis		4	10	3	3
Black bullhead	Ameiurus melas				1	
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	1				
Madtom spp.	Noturus spp.			12		
Tadpole madtom	Noturus gyrinus				5	3
Freckled madtom	Noturus nocturnus	1				
Pirate perch	Aphredoderus sayanus			1	4	13
Blackstripe topminnow	Fundulus notatus				5	31
Blackspotted topminnow	Fundulus olivaceus	1				1
Mosquitofish	Gambusia affinis				5	3
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek
Date		2003JUL15	1964JUL09	1964JUL14	1995JUL20	2000JUL24
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus				1	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	1		2	30	
Largemouth bass	Micropterus salmoides	4		1	1	9
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	2		1	6	1
Green sunfish	Lepomis cyanellus	2	12	8	9	43
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	3		9	75	21
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus				1	
Longear sunfish	Lepomis megalotis	17	23	7	2	1
Orangespotted sunfish	Lepomis humilis	1		18	6	2
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid				2	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes				1	
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene				12	
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile				1	1
Freshwater drum	Aplodinotus grunniens	7			1	

Water body		Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek
Date		2013JUL15	1995SEP06	2013AUG12	1995JUL18	2003JUL15
Station code		NC-09	NC-10	NC-10	NC-11	NC-11
Species		14	20	22	8	10
Non-native proportion		0.01	0.06		0.07	0.11
Total fish		77	108	330	29	39
Electrode minutes		28.25	46.09	28.53	30	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus				1	1
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		4	12	5	9
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	1	7		2	4
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas	2				
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storerlana					
Silvery minnow	Hybognathus nuchalis				3	
Redfin shiner	Lythrurus umbratilus		1	11		
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	4	1	37	14	3
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	3	10	5		
Bullhead minnow	Pimephales vigilax		10	17		
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus			142		
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					1
Smallmouth buffalo	Ictiobus bubalus					2
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		1	3		2
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	5	1	2		
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris		3		1	5
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus			12		
Freckled madtom	Noturus nocturnus			5		
Pirate perch	Aphredoderus sayanus	3	1			
Blackstripe topminnow	Fundulus notatus	5	1	1		
Blackspotted topminnow	Fundulus olivaceus	1	10	7		
Mosquitofish	Gambusia affinis	1	4		2	
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek
Date		2013JUL15	1995SEP06	2013AUG12	1995JUL18	2003JUL15
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	1	1			
Largemouth bass	Micropterus salmoides	4	2	3		
Spotted bass	Micropterus punctulatus			2		
Warmouth	Lepomis gulosus			1		
Green sunfish	Lepomis cyanellus	14	4	1		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	23	22	10		
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis		22	46		4
Orangespotted sunfish	Lepomis humilis			5		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	10		5		
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene			1		
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile			2		
Freshwater drum	Aplodinotus grunniens		2		1	7

Water body		Rattlesnake Creek	Rattlesnake Creek	Walkers Creek	Walkers Creek	Galum Creek
Date		1995JUL18	2003JUL14	1995JUL31	2013JUN24	1995JUL18
Station code		NCB-01	NCB-01	NCC-01	NCC-01	NCD-03
Species		15	20	10	12	14
Non-native proportion		0.08	0.02			
Total fish		62	129	50	148	59
Electrode minutes		30	18.63			
Seine hauls				2	6	2
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus				1	1
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum				44	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					1
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	4		1		
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	5	2			
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus	7	16			
Central stoneroller	Campostoma anomalum		10			
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis		33			
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		11	9	4	18
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	1	1			
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		1			
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	1	18			
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus			2		3
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	3		7		
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	5	5			1
Blackstripe topminnow	Fundulus notatus		1		1	
Blackspotted topminnow	Fundulus olivaceus		1	2	1	2
Mosquitofish	Gambusia affinis		2			7
Brook silverside	Labidesthes sicculus					3
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Rattlesnake Creek	Rattlesnake Creek	Walkers Creek	Walkers Creek	Galum Creek
Date		1995JUL18	2003JUL14	1995JUL31	2013JUN24	1995JUL18
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus	4				
Black crappie	Pomoxis nigromaculatus				8	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis				6	2
Largemouth bass	Micropterus salmoides	1	7		12	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus					
Green sunfish	Lepomis cyanellus	13	8	1	1	8
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus	1				
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	6	3	19	66	7
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					1
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	5	1	1	1	3
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	1	3	2	3	
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					1
Orangethroat darter	Etheostoma spectabile	3	2			
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	2	3	6		1
Freshwater drum	Aplodinotus grunniens					

Water body		Galum Creek	Galum Creek	Galum Creek	Galum Creek	Pipestone Creek
Date		1995JUL27	2003JUL14	1964JUL14	2003JUL15	1995JUL12
Station code		NCD-05	NCD-05	NCD-06	NCD-07	NCDA-01
Species		9	9	5	16	18
Non-native proportion		0.08			0.23	0.02
Total fish		129	122	276	81	352
Electrode minutes		30			60	
Seine hauls			14			
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum				19	6
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					2
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	10			19	6
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)			206		
Golden shiner	Notemigonus crysoleucas					21
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					1
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	12			4	13
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	2				
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus				2	
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio				3	
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	15			4	168
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis			3		1
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris				2	
Madtom spp.	Noturus spp.			4		
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus				1	
Pirate perch	Aphredoderus sayanus			38		2
Blackstripe topminnow	Fundulus notatus	13	14			4
Blackspotted topminnow	Fundulus olivaceus		2			5
Mosquitofish	Gambusia affinis		13		1	10
Brook silverside	Labidesthes sicculus					43
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Galum Creek	Galum Creek	Galum Creek	Galum Creek	Pipestone Creek
Date		1995JUL27	2003JUL14	1964JUL14	2003JUL15	1995JUL12
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	3	20		1	1
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus		1		1	
Green sunfish	Lepomis cyanellus	10	1	2	4	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus	4				
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus			4		
Bluegill	Lepomis macrochirus	39	68	7	9	34
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus		1			
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	18	1	12	6	3
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	3				1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum		1		1	3
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					28
Freshwater drum	Aplodinotus grunniens				4	

Water body		Pipestone Creek	Rocky Fork	Little Galum Creek	Little Galum Creek	Little Galum Creek
Date		2003JUL14	2013JUN13	2013JUL31	1995JUL12	2008JUN11
Station code		NCDA-01	NCDAA-01	NCDB-	NCDB-01	NCDB-01
Species		6	13	12	12	11
Non-native proportion						
Total fish		22	230	246	131	259
Electrode minutes			26.22		30	
Seine hauls		3		9.9		7.5
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1				
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum					
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus		46		12	
Central stoneroller	Campostoma anomalum		8		35	
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus			214	4	60
Ribbon shiner	Lythrurus fumeus			1		
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	8	1	5	1	19
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus			5		6
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus		118			3
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni			1		145
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis		1		1	
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus		17	1	6	
Blackstripe topminnow	Fundulus notatus	2		2		4
Blackspotted topminnow	Fundulus olivaceus	2	15	9	1	
Mosquitofish	Gambusia affinis			1		
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Pipestone Creek	Rocky Fork	Little Galum Creek	Little Galum Creek	Little Galum Creek
Date		2003JUL14	2013JUN13	2013JUL31	1995JUL12	2008JUN11
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides		4	2	8	14
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus				1	
Green sunfish	Lepomis cyanellus		4		42	1
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	8	2		19	5
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis		6	1		1
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata	1				
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum			4	1	1
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps		7			
Slough darter	Etheostoma gracile		1			
Freshwater drum	Aplodinotus grunniens					

Water body		Little Galum Creek	Bonnie Creek	Bonnie Creek	Panther Creek	Panther Creek
Date		2013JUL31	1995JUL27	2013JUN13	1995JUL25	2000JUL24
Station code		NCDB-01	NCDC-01	NCDC-01	NCE-02	NCE-02
Species		12	15	11	25	18
Non-native proportion					0.01	0.04
Total fish		88	145	120	248	115
Electrode minutes			35.17			53.5
Seine hauls		8.1		9.7	2	
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					1
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum				5	2
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus				6	1
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio				2	5
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas		4			
Creek chub	Semotilus atromaculatus	16	8			
Central stoneroller	Campostoma anomalum	4				
Suckermouth minnow	Phenacobius mirabilis	1		1		
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					1
Redfin shiner	Lythrurus umbratilus	7		3	4	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		2	17	30	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	10	3	1	11	
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus	8	2			
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus				1	
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops				1	
Creek chubsucker	Erimyzon oblongus		1			
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus				6	7
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	3	1			
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus		3		2	3
Blackstripe topminnow	Fundulus notatus	5	1	4	6	10
Blackspotted topminnow	Fundulus olivaceus	14	2	10	6	1
Mosquitofish	Gambusia affinis				7	
Brook silverside	Labidesthes sicculus			1	3	4
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Little Galum Creek	Bonnie Creek	Bonnie Creek	Panther Creek	Panther Creek
Date		2013JUL31	1995JUL27	2013JUN13	1995JUL25	2000JUL24
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					3
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis				2	
Largemouth bass	Micropterus salmoides	6	2	32	2	17
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus					3
Green sunfish	Lepomis cyanellus	6	28			3
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus		23	44	95	41
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus				1	
Longear sunfish	Lepomis megalotis		64	4	21	5
Orangespotted sunfish	Lepomis humilis					1
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					3
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata				1	
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes				3	
Johnny darter	Etheostoma nigrum	8		3	24	4
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene				4	
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile		1		1	
Freshwater drum	Aplodinotus grunniens				4	

Water body		White Walnut Cree	ittle Beaucoup Cree	ittle Beaucoup Cree	Swanwick Creek	Swanwick Creek
Date		2013JUL22	1995AUG01	2008JUL08	1995JUL20	2008JUN11
Station code		NCH-01	NCI-01	NCI-01	NCK-01	NCK-02
Species		13	13	12	17	15
Non-native proportion					0.14	
Total fish		219	104	55	130	73
Electrode minutes		20.1	25.17	24.5	35	23.4
Seine hauls					60	
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	2			27	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		6	1	1	1
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio				18	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas		3	14		1
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	2	7			1
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		1			1
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni				6	
Spotted sucker	Minytrema melanops				1	
Creek chubsucker	Erimyzon oblongus		12	3		4
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus				2	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	4			6	1
Black bullhead	Ameiurus melas				3	
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	3	18	5	1	2
Blackstripe topminnow	Fundulus notatus	18		4	3	7
Blackspotted topminnow	Fundulus olivaceus	10	8	4		
Mosquitofish	Gambusia affinis	17	1	4		
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		White Walnut Cree	little Beaucoup Cree	ttle Beaucoup Cree	Swanwick Creek	Swanwick Creek
Date		2013JUL22	1995AUG01	2008JUL08	1995JUL20	2008JUN11
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis				5	1
Largemouth bass	Micropterus salmoides	16		4	1	1
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus				2	
Green sunfish	Lepomis cyanellus	40	19	3	2	18
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	73	20	9	36	30
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus	2		2		
Longear sunfish	Lepomis megalotis	27	6	2	15	3
Orangespotted sunfish	Lepomis humilis				1	1
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid		1			
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	5				
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile		1			1
Freshwater drum	Aplodinotus grunniens					

Water body		Locust Creek	Locust Creek	Locust Creek	Glenn Creek	Crab Orchard Creek
Date		1995JUL20	2000JUL11	2013JUL15	2013JUN24	1995JUL18
Station code		NCN-02	NCN-02	NCN-02	NCS-01	ND-01
Species		22	19	12	18	18
Non-native proportion		0.01		0.02	0.06	0.12
Total fish		166	142	251	383	82
Electrode minutes		30	35.7	35.03		30
Seine hauls					7.26	
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus				5	1
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					2
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	12	7		16	32
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	1	1			
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	1		4	22	10
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas				10	
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					5
Redfin shiner	Lythrurus umbratilus	2	1			
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis				1	5
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	16				
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					1
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus				93	
Smallmouth buffalo	Ictiobus bubalus				17	5
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	1	6			
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus	2	2			
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		1			
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	9	11	4		
Black bullhead	Ameiurus melas		1			
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					1
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus	6	6	3		
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	9	5	3	1	
Blackstripe topminnow	Fundulus notatus	8	2	14	14	1
Blackspotted topminnow	Fundulus olivaceus	3	6	6	3	
Mosquitofish	Gambusia affinis				77	1
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Locust Creek	Locust Creek	Locust Creek	Glenn Creek	Crab Orchard Creek
Date		1995JUL20	2000JUL11	2013JUL15	2013JUN24	1995JUL18
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis	1				1
Flier	Centrarchus macropterus				25	
Black crappie	Pomoxis nigromaculatus				2	1
Blacknose crappie	Pomoxis migromaculatus				5	
White crappie	Pomoxis annularis	5	1		10	
Largemouth bass	Micropterus salmoides	2	12	7	43	7
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus			3		
Green sunfish	Lepomis cyanellus	16	7	16		1
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	36	43	163	38	4
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	27	27	17		1
Orangespotted sunfish	Lepomis humilis	3				3
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	3		6		
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes	1				
Johnny darter	Etheostoma nigrum	1	2	5		
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene				1	
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	1	1			
Freshwater drum	Aplodinotus grunniens					

Water body		Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek
Date		2003JUL16	2008SEP02	2003JUL23	2008JUL07	1999JUL14
Station code		ND-01	ND-01	ND-04	ND-04	ND-08
Species		27	29	17	13	11
Non-native proportion		0.08	0.05	0.07	0.07	
Total fish		270	285	183	99	72
Electrode minutes		60	53	60	26.1	21
Seine hauls				3		
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	9				
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva	4	1	1		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	50	88	30	6	2
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus			8	2	2
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis		2			
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	22	12	12	7	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	85				
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus	4				
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	2	2			
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	2	2			
Bullhead minnow	Pimephales vigilax	3	5			
Emerald shiner	Notropis atherinoides		6			
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi	14				
Bigmouth buffalo	Ictiobus cyprinellus	3	1			
Smallmouth buffalo	Ictiobus bubalus	7	13			
Black buffalo	Ictiobus niger	1	3			
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus	1				
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni			3		
Spotted sucker	Minytrema melanops		2			
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum	2				
Channel catfish	Ictalurus punctatus	1		1	5	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					7
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris				1	
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus	1				
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus		1	1		4
Blackstripe topminnow	Fundulus notatus		1	4	1	1
Blackspotted topminnow	Fundulus olivaceus		1			
Mosquitofish	Gambusia affinis			20		2
Brook silverside	Labidesthes sicculus		4			1
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops		3			

Water body		Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek
Date		2003JUL16	2008SEP02	2003JUL23	2008JUL07	1995JUL14
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis		2			
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		12	3	2	
Blacknose crappie	Pomoxis nigromaculatus					
White crappie	Pomoxis annularis	1	4			
Largemouth bass	Micropterus salmoides	6	6	10	3	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	1	13	3		
Green sunfish	Lepomis cyanellus	4	1	4	7	44
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	6	34	31	22	4
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus			1		
Longear sunfish	Lepomis megalotis	9	44	34	34	2
Orangespotted sunfish	Lepomis humilis	3	12		3	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					1
Walleye	Stizostedion vitreum		2			
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes	4				
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene	1				
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					2
Freshwater drum	Aplodinotus grunniens	24	7	17	6	

Water body		Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek	Little Crab Orchard	Piles Fork
Date		2000JUL26	1995AUG04	2000JUL26	1995JUL07	1995JUL10
Station code		ND-08	ND-14	ND-14	NDA-01	NDB-03
Species		7	16	15	23	12
Non-native proportion			0.04	0.02	0.17	0.14
Total fish		61	95	55	117	50
Electrode minutes		25.62	30	35.5	23.5	23.16
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	39	17	4	1	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		1	4		
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio		4	1	19	7
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas				1	
Creek chub	Semotilus atromaculatus				14	
Central stoneroller	Campostoma anomalum				3	
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus				5	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					1
Bluntnose minnow	Pimephales notatus				4	
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					5
Smallmouth buffalo	Ictiobus bubalus				4	2
Black buffalo	Ictiobus niger					4
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni				3	
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus				5	1
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		2	1		
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis		6	5		1
Black bullhead	Ameiurus melas		5			1
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus		1	4	2	
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	1		1	9	
Blackstripe topminnow	Fundulus notatus	1		3	2	
Blackspotted topminnow	Fundulus olivaceus				3	4
Mosquitofish	Gambusia affinis		1		2	
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek	Little Crab Orchard	Piles Fork
Date		2000JUL26	1995AUG04	2000JUL26	1995JUL07	1995JUL10
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis		1			
Flier	Centrarchus macropterus		1	1	1	2
Black crappie	Pomoxis nigromaculatus		1			
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	1	2	1	6	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus				2	
Green sunfish	Lepomis cyanellus	13	38	16	7	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	3	10	11	8	3
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	3	4	1	3	19
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid				2	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes			1		
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum				1	
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile				10	
Freshwater drum	Aplodinotus grunniens		1	1		

Water body		Piles Fork	Glade Creek	Drury Creek	Drury Creek	Drury Creek
Date		2013JUN10	2013MAY29	1964JUL10	2000JUL25	1995AUG03
Station code		NDB-05	NDBA-01	NDC-01	NDC-01	NDC-02
Species		12	9	6	21	24
Non-native proportion						
Total fish		116	865	1055	149	377
Electrode minutes		20.92			24.4	30
Seine hauls			8.1			
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					2
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus	1				
Bowfin	Amia calva				1	
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		2		3	5
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus			1	1	1
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)			904		
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					6
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis				26	201
Redfin shiner	Lythrurus umbratilus	2				4
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis				31	24
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	5			5	5
Bullhead minnow	Pimephales vigilax				1	
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops			1	1	
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					2
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis			43	4	6
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.			11		
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	1	6	17	3	2
Blackstripe topminnow	Fundulus notatus		158		2	1
Blackspotted topminnow	Fundulus olivaceus	25			1	
Mosquitofish	Gambusia affinis	7	507			13
Brook silverside	Labidesthes sicculus					4
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Piles Fork	Glade Creek	Drury Creek	Drury Creek	Drury Creek
Date		2013JUN10	2013MAY29	1964JUL10	2000JUL25	1995AUG03
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					1
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	2			7	6
Spotted bass	Micropterus punctulatus					4
Warmouth	Lepomis gulosus	1			4	
Green sunfish	Lepomis cyanellus	10	22	50	22	25
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	16	141		10	25
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					1
Longear sunfish	Lepomis megalotis	45	6	28	20	21
Orangespotted sunfish	Lepomis humilis		22			
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1		1	2
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes				2	
Johnny darter	Etheostoma nigrum	1			2	10
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile				2	5
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens					

Water body		Drury Creek	Drury Creek	Drury Creek	Sycamore Creek	Sycamore Creek
Date		2003JUL22	2013JUN10	2008JUN16	2008JUN05	2013JUN10
Station code		NDC-02	NDC-02	NDC-99	NDCA-01	NDCA-02
Species		17	19	18	10	8
Non-native proportion				0.04		
Total fish		70	365	171	46	51
Electrode minutes		29.33	28.33	35	19.2	15.22
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1	2			
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva			1		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	1		6		
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		1	1		
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio			7		
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus	6			9	
Central stoneroller	Campostoma anomalum	7	6		10	18
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	4				
Redfin shiner	Lythrurus umbratilus		1	38		
Ribbon shiner	Lythrurus fumeus	1	3			
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	14	18			8
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		55	1	9	
Bullhead minnow	Pimephales vigilax		6			
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus		168			
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi	2				
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni			12	1	
Spotted sucker	Minytrema melanops			11		
Creek chubsucker	Erimyzon oblongus			1	5	
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus			2		
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	3			2	
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus		1			
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	2				
Blackstripe topminnow	Fundulus notatus		11			
Blackspotted topminnow	Fundulus olivaceus	1		4		
Mosquitofish	Gambusia affinis	1	3			2
Brook silverside	Labidesthes sicculus			1		
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Drury Creek	Drury Creek	Drury Creek	Sycamore Creek	Sycamore Creek
Date		2003JUL22	2013JUN10	2008JUN16	2008JUN05	2013JUN10
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		1			
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	4	2	13	1	2
Spotted bass	Micropterus punctulatus			6		
Warmouth	Lepomis gulosus					
Green sunfish	Lepomis cyanellus	14	20	10	2	2
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	4	10	7	3	12
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	4	53	48		6
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid				3	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					1
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	1	3			
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile				1	
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile		1			
Freshwater drum	Aplodinotus grunniens			2		

Water body		Indian Creek	Indian Creek	Indian Creek	Indian Creek	Grassy Creek
Date		1995JUL26	2000JUL25	2008JUN10	2008JUL29	1995JUL06
Station code		NDCB-01	NDCB-01	NDCB-01	NDCB-02	NDD-03
Species		14	15	9	15	15
Non-native proportion						
Total fish		176	49	37	1503	732
Electrode minutes		30	44.5	27.1	27.8	31
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum					
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		1			
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus	5			69	36
Central stoneroller	Campostoma anomalum	14			133	54
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					163
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	7		3	26	11
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	15	5	3	622	228
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	1			1	1
Spotted sucker	Minytrema melanops		1			
Creek chubsucker	Erimyzon oblongus	19	2		116	57
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	3			1	7
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus		1			
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus		6	1		
Blackstripe topminnow	Fundulus notatus		1	15	5	1
Blackspotted topminnow	Fundulus olivaceus	18			6	8
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Indian Creek	Indian Creek	Indian Creek	Indian Creek	Grassy Creek
Date		1995JUL26	2000JUL25	2008JUN10	2008JUL29	1995JUL06
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	2	1	1	3	
Spotted bass	Micropterus punctulatus		1			
Warmouth	Lepomis gulosus			1		
Green sunfish	Lepomis cyanellus	25	8	4	76	49
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	2	3	1	135	1
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	53	10	8	293	97
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	3	3		4	3
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile	9	3		13	16
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile		3			
Freshwater drum	Aplodinotus grunniens					

Water body		Grassy Creek	Grassy Creek	Little Grassy Creek	Little Grassy Creek	Wolf Creek
Date		2008JUN16	1995JUN02	1995JUL05	2008JUN12	1995JUL28
Station code		NDD-03	NDD-04	NDDA-01	NDDA-01	NDJ-01
Species		15	13	16	10	22
Non-native proportion						
Total fish		346	155	336	55	165
Electrode minutes		35.4	28.33	30	37.1	30
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		1	4		5
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus			5	2	
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas		1	1		
Creek chub	Semotilus atromaculatus	17				4
Central stoneroller	Campostoma anomalum	33				26
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	25				1
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					1
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas			140		
Bluntnose minnow	Pimephales notatus	104	31	3	14	25
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	1				2
Spotted sucker	Minytrema melanops		1			4
Creek chubsucker	Erimyzon oblongus	10				2
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus			6	7	1
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	3	4	11		3
Black bullhead	Ameiurus melas					2
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus			3		
Blackstripe topminnow	Fundulus notatus	4	1	1	3	
Blackspotted topminnow	Fundulus olivaceus	6	3	1	4	1
Mosquitofish	Gambusia affinis					6
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Grassy Creek	Grassy Creek	Little Grassy Creek	Little Grassy Creek	Wolf Creek
Date		2008JUN16	1995JUN02	1995JUL05	2008JUN12	1995JUL28
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	6	2	11	1	2
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus		2	1		
Green sunfish	Lepomis cyanellus	10	23	5	6	11
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	25	9	56	7	20
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus			30	1	
Longear sunfish	Lepomis megalotis	77	66	56	10	21
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid			2		7
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes		11			3
Johnny darter	Etheostoma nigrum	4				10
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile	21				7
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					1
Freshwater drum	Aplodinotus grunniens					

Water body		Wolf Creek	Little Muddy River	Little Muddy River	Little Muddy River	Little Muddy River
Date		2008JUN16	1995JUL19	2000JUL27	2013AUG12	1964JUL10
Station code		NDJ-01	NE-04	NE-04	NE-04	NE-05
Species		20	19	24	25	13
Non-native proportion			0.22	0.11		0.05
Total fish		245	158	174	150	226
Electrode minutes		27.6	50	40	28.67	
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus			1		
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus		1			
Bowfin	Amia calva	1	2	1		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		71	45		
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	25	3	2	3	4
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio		35	19		8
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					47
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus	13				
Central stoneroller	Campostoma anomalum	17				
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	8		1	1	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		1	3		
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	34	1	4	1	
Bullhead minnow	Pimephales vigilax				1	
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus				1	
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		2	2		2
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					1
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops			3	2	7
Creek chubsucker	Erimyzon oblongus	7				
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus			1		6
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	1	1			
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					1
Madtom spp.	Noturus spp.					28
Tadpole madtom	Noturus gyrinus				3	
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	6		9	2	11
Blackstripe topminnow	Fundulus notatus	11	1		18	
Blackspotted topminnow	Fundulus olivaceus	2		7	7	
Mosquitofish	Gambusia affinis	2			1	
Brook silverside	Labidesthes sicculus			5	2	
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Wolf Creek	Little Muddy River	Little Muddy River	Little Muddy River	Little Muddy River
Date		2008JUN16	1995JUL19	2000JUL27	2013AUG12	1964JUL10
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus			3	1	6
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis		3	2		7
Largemouth bass	Micropterus salmoides	4	2	17	7	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus		8	11	12	11
Green sunfish	Lepomis cyanellus	15	6	6	10	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					1
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus		1			
Bluegill	Lepomis macrochirus	42	4	13	17	
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus		1			
Longear sunfish	Lepomis megalotis	38	6	2	36	74
Orangespotted sunfish	Lepomis humilis		1	10	7	10
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	3				
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata			2	1	
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes	5			4	
Johnny darter	Etheostoma nigrum	6			5	
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene				2	
Orangethroat darter	Etheostoma spectabile	4			1	
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	1			5	
Freshwater drum	Aplodinotus grunniens		8	5		2

Water body		Little Muddy River	Little Muddy River	Little Muddy River	Little Muddy River	Little Muddy River
Date		1995JUL19	2000AUG16	2003JUL17	2008JUN19	1995AUG07
Station code		NE-05	NE-05	NE-05	NE-05	NE-06
Species		19	20	19	21	8
Non-native proportion		0.31	0.13	0.19	0.02	
Total fish		49	104	102	226	156
Electrode minutes		40	60	60	50	27
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1	1	4		
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus	2	2	2	4	
Bowfin	Amia calva			2		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	7	25	9	16	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	1				
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	15	14	19	4	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					100
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	2	12		13	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		1		5	14
Bullhead minnow	Pimephales vigilax	3		3		
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		2	2	2	
Smallmouth buffalo	Ictiobus bubalus		4	1	1	
Black buffalo	Ictiobus niger		1		1	
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus	1				
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					16
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		3	1	7	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					3
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris		1			
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus				2	
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	1	1	2		11
Blackstripe topminnow	Fundulus notatus				2	1
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis	1			1	
Brook silverside	Labidesthes sicculus				2	
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Little Muddy River	Little Muddy River	Little Muddy River	Little Muddy River	Little Muddy River
Date		1995JUL19	2000AUG16	2003JUL17	2008JUN19	1995AUG07
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus	1	3	2	3	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	3	3	4	4	
Largemouth bass	Micropterus salmoides	1	2	7		1
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	1	3	13	56	
Green sunfish	Lepomis cyanellus	2			2	7
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	2	6	3	26	
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis		2	3	8	
Orangespotted sunfish	Lepomis humilis	1	10	16	61	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid			2		3
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene	1				
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile			1		
Freshwater drum	Aplodinotus grunniens	3	8	6	6	

Water body		Little Muddy River	Little Muddy River	Little Muddy River	Six Mile Creek	Reese Creek
Date		1964JUL01	2003JUL08	2013JUL17	1995JUL13	1995JUL13
Station code		NE-08	NE-09	NE-09	NEA-02	NEB-02
Species		7	18	17	19	17
Non-native proportion			0.04		0.01	
Total fish		116	94	196	251	276
Electrode minutes			42.13	44.7		
Seine hauls					2	
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva		1			
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		5	7		1
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	3			12	15
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio		4		2	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)	29				
Golden shiner	Notemigonus crysoleucas				9	
Creek chub	Semotilus atromaculatus				20	
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus			3	2	19
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis				14	
Pugnose minnow	Opsopoeodus emiliae		1			
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		6	8		
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		3			
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni		7			
Spotted sucker	Minytrema melanops	11	6			
Creek chubsucker	Erimyzon oblongus		2		1	
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum	2				
Channel catfish	Ictalurus punctatus			1		
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	6		5	2	1
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.	9				
Tadpole madtom	Noturus gyrinus			2		
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	23	1	6	15	15
Blackstripe topminnow	Fundulus notatus		8	42		3
Blackspotted topminnow	Fundulus olivaceus				16	
Mosquitofish	Gambusia affinis			1	1	9
Brook silverside	Labidesthes sicculus				1	1
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Little Muddy River	Little Muddy River	Little Muddy River	Six Mile Creek	Reese Creek
Date		1964JUL01	2003JUL08	2013JUL17	1995JUL13	1995JUL13
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					4
Black crappie	Pomoxis nigromaculatus		1			2
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis			3		
Largemouth bass	Micropterus salmoides		7	3		2
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus			2		2
Green sunfish	Lepomis cyanellus	5	7	19	8	13
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus		32	65	32	41
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus			4		
Longear sunfish	Lepomis megalotis	28	1	16	25	1
Orangespotted sunfish	Lepomis humilis				4	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid			1		
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum		1	8	31	
Bluntnose darter	Etheostoma chlorosomum				11	10
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile				45	137
Freshwater drum	Aplodinotus grunniens					

Water body		Reese Creek	Little Indian Creek	Puncheon Creek	Puncheon Creek	Puncheon Creek
Date		2008JUL08	1995JUL21	1995JUL25	2003JUL08	2013JUL17
Station code		NEB-02	NEE-01	NEI-01	NEI-01	NEI-01
Species		21	16	13	17	12
Non-native proportion						
Total fish		98	127	161	131	152
Electrode minutes		31.7		17.5	25.93	17.33
Seine hauls			2			
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1				
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	1				
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	7	1	2	2	
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas	3			12	
Creek chub	Semotilus atromaculatus	1	4	78	1	18
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis				3	
Redfin shiner	Lythrurus umbratilus		21		1	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	3	4	7	2	7
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops	2				
Creek chubsucker	Erimyzon oblongus	1	3	3	16	3
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	2	1	14		19
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus				1	
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus	2				
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	9	1	2	6	6
Blackstripe topminnow	Fundulus notatus	3	6	2	9	10
Blackspotted topminnow	Fundulus olivaceus	4				4
Mosquitofish	Gambusia affinis		30	2		2
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Reese Creek	Little Indian Creek	Puncheon Creek	Puncheon Creek	Puncheon Creek
Date		2008JUL08	1995JUL21	1995JUL25	2003JUL08	2013JUL17
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus	11				
Black crappie	Pomoxis nigromaculatus	12			1	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis		1			
Largemouth bass	Micropterus salmoides	1	2		6	29
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	6	1		2	
Green sunfish	Lepomis cyanellus	4	20	12	20	8
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	9	16	17	45	34
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus				1	
Longear sunfish	Lepomis megalotis	8	6	1		
Orangespotted sunfish	Lepomis humilis	8				
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid		5		2	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum			18	1	12
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile		5	3		
Freshwater drum	Aplodinotus grunniens					

Water body		Hurricane Creek	Hurricane Creek	Pond Creek	Pond Creek	Pond Creek
Date		1995JUL17	2008JUN10	1995JUL21	2000AUG17	1995JUL11
Station code		NF-01	NF-01	NG-03	NG-03	NG-04
Species		12	16	15	17	19
Non-native proportion			0	0.24	0.27	0.04
Total fish		99	239	113	97	167
Electrode minutes			36	50	40	30
Seine hauls		2				
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus			1	1	
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		14	44	31	1
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	4	8	1		27
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio		1	27	26	6
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					1
Silvery minnow	Hybognathus nuchalis				2	
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		11	4	1	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					1
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	1		3		
Smallmouth buffalo	Ictiobus bubalus			2	3	
Black buffalo	Ictiobus niger				2	
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					4
Spotted sucker	Minytrema melanops					1
Creek chubsucker	Erimyzon oblongus					1
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		2	2	1	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					4
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus		2			
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	5	1			20
Blackstripe topminnow	Fundulus notatus					2
Blackspotted topminnow	Fundulus olivaceus	6	50			
Mosquitofish	Gambusia affinis		17	1		
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Hurricane Creek	Hurricane Creek	Pond Creek	Pond Creek	Pond Creek
Date		1995JUL17	2008JUN10	1995JUL21	2000AUG17	1995JUL11
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus	7				1
Black crappie	Pomoxis nigromaculatus	4		2		
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis			1		
Largemouth bass	Micropterus salmoides	14	4	1	3	3
Spotted bass	Micropterus punctulatus				1	
Warmouth	Lepomis gulosus	2	5	5	2	8
Green sunfish	Lepomis cyanellus	2	44		1	12
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	27	42	3	3	42
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus		1			
Longear sunfish	Lepomis megalotis	25	31	16	11	25
Orangespotted sunfish	Lepomis humilis				3	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	1	5			1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes	1			1	
Johnny darter	Etheostoma nigrum					2
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile		1			
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					5
Freshwater drum	Aplodinotus grunniens				5	

Water body		Pond Creek	Pond Creek	Lake Creek	Lake Creek	d. Fk. Big Muddy Ri
Date		2003JUL21	2008JUN12	1995JUL25	2008JUN12	1964JUL02
Station code		NG-04	NG-05	NGA-02	NGA-02	NH-06
Species		18	11	14	12	11
Non-native proportion		0.01				0.05
Total fish		178	189	105	244	136
Electrode minutes		37.22		27.3	28.1	
Seine hauls			8.7			
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva	8				
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	2				
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	39		6	12	4
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus	2				
Carp	Cyprinus carpio					5
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					37
Golden shiner	Notemigonus crysoleucas	2	8		4	
Creek chub	Semotilus atromaculatus		2			
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus		12		2	
Ribbon shiner	Lythrurus fumeus		3			
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		1			
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni			1		
Spotted sucker	Minytrema melanops	1		1		
Creek chubsucker	Erimyzon oblongus	2		3	3	
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis			1	1	2
Black bullhead	Ameiurus melas				1	
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					3
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	24		4	1	34
Blackstripe topminnow	Fundulus notatus	3	18	2	1	
Blackspotted topminnow	Fundulus olivaceus	6			8	
Mosquitofish	Gambusia affinis	10				
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Pond Creek	Pond Creek	Lake Creek	Lake Creek	d. Fk. Big Muddy Ri
Date		2003JUL21	2008JUN12	1995JUL25	2008JUN12	1964JUL02
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus	19				2
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					3
Largemouth bass	Micropterus salmoides	4		2		
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	7		1		9
Green sunfish	Lepomis cyanellus	19	81	31	180	3
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus			2		
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	22	44	21	25	29
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus		4	2		
Longear sunfish	Lepomis megalotis	6	3	27	6	4
Orangespotted sunfish	Lepomis humilis					1
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid		12			
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum			1		
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	2	1			
Freshwater drum	Aplodinotus grunniens					

Water body		d. Fk. Big Muddy Rir	le Fork Big Muddy	d. Fk. Big Muddy Ri	. Fork Big Muddy R	d. Fk. Big Muddy Ri
Date		1995JUL25	2000SEP05	2003JUL09	2013JUN11	2003JUL10
Station code		NH-07	NH-07	NH-07	NH-09	NH-23
Species		19	22	21	10	25
Non-native proportion		0.1	0.07	0.14		0.11
Total fish		205	240	122	58	229
Electrode minutes		60	60	60	18	60
Seine hauls		60				
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					1
Longnose gar	Lepisosteus osseus	1				
Spotted gar	Lepisosteus oculatus	2	1	1		3
Bowfin	Amia calva	1	4	4		10
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	37	50	2		13
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus			4		
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	20	17	17		26
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas			1	4	
Creek chub	Semotilus atromaculatus				7	
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis			2		1
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	8	17	3		2
Smallmouth buffalo	Ictiobus bubalus	3	7	1		14
Black buffalo	Ictiobus niger		1	1		
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					1
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		1			
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	3	2	1		2
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					2
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	6	5	2	3	6
Blackstripe topminnow	Fundulus notatus	2	2		4	1
Blackspotted topminnow	Fundulus olivaceus	1			2	
Mosquitofish	Gambusia affinis			1		1
Brook silverside	Labidesthes sicculus		2			
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		d. Fk. Big Muddy Ri	le Fork Big Muddy	d. Fk. Big Muddy Ri	. Fork Big Muddy R	d. Fk. Big Muddy Ri
Date		1995JUL25	2000SEP05	2003JUL09	2013JUN11	2003JUL10
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis		1			
Flier	Centrarchus macropterus					1
Black crappie	Pomoxis nigromaculatus		2	1		5
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	2	2	2		7
Largemouth bass	Micropterus salmoides	2	2	12		13
Spotted bass	Micropterus punctulatus					2
Warmouth	Lepomis gulosus	21	22	21		37
Green sunfish	Lepomis cyanellus	8	9	9	25	8
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	67	60	26	8	32
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	8	10		3	5
Orangespotted sunfish	Lepomis humilis	10	11	9	1	33
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid		1	1		
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum				1	
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile			1		
Freshwater drum	Aplodinotus grunniens	3	11			3

Water body		d. Fk. Big Muddy Rid. Fk. Big Muddy Rid		le Fork Big Muddy	Ewing Creek	Ewing Creek
Date		2008AUG20	1995JUL17	2000AUG17	1995JUL11	2000JUL26
Station code		NH-23	NH-26	NH-26	NHB-01	NHB-01
Species		25	19	30	20	21
Non-native proportion		0.08	0.08	0.09	0.01	0.02
Total fish		338	220	243	476	196
Electrode minutes		60	60	60	28.08	43
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1				
Longnose gar	Lepisosteus osseus			1		
Spotted gar	Lepisosteus oculatus	1		1		
Bowfin	Amia calva	5	1	1		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	85	63	61	10	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		1		1	1
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix	1				
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	27	17	23	4	4
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas		1		1	1
Creek chub	Semotilus atromaculatus				3	4
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus		2	1	50	1
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	2				
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus				29	2
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides	3				3
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	7	55	6		
Smallmouth buffalo	Ictiobus bubalus	44	1	3		
Black buffalo	Ictiobus niger	1		3		
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus			1		
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					9
Spotted sucker	Minytrema melanops		1	1		
Creek chubsucker	Erimyzon oblongus				20	30
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus			6		
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	8		2	4	1
Black bullhead	Ameiurus melas		1		1	
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris			1		
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus		1	3		
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	6	2	3	6	34
Blackstripe topminnow	Fundulus notatus	6	5	2	10	12
Blackspotted topminnow	Fundulus olivaceus				8	
Mosquitofish	Gambusia affinis		5	1	3	2
Brook silverside	Labidesthes sicculus	10		2		
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		d. Fk. Big Muddy Riv	d. Fk. Big Muddy Riv	le Fork Big Muddy	Ewing Creek	Ewing Creek
Date		2008AUG20	1995JUL17	2000AUG17	1995JUL11	2000JUL26
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis	1		3		
Flier	Centrarchus macropterus		3	1		
Black crappie	Pomoxis nigromaculatus	5	27	17		
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	9	2	2		1
Largemouth bass	Micropterus salmoides	8		8	10	11
Spotted bass	Micropterus punctulatus		1			
Warmouth	Lepomis gulosus	36		44	1	
Green sunfish	Lepomis cyanellus	3			36	8
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	39	31	27	19	24
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	6		4	257	42
Orangespotted sunfish	Lepomis humilis	14		7		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					1
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					1
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile			1	3	3
Freshwater drum	Aplodinotus grunniens	10		7		

Water body		Ewing Creek	Little Bessie Creek	Akin Creek	Akin Creek	Sugar Camp Creek
Date		2013JUN11	2013JUN11	2008JUN04	2013MAY30	199SJUL25
Station code		NHB-02	NHD-01	NHG-01	NHG-01	NHH-01
Species		17	12	6	5	17
Non-native proportion						
Total fish		210	88	17	30	241
Electrode minutes		22.63	15.28	16.7	24	29.1
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum					1
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					5
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					14
Creek chub	Semotilus atromaculatus	24		1	2	
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	3		1		
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas			1		
Bluntnose minnow	Pimephales notatus	58	2			1
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	2			1	1
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus	1	1			45
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	2	2			3
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus	1				
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	2	5			5
Blackstripe topminnow	Fundulus notatus	14	9	1		14
Blackspotted topminnow	Fundulus olivaceus	12	5		12	32
Mosquitofish	Gambusia affinis	1	2			2
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Ewing Creek	Little Bessie Creek	Akin Creek	Akin Creek	Sugar Camp Creek
Date		2013JUN11	2013JUN11	2008JUN04	2013MAY30	1995JUL25
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	3	7			
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus					5
Green sunfish	Lepomis cyanellus	26	21	1	13	15
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus			4		
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	40	30	8	1	15
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	13	3			79
Orangespotted sunfish	Lepomis humilis	1				3
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid				1	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	7	1			1
Freshwater drum	Aplodinotus grunniens					

Water body		Sugar Camp Creek	Gun Creek	Gun Creek	Casey Fork	Casey Fork
Date		2003JUL21	1995JUL21	2008AUG18	1990JUL24	1992JUL14
Station code		NHH-01	NJ-01	NJ-01	NJ-07	NJ-07
Species		23	17	13	14	4
Non-native proportion			0.02	0.03	0.14	0.25
Total fish		254	84	103	44	20
Electrode minutes		33.38	30	15.8	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus				1	
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		1	13	4	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	12				
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus				1	
Carp	Cyprinus carpio		2	3	5	5
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas		1			
Creek chub	Semotilus atromaculatus	2				
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	1				
Redfin shiner	Lythrurus umbratilus	8	1			
Ribbon shiner	Lythrurus fumeus	6				
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	6				
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	34				
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus			1	1	
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	2	3	9		
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus	24	2			
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		1		5	5
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	7	6			
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	19	10	5	1	
Blackstripe topminnow	Fundulus notatus	4	6	24	1	
Blackspotted topminnow	Fundulus olivaceus	5				
Mosquitofish	Gambusia affinis	3	5	10		
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Sugar Camp Creek	Gun Creek	Gun Creek	Casey Fork	Casey Fork
Date		2003JUL21	1995JUL21	2008AUG18	1990JUL24	1992JUL14
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus				3	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis				8	5
Largemouth bass	Micropterus salmoides	1	2	11	9	5
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	1	7	1		
Green sunfish	Lepomis cyanellus	38	8	4		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	31	26	5	3	
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	29	2	15		
Orangespotted sunfish	Lepomis humilis	11			1	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes	3				
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum	1				
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	6	1	2		
Freshwater drum	Aplodinotus grunniens				1	

Water body		Casey Fork	Casey Fork	Casey Fork	Casey Fork	Casey Fork
Date		1995JUN22	1995JUL21	2000JUL27	2003JUL09	2008JUN18
Station code		NJ-07	NJ-07	NJ-07	NJ-07	NJ-07
Species		14	15	24	14	22
Non-native proportion		0.11	0.01	0.09		0.02
Total fish		217	132	222	268	279
Electrode minutes			15	60	60	60
Seine hauls					3	
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus	1				1
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	22	22	25	21	15
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus			3	4	
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	24	1	20		6
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas	2				10
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus		1	1	2	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		48	4		5
Pugnose minnow	Opsopoeodus emiliae			1		
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus			4		4
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	7				3
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni		2	13	9	5
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	5		3		6
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	1	1	3	1	3
Black bullhead	Ameiurus melas				1	
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus			5		3
Blackstripe topminnow	Fundulus notatus		3	4		16
Blackspotted topminnow	Fundulus olivaceus			1		
Mosquitofish	Gambusia affinis		11			
Brook silverside	Labidesthes sicculus			2		
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops	2				

Water body		Casey Fork	Casey Fork	Casey Fork	Casey Fork	Casey Fork
Date		1995JUN22	1995JUL21	2000JUL27	2003JUL09	2008JUN18
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					5
Black crappie	Pomoxis nigromaculatus	10		1		1
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	16		5	1	3
Largemouth bass	Micropterus salmoides	29	2	23	10	3
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	4	2	9	4	16
Green sunfish	Lepomis cyanellus		4	6	21	9
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus		14			
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus		3			
Bluegill	Lepomis macrochirus	90	10	64	39	95
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus			2		
Longear sunfish	Lepomis megalotis		5	8	84	28
Orangespotted sunfish	Lepomis humilis			8	59	12
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid			1	1	1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum		1			
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	4	2	6	11	29

Water body		Casey Fork	Casey Fork	Casey Fork	Casey Fork	Atchison Creek
Date		2013SEP13	1995JUL27	2003JUL07	1964JUL03	2013JUN12
Station code		NJ-07	NJ-10	NJ-10	NJ-30	NJA-02
Species		17	16	11	9	11
Non-native proportion						0.02
Total fish		227	122	229	126	55
Electrode minutes		21	26	38.25		19.57
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus	1	1			
Bowfin	Amia calva				1	
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	37	3	12		9
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus				3	
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					1
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)				66	
Golden shiner	Notemigonus crysoleucas	34		1		
Creek chub	Semotilus atromaculatus			14		
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus		2			
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	8	1	1		
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	6	16			
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni		2	35		1
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					1
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					1
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis		2		1	1
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.				14	
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus				2	2
Blackstripe topminnow	Fundulus notatus	14	1	3		13
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis	3	1	5		
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Casey Fork	Casey Fork	Casey Fork	Casey Fork	Atchison Creek
Date		2013SEP13	1995JUL27	2003JUL07	1964JUL03	2013JUN12
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops			1		
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus	1				
Black crappie	Pomoxis nigromaculatus	2				
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	8	5	29	1	5
Spotted bass	Micropterus punctulatus		2			
Warmouth	Lepomis gulosus				1	
Green sunfish	Lepomis cyanellus	18	6	60	24	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus			1		
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	48	65	66	12	11
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus	3				
Longear sunfish	Lepomis megalotis	18	11	1	1	9
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	11				1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	3				
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene	4				
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	8	1			
Freshwater drum	Aplodinotus grunniens		3			

Water body		Sevenmile Creek	Sevenmile Creek	Seven Mile Creek	Rayse Creek	Rayse Creek
Date		1995JUL27	2000JUL17	2013JUN12	2008AUG18	1995JUL26
Station code		NJC-01	NJC-01	NJC-01	NK-01	NK-02
Species		16	9	17	22	21
Non-native proportion			0.04			0.01
Total fish		157	75	175	694	191
Electrode minutes		21	38.5	37	34.3	30
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum			19		
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus				6	2
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio		3			1
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					4
Creek chub	Semotilus atromaculatus	17	5		20	20
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	9		1		8
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	2			114	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	19	1	10	206	2
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus			1		
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	1		1	6	4
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus	9	11		21	29
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus				7	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis			4	40	9
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris				1	
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus			1	7	2
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	8	26	2	9	16
Blackstripe topminnow	Fundulus notatus	11	1	27	39	2
Blackspotted topminnow	Fundulus olivaceus				5	
Mosquitofish	Gambusia affinis				13	
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Sevenmile Creek	Sevenmile Creek	Seven Mile Creek	Rayse Creek	Rayse Creek
Date		1995JUL27	2000JUL17	2013JUN12	2008AUG18	1995JUL26
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis			1		1
Largemouth bass	Micropterus salmoides	1	3	4	11	4
Spotted bass	Micropterus punctulatus	2				
Warmouth	Lepomis gulosus	1			1	
Green sunfish	Lepomis cyanellus	31	11	16	23	28
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					7
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					3
Bluegill	Lepomis macrochirus	36	14	66	5	39
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					1
Redear sunfish	Lepomis microlophus			11		1
Longear sunfish	Lepomis megalotis	4		8	11S	2
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	1			34	1
Bluntnose darter	Etheostoma chlorosomum				1	
Mud darter	Etheostoma asprigene			1		
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	5			10	1
Freshwater drum	Aplodinotus grunniens			2		4

Water body		Rayse Creek	Rayse Creek	Snow Creek	Snow Creek	Snow Creek
Date		2000JUL18	2013AUG05	1995JUL26	2000JUL18	2008JUN17
Station code		NK-02	NK-02	NL-01	NL-01	NL-01
Species		15	20	25	19	15
Non-native proportion				0.02		
Total fish		281	235	341	190	175
Electrode minutes		44	22.6	29.2	49	28.5
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		3	4		
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		16	2		
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio			6		
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas			2	2	
Creek chub	Semotilus atromaculatus	86		2	7	
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis	27				
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	11	2	26	3	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis				2	15
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	37	3	39	15	13
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus			1		
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	30	2	11	7	11
Spotted sucker	Minytrema melanops					3
Creek chubsucker	Erimyzon oblongus	7	11	57	6	6
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		1			
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	1	6	3	3	2
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus	1	1		1	
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	16	5		12	4
Blackstripe topminnow	Fundulus notatus	5	19	12	13	13
Blackspotted topminnow	Fundulus olivaceus		21	1	1	13
Mosquitofish	Gambusia affinis		6	3	1	
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Rayse Creek	Rayse Creek	Snow Creek	Snow Creek	Snow Creek
Date		2000JUL18	2013AUG05	1995JUL26	2000JUL18	2008JUN17
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis			2		
Largemouth bass	Micropterus salmoides	17	16	3	11	9
Spotted bass	Micropterus punctulatus			6		
Warmouth	Lepomis gulosus			2		4
Green sunfish	Lepomis cyanellus	10	11	67	21	6
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus			3		
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	3	56	43	65	49
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus		12	7		
Longear sunfish	Lepomis megalotis		39	35	5	24
Orangespotted sunfish	Lepomis humilis				5	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid		1			2
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	26	3	1	10	1
Bluntnose darter	Etheostoma chlorosomum		1			
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	4		2		
Freshwater drum	Aplodinotus grunniens			1		

Water body		Mud Creek	Prairie Creek	Andy Creek	Andy Creek
Date		2008JUN09	2013JUL23	1995JUL17	2008JUN11
Station code		NZL-01	NZM-02	NZN-13	NZN-15
Species		18	6	18	14
Non-native proportion				0.04	0.05
Total fish		121	53	252	84
Electrode minutes		19	20.67	22.67	27.6
Seine hauls					
Hours set					
Paddlefish	Polyodon spathula				
Shortnose gar	Lepisosteus platostomus				
Longnose gar	Lepisosteus osseus				
Spotted gar	Lepisosteus oculatus				
Bowfin	Amia calva				1
Skipjack herring	Alosa chrysochloris				
Shad spp.	Dorosoma spp.				
Gizzard shad	Dorosoma cepedianum				8
Threadfin shad	Dorosoma petenense				
Goldeye	Hiodon alosoides				
Mooneye	Hiodon tergisus				
Grass pickerel	Esox americanus			1	1
Grass carp	Ctenopharyngodon idella				
Bighead carp	Aristichthys nobilis				
Silver carp	Hypophthalmichthys molitrix				
Goldfish	Carassius auratus				
Carp	Cyprinus carpio			9	4
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)				
Golden shiner	Notemigonus crysoleucas	3	9	5	2
Creek chub	Semotilus atromaculatus	7	3		
Central stoneroller	Campostoma anomalum	1			
Suckermouth minnow	Phenacobius mirabilis				
Blacknose dace	Rhinichthys atratulus				
Silver chub	Macrhybopsis storeriana				
Silvery minnow	Hybognathus nuchalis				
Redfin shiner	Lythrurus umbratilus	13			
Ribbon shiner	Lythrurus fumeus				
Spotfin shiner	Cyprinella spiloptera				
Blacktail shiner	Cyprinella venusta				
Red shiner	Cyprinella lutrensis	6			
Pugnose minnow	Opsopoeodus emiliae				
Fathead minnow	Pimephales promelas				
Bluntnose minnow	Pimephales notatus	27			
Bullhead minnow	Pimephales vigilax				
Emerald shiner	Notropis atherinoides				
River shiner	Notropis blennius				
Sand shiner	Notropis ludibundus				
Mimic shiner	Notropis volucellus				
Channel shiner	Notropis wickliffi				
Bigmouth buffalo	Ictiobus cyprinellus			3	
Smallmouth buffalo	Ictiobus bubalus			2	
Black buffalo	Ictiobus niger				
Unidentified Carpsucker	Carpiodes sp.				
Quillback	Carpiodes cyprinus			2	
River carpsucker	Carpiodes carpio				
Highfin carpsucker	Carpiodes velifer				
White sucker	Catostomus commersoni			2	2
Spotted sucker	Minytrema melanops				
Creek chubsucker	Erimyzon oblongus	2		5	
River redhorse *T*	Moxostoma carinatum				
Shorthead redhorse	Moxostoma macrolepidotum				
Golden redhorse	Moxostoma erythrurum				
Channel catfish	Ictalurus punctatus				
Blue catfish	Ictalurus furcatus				
Yellow bullhead	Ameiurus natalis			1	
Black bullhead	Ameiurus melas			3	
Brown bullhead	Ameiurus nebulosus				
Flathead catfish	Pylodictis olivaris				
Madtom spp.	Noturus spp.				
Tadpole madtom	Noturus gyrinus				
Freckled madtom	Noturus nocturnus				
Pirate perch	Aphredoderus sayanus	4	16	7	1
Blackstripe topminnow	Fundulus notatus	7			16
Blackspotted topminnow	Fundulus olivaceus	13			
Mosquitofish	Gambusia affinis	1		1	
Brook silverside	Labidesthes sicculus				
Inland silversides	Menidia beryllina				
Mississippi silversides	Menidia beryllina				
Striped bass	Morone saxatilis				
White bass	Morone chrysops				

Water body		Mud Creek	Prairie Creek	Andy Creek	Andy Creek
Date		2008JUN09	2013JUL23	1995JUL17	2008JUN11
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops				
Yellow bass	Morone mississippiensis				
Flier	Centrarchus macropterus				
Black crappie	Pomoxis nigromaculatus	1			3
Blacknose crappie	Pomoxis migromaculatus				
White crapple	Pomoxis annularis				
Largemouth bass	Micropterus salmoides			2	
Spotted bass	Micropterus punctulatus				
Warmouth	Lepomis gulosus			5	5
Green sunfish	Lepomis cyanellus	4	21	22	2
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus				
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus				
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus				
Bluegill	Lepomis macrochirus	23	3	172	35
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus				
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus				
Redear sunfish	Lepomis microlophus				
Longear sunfish	Lepomis megalotis	3			2
Orangespotted sunfish	Lepomis humilis	3			
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid			7	1
Walleye	Stizostedion vitreum				
Sauger	Stizostedion canadense				
Blackside darter	Percina maculata				
Dusky darter	Percina sciera				
River darter	Percina shumardi				
Logperch	Percina caprodes				
Johnny darter	Etheostoma nigrum	1			
Bluntnose darter	Etheostoma chlorosomum				
Mud darter	Etheostoma asprigene				1
Orangethroat darter	Etheostoma spectabile	2			
Spottail darter	Etheostoma squamiceps				
Slough darter	Etheostoma gracile		1	2	
Freshwater drum	Aplodinotus grunniens			1	

Water body		Total	Big Muddy River	Big Muddy River
ID			14458	14457
Date			2016NOV10	2016NOV09
Station code			N-12	N-23
Species		29	24	20
Non-native proportion		0.04	0.03	0.15
Total fish		241	144	97
Electrode minutes			60	60
Seine hauls				
Shortnose gar	Lepisosteus platostomus	10	2	8
Longnose gar	Lepisosteus osseus	6	2	4
Spotted gar	Lepisosteus oculatus	2	2	
Skipjack herring	Alosa chrysochloris	1		1
Gizzard shad	Dorosoma cepedianum	57	54	3
Goldeye	Hiodon alosoides	1	1	
Grass carp	Ctenopharyngodon idella	2	1	1
Silver carp	Hypophthalmichthys molitrix	8		8
Carp	Cyprinus carpio	10	4	6
Redfin shiner	Lythrurus umbratilus	1	1	
Spotfin shiner	Cyprinella spiloptera	13	6	7
Steelcolor shiner	Cyprinella whipplei	2	2	
Red shiner	Cyprinella lutrensis	10	10	
Bullhead minnow	Pimephales vigilax	9	8	1
Emerald shiner	Notropis atherinoides	6	2	4
Bigmouth buffalo	Ictiobus cyprinellus	28	16	12
Smallmouth buffalo	Ictiobus bubalus	9	1	8
Black buffalo	Ictiobus niger	2		2
Channel catfish	Ictalurus punctatus	3	2	1
Blackspotted topminnow	Fundulus olivaceus	1	1	
Brook silverside	Labidesthes sicculus	2	2	
White bass	Morone chrysops	1	1	
Black crappie	Pomoxis nigromaculatus	3	1	2
White crappie	Pomoxis annularis	4	4	
Spotted bass	Micropterus punctulatus	1		1
Bluegill	Lepomis macrochirus	13	7	6
Longear sunfish	Lepomis megalotis	15	11	4
Orangespotted sunfish	Lepomis humilis	2		2
Freshwater drum	Aplodinotus grunniens	19	3	16

Water body		Total	Big Muddy River	Big Muddy River	Big Muddy River
Date			2017NOV02	2017NOV03	2017OCT24
Station code			N-12	N-99	N-23
Species		35	26	23	20
Non-native proportion		0.05	0.07	0.04	0.23
Total fish		322	111	145	66
Electrode minutes			60	60	60
Seine hauls					
Shortnose gar	Lepisosteus platostomus	14	1	10	3
Longnose gar	Lepisosteus osseus	7	1	1	5
Spotted gar	Lepisosteus oculatus	1		1	
Bowfin	Amia calva	4	3	1	
Gizzard shad	Dorosoma cepedianum	83	37	39	7
Threadfin shad	Dorosoma petenense	2		2	
Grass carp	Ctenopharyngodon idella	2			2
Silver carp	Hypophthalmichthys molitrix	15		3	12
Carp	Cyprinus carpio	9	8	1	
Redfin shiner	Lythrurus umbratilus	9	4	4	1
Bluntnose minnow	Pimephales notatus	3			3
Bullhead minnow	Pimephales vigilax	15	5	10	
Emerald shiner	Notropis atherinoides	18	1	8	9
Sand shiner	Notropis ludibundus	3	3		
Bigmouth buffalo	Ictiobus cyprinellus	5	2		3
Smallmouth buffalo	Ictiobus bubalus	8	5	2	1
Black buffalo	Ictiobus niger	11	5	3	3
River carpsucker	Carpiodes carpio	6	3	1	2
Shorthead redhorse	Moxostoma macrolepidotum	1	1		
Channel catfish	Ictalurus punctatus	3		1	2
Flathead catfish	Pylodictis olivaris	1			1
Blackstripe topminnow	Fundulus notatus	5	1	4	
Blackspotted topminnow	Fundulus olivaceus	1	1		
Mosquitofish	Gambusia affinis	5	5		
Brook silverside	Labidesthes sicculus	2	1	1	
Inland silversides	Menidia beryllina	1			
White bass	Morone chrysops	6		3	
Black crappie	Pomoxis nigromaculatus	1	1		
Largemouth bass	Micropterus salmoides	2	2		
Warmouth	Lepomis gulosus	1	1		
Green sunfish	Lepomis cyanellus	5	2	1	2
Bluegill	Lepomis macrochirus	32	8	20	4
Longear sunfish	Lepomis megalotis	15	3	11	1
Orangespotted sunfish	Lepomis humilis	7	1	6	
Freshwater drum	Aplodinotus grunniens	19	6	12	1

Water body		Total	Big Muddy River	Big Muddy River	Big Muddy River	Cedar Creek
Date			2018JUL12	2018JUL25	2018JUL25	2018MAY29
Station code			N-05	N-06	N-11	NA-04
Species		64	16	23	17	9
Non-native proportion		0		0.15	0.06	
Total fish		5740	95	134	96	255
Electrode minutes			33	60	60	34.72
Seine hauls						
Unidentified Gar	Lepisosteus sp.	13				
Shortnose gar	Lepisosteus platostomus	46		15	6	
Longnose gar	Lepisosteus osseus	15		2	5	
Spotted gar	Lepisosteus oculatus	10		5	2	
Bowfin	Amia calva	8		5		
Gizzard shad	Dorosoma cepedianum	31		8	9	
Grass pickerel	Esox americanus	27	2			
Grass carp	Ctenopharyngodon idella	2		1		
Silver carp	Hypophthalmichthys molitrix	1		1		
Carp	Cyprinus carpio	40		18	6	
Golden shiner	Notemigonus crysoleucas	16	1			
Creek chub	Semotilus atromaculatus	699				142
Central stoneroller	Campostoma anomalum	734				59
Silver chub	Macrhybopsis storeriana	11				
Silvery minnow	Hybognathus nuchalis	8				
Redfin shiner	Lythrurus umbratilus	288	8			
Spotfin shiner	Cyprinella spiloptera	1				
Red shiner	Cyprinella lutrensis	60		4	4	
Bluntnose minnow	Pimephales notatus	720	3	1		6
Bullhead minnow	Pimephales vigilax	4			2	
Emerald shiner	Notropis atherinoides	40		1	2	
Sand shiner	Notropis ludibundus	176				
Silverjaw minnow	Notropis buccatus	85				
Bigmouth buffalo	Ictiobus cyprinellus	9		5	1	
Smallmouth buffalo	Ictiobus bubalus	64		30	33	
Black buffalo	Ictiobus niger	11		7	3	
River carpsucker	Carpiodes carpio	19		8	10	
White sucker	Catostomus commersoni	129				
Spotted sucker	Minytrema melanops	3				
Creek chubsucker	Erimyzon oblongus	159	4			2
Golden redhorse	Moxostoma erythrurum	1				
Channel catfish	Ictalurus punctatus	22	1	5	4	
Yellow bullhead	Ameiurus natalis	71				2
Black bullhead	Ameiurus melas	2				
Flathead catfish	Pylodictis olivaris	4		1	1	
Tadpole madtom	Noturus gyrinus	8	1			
Pirate perch	Aphredoderus sayanus	118	7			
Blackstripe topminnow	Fundulus notatus	263	4			
Blackspotted topminnow	Fundulus olivaceus	118	15			
Mosquitofish	Gambusia affinis	39	1			
White bass	Morone chrysops	7				
Flier	Centrarchus macropterus	2				
Black crappie	Pomoxis nigromaculatus	3				
White crappie	Pomoxis annularis	5		5		
Largemouth bass	Micropterus salmoides	292	5	1		
Spotted bass	Micropterus punctulatus	3		3		
Warmouth	Lepomis gulosus	22	11	1		1
Green sunfish	Lepomis cyanellus	225	3			17
Bluegill	Lepomis macrochirus	416	7		1	2
Redear sunfish	Lepomis microlophus	31				
Longear sunfish	Lepomis megalotis	448	22	2	1	
Orangespotted sunfish	Lepomis humilis	1				
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	9				
Sauger	Stizostedion canadense	3				
Blackside darter	Percina maculata	2				
Dusky darter	Percina sciera	1				
Logperch	Percina caprodes	5				
Johnny darter	Etheostoma nigrum	59				
Bluntnose darter	Etheostoma chlorosomum	1				
Rainbow darter	Etheostoma caeruleum	2				
Mud darter	Etheostoma asprigene	1				
Orangethroat darter	Etheostoma spectabile	79				24
Stripetail darter	Etheostoma kennicotti	5				
Fantail darter	Etheostoma flabellare	4				
Slough darter	Etheostoma gracile	3				
Freshwater drum	Aplodinotus grunniens	36		5	6	

*Six Mile Creek

-poor sample; high conductivity had to use MS,lots of debris made it hard to sample

Mill Creek	Alto Pass Creek	Kinkaid Creek	Little Kinkaid Creek	Beaucoup Creek	Rattlesnake Creek	anther Creek (South	Swanwick Creek	Crab Orchard Creek	le Crab Orchard Cre
2018JUN06	2018JUN06	2019JUN05	2018JUN05	2018JUL09	2018JUN05	2018JUN20	2018JUN20	2018JUN11	2018JUN14
NAFA-02	NAI-01	NB-02	NBA-01	NC-09	NCB-01	NCE-02	NCK-02	ND-06	NDA-01
10	6	18	23	14	17	14	14	16	17
				0.06		0.01			
130	289	990	804	111	218	114	103	188	105
21.62	43.37	36	33.75	22.6	32.55	32.23	26	36.13	31.93
		13							
						1			
						2			
			1			12			
				6				8	9
				7		1			
							2	1	7
9	172	58	24	23	20			6	
65	44	180	364		14				
					7				1
2		38	4		9		13	1	
		10			22				
7		312	54	1	26				7
		145	23		8				
		75	10						
		16	3		1				
			1		1				
		3		15				48	
			1						
						7			
1		4	5	3		5	3		5
								1	1
				28	1		7	3	3
		13	17	2	16	1	15	25	3
1	2		1						1
			5	4					6
					1	1			
									1
1			224	4		8	3	4	3
			2			3	1	1	1
3	4		10	8	21		11	16	2
39	29		22	7	13	66	28	45	29
				2			6	7	
		108	18		51	3	10	18	24
							1		
	1				2			2	1
							1		
		1							
		3	1			1			
		3		1	4		2		
								1	
			2						
		1							
2	37	2	8		1				
		5							
			4						
									1
						3		1	

Indian Creek	Little Grassy Creek	Little Muddy River	*Six Mile Creek	Little Indian Creek	Pond Creek	Sugar Camp Creek	Casey Fork	Dodds Creek	Rayse Creek
2018JUN12	2018JUN12	2018JUL09	2018JUN20	2018JUN21	2018JUN11	2018JUN19	2018JUL12	2018JUN19	2018JUN21
NDCB-02	NDDA-01	NE-06	NEA-02	NEE-01	NG-05	NHH-02	NJ-10	NJB-01	NK-01
13	9	17	4	10	9	15	17	12	13
547	38	196	8	193	150	143	145	92	204
37	30.37	24				22	23.22	17.93	22.5
	1		1						
				4					
7		18		3	1	16	1	62	33
6		1							
51	7	3		145			1		
							1		16
230	2	16		5		8	7	4	29
		62				4	7	6	26
15		12				54	6		
1	2								
2		1				1	4	1	31
						2			
						1			4
		17				30	3	3	8
		24		22	50	1	14	4	16
5	12	11	2	2	60	2	2		1
				1	11		7	3	
					2				
3	1	3		5	9	1	10	1	
			1						
81	2	9		1	4	10	8	3	5
9	3	7	4		8	8	39	1	5
					3		8		
131	8	2		5		4	2	1	24
1					2				
		1							
		7				1	25	3	6
5									
		2							

Novack Creek	Mud Creek	Big Muddy River
2018JUL09	2018JUN14	2018SEP06
NKC-01	NZL-01	N-03
11	16	22
		0.06
208	38	146
24	21.8	60
	2	22
		8
		3
		1
		1
		1
		8
	1	
102	2	
	1	
		11
6		
		1
	3	
	2	
		2
		37
		3
		1
		1
		1
4		
	1	
		2
2	1	
		2
5	3	
33	3	
	1	
	1	
		7
6		
6	1	
34	3	7
5		
	11	3
		3
5	2	
		21

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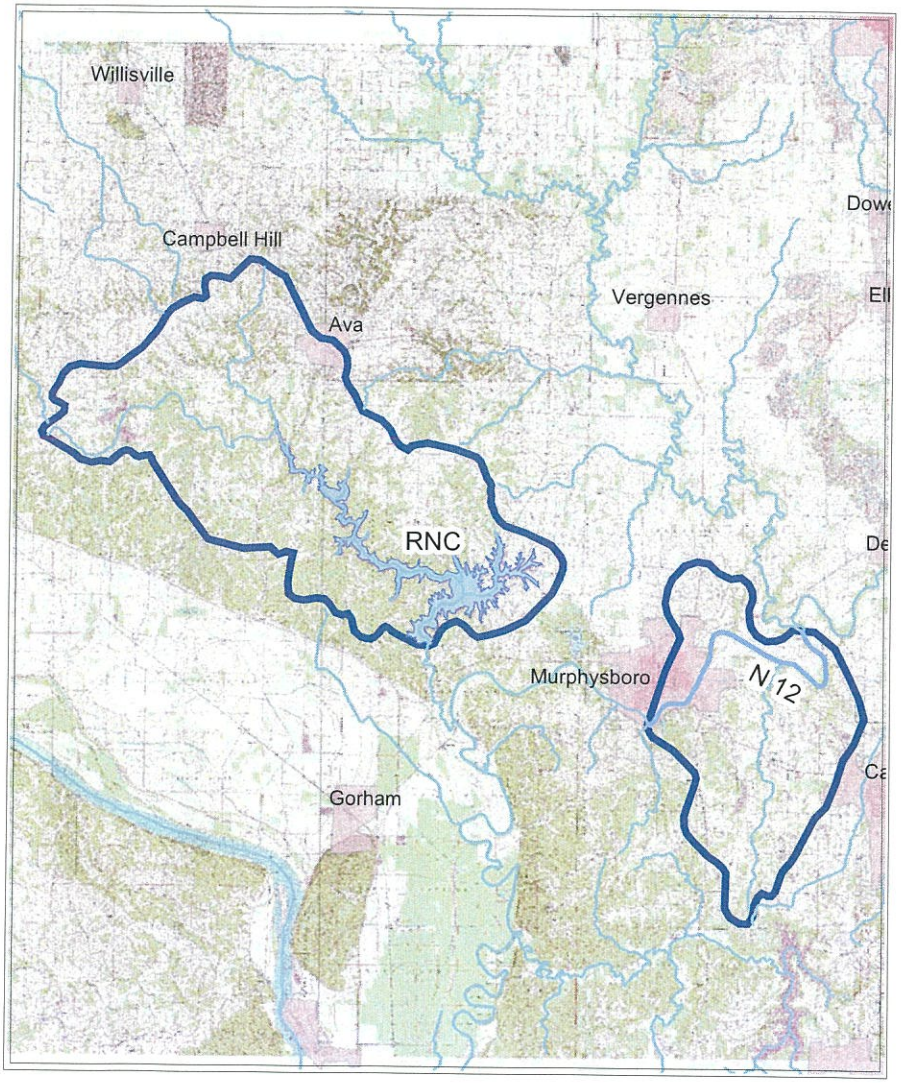
Illinois
Environmental
Protection Agency

Bureau of Water
P.O. Box 19276
Springfield, IL 62794-9276

October 2004

IEPA/BOW/04-015

BIG MUDDY RIVER TMDL REPORT





Printed on Recycled Paper

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

23 SEP 2004

REPLY TO THE ATTENTION OF:
WW-16J

RECEIVED
OCT 06 2004
Watershed Management Section
BUREAU OF WATER

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BUREAU OF WATER
BUREAU CHIEF'S OFF

Marcia Willhite, Chief
Bureau of Water
IEPA
P.O. Box 19276
1021 North Grand Avenue East
Springfield, Illinois 62794-9276

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has conducted a complete review of the final Total Maximum Daily Loads (TMDLs) for phosphorus, manganese, and sulfate, including supporting documentation, for the Big Muddy River watershed, located in Jackson County, Illinois. Based on this review, U.S. EPA has determined that Illinois's TMDLs for these waterbodies meets the requirements of Section 303(d) of the Clean Water Act (CWA) and U.S. EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, by this letter, U.S. EPA hereby approves three TMDLs for the Big Muddy River watershed as listed below:

Waterbody	Pollutant
Kinkaid Lake (RNC)	phosphorus
Big Muddy River (N12)	manganese, sulfate

The statutory and regulatory requirements, and U.S. EPA's review of Illinois's compliance with each requirement, are described in the enclosed decision document.

We wish to acknowledge Illinois's effort in these submitted TMDLs, and look forward to future quality TMDL submissions by the State of Illinois. If you have any questions, please contact Mr. Kevin Pierard, Chief of the Wetlands and Watersheds Branch at 312-886-4448.

Sincerely yours,

Jo Lynn Traub
Director, Water Division

Enclosure

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Parameter changes for developing TMDLs

In May 2001, Illinois EPA entered into a contract with Camp Dresser & McKee to develop Total Maximum Daily Loads (TMDL) for Big Muddy River (N12) and Kinkaid Lake. In the 1998 Section 303(d) List, Big Muddy River (N12) was listed as impaired for the following parameters: Manganese, cyanide, sulfates, nitrogen, pH, siltation, low dissolved oxygen (DO), total dissolved solids (TDS), and total suspended solids (TSS). Kinkaid Lake was initially listed as impaired for: Manganese, mercury, phosphorus, nitrogen, siltation, low DO, TSS, excessive algal growth, and chlorophyll-a.

Since then, new data assessed in 2002 showed that Big Muddy River (N12) is now impaired for manganese, sulfates, pH, low DO, and TSS. The listing of cyanide as a cause of impairment for Big Muddy River (N12) was done so in error and should not have been listed as such. New data assessed in 2002 for Kinkaid Lake showed it is now impaired only for pH, mercury, and siltation.

Illinois EPA has since determined that at this time TMDLs will only be developed for those parameters with numeric water quality standards. These numeric water quality standards will serve as the target endpoints for TMDL development and provide a greater degree of clarity and certainty about the TMDL and implementation plans. As a result, the TMDL for Big Muddy River (N12) will only focus on the parameters of manganese, sulfates, pH, and low DO, for which numeric water quality standards exist. Likewise, the TMDL for Kinkaid Lake will only focus on the parameter of pH. While the impairment caused by mercury is acknowledged, a TMDL will not be developed for it at this time, as mercury contamination is considered to be an interstate and international issue caused primarily by air deposition.

Causes of impairment not based on numeric water quality standards will be assigned a lower priority for TMDL development. Pending the development of numeric water quality standards for these parameters, as may be proposed by the Agency and adopted by the Illinois Pollution Control Board, Illinois EPA will continue to work toward improving water quality throughout the state by promoting and administering existing programs and working toward creating new methods for treating these potential causes of impairment.

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Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	micrograms per liter
ALMP	Ambient Lake Monitoring Program
AMLRD	Abandoned Mined Lands Reclamation Division
AS	acute standard
AWQMN	Ambient Water Quality Monitoring Network
BMP	best management practice
BOD	biochemical oxygen demand
BOD_5	5-day biochemical oxygen demand
$CBOD_{20}$	20-day carbonaceous biochemical oxygen demand
$CBOD_5$	5-day carbonaceous biochemical oxygen demand
CCC	Commodity Credit Corporation
cfs	cubic feet per second
CO_2	carbon dioxide
CRP	Conservation Reserve Program
CS	chronic standard
CWA	Clean Water Act
DEM	Digital Elevation Model
DO	dissolved oxygen
EQIP	Environmental Quality Incentive Program
ET	evapotranspiration
FSA	Farm Service Agency
GIS	geographic information system
GWLF	Generalized Watershed Loading Function
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
ICLP	Illinois Clean Lakes Program
IDA	Illinois Department of Agriculture
IDNR	Illinois Department of Natural Resources
Illinois EPA	Illinois Environmental Protection Agency
IPCB	Illinois Pollution Control Board
ISWS	Illinois State Water Survey
KAWP	Kinkaid Area Watershed Project, Inc.
KDEP	Kentucky Department of Environmental Protection
kg/km^2-yr	kilograms per kilometer squared per year

LA	Load Allocation
LC	Loading Capacity
LTA	long-term average
MBI	Macroinvertebrate Biotic Index
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MOS	Margin of Safety
NASS	National Agricultural Statistics Service
NCSU	North Carolina State University
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service
NWIS	National Water Inventory System
PBT	persistent, bioaccumulative toxic (chemical)
PDEP	Pennsylvania Department of Environmental Protection
ppm	parts per million
SOD	sediment oxygen demand
SSRP	Streambank Stabilization and restoration Practice
STATSGO	State Soil Geographic (database)
STORET	Storage and Retrieval (USEPA database)
TDS	total dissolved solids
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geographical Survey
WERF	Water Environment Research Foundation
WHIP	Wildlife Habitat Incentives Program
WLA	Waste Load Allocation
WRP	Wetlands Reserve Program
WWTP	wastewater treatment plants

Executive Summary
Big Muddy River Watershed

TMDL Fact Sheet

Watershed Name:	Kinkaid Lake	Big Muddy River
Impaired Segments:	RNC	N12
Location:	Jackson County, Illinois	Jackson County, Illinois
Size:	2,350 acres at normal storage	8.0 miles
Primary Watershed Land Uses:	Forest, grassland, and agriculture	Forest, grassland, and agriculture
Criteria of Concern:	pH and Mercury	Manganese, sulfates, pH, and DO
Designated Uses Affected:	General use	General use
Environmental Indicators: ***General use and public and food processing water supply***	pH monitoring	Manganese, sulfates, pH and DO monitoring
Major Sources:	Nonpoint from agriculture	Potentially contaminated groundwater, stagnant stream conditions, elevated instream temperatures, and nonpoint source loading from agriculture
Loading Capacity:	13,983 pounds/year total phosphorus	Mn = 2,244 lbs/day Sulfate = 1,163,422 lbs/day pH = No Allocation DO = No allocation
Waste Load Allocation:	Zero; No point sources	No Allocation
Margin of Safety:	Implicit through conservative modeling; additional explicit of 10 percent	Implicit through data selected for development of TMDL; additional explicit of 10 percent

This Total Maximum Daily Load (TMDL) assessment for impaired water bodies in the Big Muddy River Watershed addresses the sources of water body impairments, reductions in source loading necessary to comply with water quality standards, and the implementation of procedures to mitigate the impairment.

A correlation between pH and total phosphorus was established for Kinkaid Lake, and modeling demonstrates a reduction of 43 percent total phosphorus necessary so that pH water quality standards can be achieved. Primary sources of phosphorus loading to Kinkaid Lake include runoff from agricultural lands. Procedures outlined in the implementation plan to decrease phosphorus loading to the lake include measures applied to the watershed to control nutrients in surface runoff and eroded sediment. Watershed controls include filter strips and wetlands to prevent phosphorus in surface runoff from reaching the lake, conservation tillage to decrease nutrient-rich soil erosion from agricultural fields, and development of nutrient management plans to ensure that excess phosphorus is not applied to agricultural fields.

The TMDLs for manganese and sulfates in Big Muddy River segment N12 was based on analyses performed in a Monte Carlo simulation. The simulation for manganese showed a manganese reduction of 70 percent necessary to achieve water quality standards. Results of the Monte Carlo simulation for sulfates showed a 62 percent reduction for segment N12 necessary to achieve the water quality standard. The

potential source of manganese and sulfates in the Big Muddy River Watershed is contaminated groundwater. The groundwater is potentially contaminated by abandoned coal mines; however, further source identification is recommended. Confirmation that abandoned mines are a source of manganese and sulfates in the watershed would require reclamation of the mines. Passive treatment for mine reclamation is recommended.

The TMDL analysis for DO in Big Muddy River segment N12 was made through investigation of the relationship between DO, total organic carbon (TOC), 5-day biochemical oxygen demand (BOD5), and reaeration in the creek. The likely source of DO impairments in the segment is primarily a lack of aeration caused by stagnant stream conditions and elevated instream temperatures. BOD loadings in runoff from nonpoint source loads may also contribute to DO impairments. However, examination of BOD in the stream segment showed that the concentrations of BOD are low and likely represent ambient conditions in the stream; therefore, reductions in BOD concentrations are not recommended at this time. Due to data limitations and technical considerations of implementation difficulties, a load allocation cannot be developed for reaeration or temperature, so allocations were not developed for segment N12. Procedures to alleviate low DO caused by slow-moving waters can be addressed with in-stream mitigation methods such as reaeration. Additionally, riparian buffer strips aid in decreasing instream temperatures, which could help to alleviate the DO impairment. Excess nutrients can cause excessive algal growth that can also deplete DO in streams; however, analytical tools were not used to assess nutrients, algae, and DO as no algal data was available for Big Muddy River segment N12. Methods to control nutrients were still included in the implementation plan, such as buffer strips along the stream banks, which are similar to filter strips in their ability to remove nutrients from surface runoff. The potential contributions to BOD from nonpoint source loads are attributed to agricultural land uses requiring mitigation methods to control nutrients in sediment erosion and surface runoff from the land contributing to segment N12. These methods include filter strips, wetlands, conservation tillage, and nutrient management plans as discussed above.

The analysis for pH was based on hydrogen ion concentrations and the three-year flow observed in Big Muddy River segment N12. Analysis showed that the existing average hydrogen ion concentration was below the allowable loading, so allocations were not developed for pH in segment N12 at this time. Although an allocation was not developed, mitigation measures for manganese, sulfates, and DO will help control pH in Big Muddy River segment N12.

Section 1
Goals and Objectives for Big Muddy River Watershed (ILN12)

1.1 Total Maximum Daily Load (TMDL) Overview

A Total Maximum Daily Load, or TMDL, is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. TMDLs are a requirement of Section 303(d) of the Clean Water Act (CWA). To meet this requirement, the Illinois Environmental Protection Agency (Illinois EPA) must identify water bodies not meeting water quality standards and then establish TMDLs for restoration of water quality. Illinois EPA lists water bodies not meeting water quality standards every two years. This list is called the 303(d) list, and water bodies on the list are then targeted for TMDL development.

In general, a TMDL is a quantitative assessment of water quality problems, contributing sources, and pollution reductions needed to attain water quality standards. The TMDL specifies the amount of pollution or other stressor that needs to be reduced to meet water quality standards, allocates pollution control or management responsibilities among sources in a watershed, and provides a scientific and policy basis for taking actions needed to restore a water body (U.S. Environmental Protection Agency [USEPA] 1998a).

Water quality standards are laws or regulations that states authorize to enhance water quality and protect public health and welfare. Water quality standards provide the foundation for accomplishing two of the principal goals of the CWA. These goals are:

- restore and maintain the chemical, physical, and biological integrity of the nation's waters,
- where attainable, to achieve water quality that promotes protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water.

Water quality standards consist of three elements:

- the designated beneficial use or uses of a water body or segment of a water body,
- the water quality criteria necessary to protect the use or uses of that particular water body,
- an antidegradation policy.

Examples of designated uses are swimming, recreation, and protection of aquatic life. Water quality criteria describe the quality of water that will support a designated use. Water quality criteria can be expressed as numeric limits or as a narrative statement.

Antidegradation policies are adopted so that water quality improvements are conserved, maintained, and protected.

1.2 TMDL Goals and Objectives for Big Muddy River Watershed

The TMDL goals and objectives for the Big Muddy River Watershed include developing TMDLs for all impaired water bodies within the watershed, describing all of the necessary elements of the TMDL, developing an implementation plan for each TMDL, and gaining public acceptance of the process. Following are the impaired water body segments in the Big Muddy River Watershed, which are also shown in Figure 1-1:

- Big Muddy River (N12)
- Kinkaid Lake (RNC)

The TMDL for each of the segments listed above will specify the following elements:

- Loading Capacity (LC) or the maximum amount of pollutant loading a water body can receive without violating water quality standards
- Waste Load Allocation (WLA) or the portion of the TMDL allocated to existing or future point sources
- Load Allocation (LA) or the portion of the TMDL allocated to existing or future nonpoint sources and natural background
- Margin of Safety (MOS) or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality

These elements are combined into the following equation:

$$\mathbf{TMDL = LC = \Sigma WLA + \Sigma LA + MOS}$$

Each TMDL developed must also take into account the seasonal variability of pollutant loads so that water quality standards are met during all seasons of the year. Also, reasonable assurance that the TMDLs will be achieved is described in the implementation plan. The implementation plan for the Big Muddy River Watershed describes how water quality standards will be attained. This implementation plan includes recommendations for implementing best management practices (BMP), cost estimates, institutional needs to implement BMPs and controls throughout the watershed, and timeframe for completion of implementation activities.

1.3 Report Overview

The remaining sections of this report contain:

- **Section 2 Big Muddy River Watershed Description** provides a description of the impaired water bodies and general watershed characteristics.
- **Section 3 Public Participation and Involvement** discusses public participation activities that occurred throughout the TMDL development.
- **Section 4 Big Muddy River Watershed Water Quality Standards** defines the water quality standards for the impaired water bodies. Pollution sources will also be discussed in this section.
- **Section 5 Big Muddy River Watershed Data Review** provides an overview of available data for the Big Muddy River Watershed.
- **Section 6 Methodologies to Complete TMDLs for the Big Muddy River Watershed** discusses the models and analyses needed for TMDL development.
- **Section 7 Model Development for Kinkaid Lake** provides an explanation of model development for Kinkaid Lake.
- **Section 8 Total Maximum Daily Load for the Kinkaid Lake Watershed** discusses the allowable loadings to water bodies to meet water quality standards and the reduction in existing loadings needed to meet allowable loads.
- **Section 9 Implementation Plan for Kinkaid Lake** provides methods to reduce loadings to impaired water bodies.
- **Section 10 Methodology Development for Big Muddy River** describes the analytical procedures used to examine Big Muddy River.
- **Section 11 Total Maximum Daily Load for Big Muddy River** discusses the allowable loadings to water bodies to meet water quality standards and the reduction in existing loadings needed to meet allowable loads.
- **Section 12 Implementation Plan for Big Muddy River** provides methods to reduce loadings to impaired water bodies.
- **Section 13 References** lists references used in this report.

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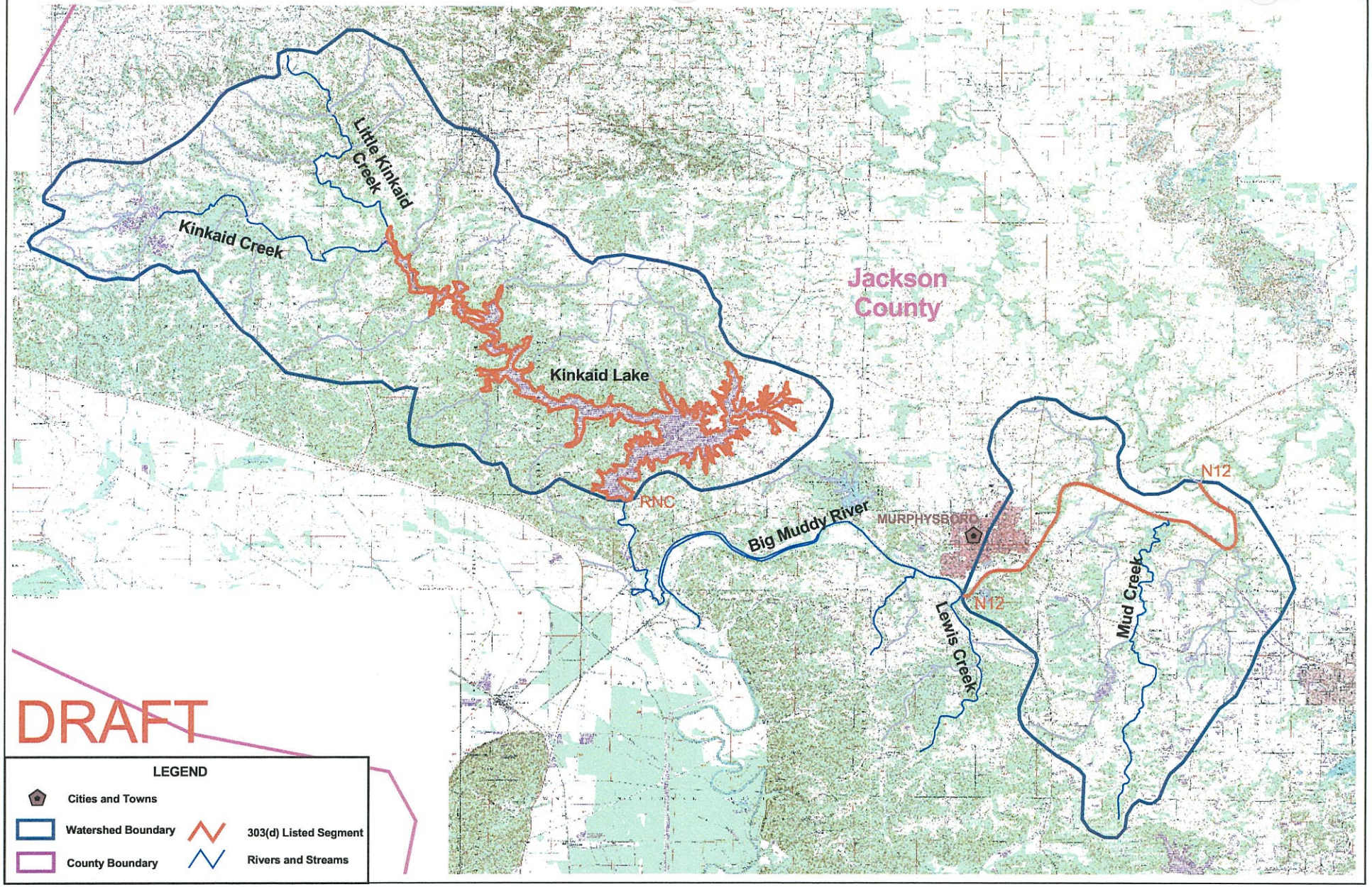


Figure 1-1
Big Muddy River #1 Watershed (ILN12)
Impaired Water Bodies

CDM

iepa/gis_data/apr/bigmuddy1.apr 032903

R00880

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Section 2
Big Muddy River Watershed Description

2.1 Big Muddy River Watershed Overview

The Big Muddy River originates in Jefferson County and flows southward. It then flows west towards Kinkaid Lake in Jackson County. Kinkaid Lake is located in Jackson County where the flow moves east towards the Big Muddy River. Big Muddy River segment N12 is located entirely in Jackson County. The entire Big Muddy River watershed, including Kinkaid Lake and all tributaries to Big Muddy River, encompasses an area of approximately 200 square miles and is located in the U.S. Geological Survey (USGS) Big Muddy Basin (Hydrologic Unit Code [HUC] 07140106). Figure 1-1 shows the impaired river and lake segments within the watershed. Impaired segments are shown in red. Table 2-1 lists the water body segments, water body size, and potential causes of impairment for each water body.

Table 2-1 Impaired Water Bodies in Big Muddy River Watershed

Water Body Segment ID	Water Body Name	Size	Potential Causes of Impairment
N12	Big Muddy River	8 miles	Manganese, sulfates, pH, dissolved oxygen (DO)
RNC	Kinkaid Lake	3,475 acres	pH, mercury

Land use data was obtained from the Critical Trends Assessment Land Cover Database of Illinois (Illinois Department of Natural Resources [IDNR] 1996). Land use in the watershed is predominantly forested followed by rural grassland and agricultural land uses. Farmers in the area primarily raise cash crops, such as corn and soybeans.

Soils within the Big Muddy River Watershed are primarily silty soils over clayey sediment. The surface layer is typically seven inches of dark grayish brown silt loam. The subsurface layer is about five inches of light brownish silt loam. The subsoil is a grayish silty clay loam that extends to a depth of more than 60 inches. Permeability is slow, and the available water capacity is moderate to high (U.S. Department of Agriculture [USDA] 1979).

The climate in Big Muddy River Watershed is cold in the winter and warm in the summer. In the winter, October through March, the average temperature is 43 degrees Fahrenheit (°F) and the average daily minimum temperature is 32°F, according to data collected at DuQuoin, Illinois. Summer temperatures are typically 70°F with an average daily maximum of 82°F. Annual precipitation is 46 inches, of which 25 inches, approximately 54 percent, usually falls in April through September (NCDC 2002).

2.2 Stream Segment Site Reconnaissance of Big Muddy River Watershed

The project team conducted a site reconnaissance of the Big Muddy River Watershed on June 19, 2001. This section briefly describes the stream segment and the site reconnaissance.

Table 2-1 lists the impaired stream segments in the Big Muddy River Watershed. Based on the 1998 303(d) list, Illinois EPA determined that one segment of Big Muddy River was impaired, Segment N12. This segment is shown in Figure 1-1. Segment N12 flows from roughly east to west, and includes a large bend to the south. The segment is located entirely in Jackson County, Illinois.

2.3 Lake Segment Site Reconnaissance of Big Muddy River Watershed

The project team visited one site on Kinkaid Lake during the site reconnaissance of the Big Muddy River Watershed on June 19, 2001. This section briefly describes a lake segment and the site reconnaissance.



Kinkaid Lake at Illinois Rt. 151 crossing.

Illinois EPA has listed one lake segment as impaired based on 1998 303(d) list data in the Big Muddy River Watershed. Kinkaid Lake, Segment RNC, is located on Kinkaid Creek in eastern Jackson County as shown in Figure 1-1. Crissenberry Dam was constructed on Kinkaid Creek in 1972. The dam is owned by the IDNR. The dam structure is 980 feet in length and 96 feet tall enabling it to store a maximum of 153,000 acre-feet, although the normal storage volume is 78,500 acre-feet. The lake is used for both recreation and a water supply (U.S. Army Corps of Engineers [USACE] 1999). The drainage area of Kinkaid Lake is approximately 62 square miles and is fed by Kinkaid, Little Kinkaid, Spring and Johnson Creeks.

Kinkaid Lake was observed from the Boat Access at Marina Road. The spillway was also observed, although the lake was not visible from the bottom of the spillway. Kinkaid Lake is a recreational area with both boating and swimming. A marina houses several boats at the lake. The spillway from Kinkaid Lake is a natural rock formation with a few enhancements, and was busy with swimmers and anglers at the time of observation.



Kinkaid Lake spillway.

Section 3
Public Participation and Involvement

3.1 Big Muddy River Watershed Public Participation and Involvement

Public knowledge, acceptance, and follow through are necessary to implement a plan to meet recommended TMDLs. It was important to involve the public as early in the process as possible to achieve maximum cooperation and counter concerns as to the purpose of the process and the regulatory authority to implement the recommendations. Public meetings were held to discuss the Big Muddy River Watershed at 3:00 p.m. and 6:20 p.m. on December 12, 2001 at the Davis McCann Center in Murphysboro, Illinois. A total of 44 interested citizens including public officials and organizations other than Illinois EPA attended the public meeting.

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Section 4
Big Muddy River Watershed Water Quality Standards

4.1 Illinois Water Quality Standards

Water quality standards are developed and enforced by the state to protect the "designated uses" of the state's waterways. In the state of Illinois, setting the water quality standards is the responsibility of the Illinois Pollution Control Board (IPCB). Illinois is required to update water quality standards every three years in accordance with the CWA. The standards requiring modifications are identified and prioritized by Illinois EPA, in conjunction with USEPA. New standards are then developed or revised during the three-year period.

Illinois EPA is also responsible for developing scientifically based water quality criteria and proposing them to the IPCB for adoption into state rules and regulations. The Illinois water quality standards are established in the Illinois Administrative Rules Title 35, Environmental Protection; Subtitle C, Water Pollution; Chapter I, Pollution Control Board; Part 302, Water Quality Standards.

4.2 Designated Uses

The waters of Illinois are classified by designated uses, which include: General Use, Public and Food Processing Water Supplies, Lake Michigan, and Secondary Contact and Indigenous Aquatic Life Use (Illinois EPA 2000). The only designated uses applicable to the Big Muddy River are General Use.

The General Use classification provides for the protection of indigenous aquatic life, primary and secondary contact recreation (e.g., swimming or boating), and agricultural and industrial uses. The General Use is applicable to the majority of Illinois streams and lakes (Illinois EPA 2000).

4.3 Illinois Water Quality Standards

To make 303(d) listing determinations, Illinois EPA compares collected data for the water body to the available water quality standards developed by Illinois EPA for assessing water body impairment. Table 4-1 presents the water quality standards of the potential causes of impairment for TMDLs that will be developed in the Big Muddy River Watershed. These water quality standards are further discussed in the remainder of the section.

Table 4-1 Summary of General Use Water Quality Standards for Big Muddy River Watershed

Parameter	General Use Water Quality Standard
pH	6.5 to 9.0
DO	Greater than 5.0 milligrams per liter (mg/L) Greater than 6.0 mg/L (16 hours of any 24-hour period)
Phosphorus	0.05 mg/L Lakes/reservoirs >20 acres and streams entering lakes or reservoirs
Mercury	AS = 2.6 micrograms per liter (µg/L) CS = 1.3 µg/L
Manganese	1.0 mg/L
Sulfates	500 mg/L

4.3.1 pH

The parameter pH is listed as a cause of impairment for the Big Muddy River segment N12. The General Use water quality standard for pH is a range with a minimum of 6.5 and maximum of 9.0. This is with the exception of pH levels outside this range due to natural causes.

The pH parameter is listed as a cause of less than full support use attainment in streams if there is at least one General Use water quality violation based on the last three years of Ambient Water Quality Monitoring Network (AWQMN) data, or at least one violation determined from the most recent basin survey or facility survey data. The AWQMN is a series of fixed stations throughout Illinois streams that are sampled every six weeks for a minimum of 55 parameters. Segments without AWQMN stations are sampled as part of the intensive basin survey, which occurs every five years.

4.3.2 Dissolved Oxygen

DO is listed as a cause of impairment for Big Muddy River and Kinkaid Lake. The General Use water quality standard for DO is based on a minimum value of 5.0 mg/L. Therefore, DO levels shall not be less than 5.0 mg/L at any time. In addition, DO levels should not be less than 6.0 mg/L for more than 16 hours of any 24-hour period.

DO is listed as a cause of less than full support use attainment in streams if there is at least one General Use water quality violation based on the last three years of AWQMN data or at least one violation determined from the most recent basin survey or facility survey data. DO is a source of impairment in lakes and reservoirs if there is at least one General Use water quality violation based on Ambient Lake Monitoring Program (ALMP), or Illinois Clean Lakes Program (ICLP) data, or if there was a known fish kill due to DO depletion.

4.3.3 Mercury

Mercury is listed as a cause of impairment for Kinkaid Lake. The General Use water quality standard for mercury is based on an acute standard (AS) and chronic standard (CS). The AS for mercury is 2.6 µg/L and the CS is 1.3 µg/L.

Mercury is listed as a cause of less than full support use attainment in lakes and reservoirs if there is at least one General Use water quality violation based on ALMP or ICLP data. Mercury is also listed as a cause of less than full support if the sediment concentration is 0.701 milligrams per kilogram (mg/kg) or higher based on dry weight, or if there have been fish advisory reports due to mercury.

4.3.4 Manganese

Manganese is listed as a cause of impairment for Big Muddy River segment N12. The General Use water quality standard for manganese is 1.0 mg/L and is based on total manganese. Manganese is listed as a cause of less than full support use attainment in streams if there is at least one General Use water quality violation based on the last three years of AWQMN data, or at least one violation determined from the most recent basin survey or facility survey data. Manganese is also listed as a cause of less than full support if there have been fish advisory reports due to manganese or the manganese concentration in the sediment is 2,800 mg/kg or higher (Illinois EPA 2000).

Manganese is listed as a cause of less than full support use attainment in lakes or reservoirs if there is at least one General Use water quality violation based on ICLP, or if the sediment concentration exceeds 2,800 mg/kg (M.B. Short 1997).

4.3.5 Sulfates

Sulfates are listed as a cause of impairment for the Big Muddy River. The General Use water quality standard for sulfates is 500 mg/L and the public and food processing water supplies standard is 250 mg/L. Sulfate is listed as a cause of a less than full support use attainment in streams if there is at least one General Use water quality violation based on the last three years of AWQMN data, or at least one violation from the most recent basin survey or facility survey data.

4.3.6 Parameters without Water Quality Standards

It should be noted that although formal TMDLs will not be developed for parameters without water quality standards in the Little Muddy River Watershed, many of the management measures discussed in Section 9 of this report will result in reductions of the parameters listed in the 1998 and 2002 303(d) lists that do not currently have adopted water quality standards. For example, many of the management measures that will be discussed in Section 9 address the other parameters of concern for the watershed. For total suspended sediments (TSS) and siltation management measures that control erosion, such as filter strips and wetlands, will reduce sediment from entering the waterways thereby reducing TSS caused by eroding stream banks.

4.4 Pollution Sources

As part of the Illinois EPA use assessment presented in the annual Illinois Water Quality Report, the causes of the pollutants resulting in a less than full support use attainment are associated with a potential source, based on data, observations, and other existing information. The following is a summary of the sources associated with the listed causes for the TMDL listed segments in this watershed. They are summarized in Table 4-2.

Table 4-2 Summary of Potential Sources of Pollutants

Potential Source	Cause of Impairment
Municipal Point Source	DO
Agriculture Nonirrigated crop production Pasture Land Animal Holding/Management Areas	DO
Resource Extraction Mining Mine Tailings	Sulfates pH Mercury Manganese
Contaminated Sediments	Mercury Manganese DO
Urban Runoff/Storm Sewers	DO

4.4.1 Municipal Point Sources

Municipal point sources include wastewater treatment plants (WWTP) operated by municipalities to treat municipal wastewater generated by the community. A National Pollutant Discharge Elimination System (NPDES) permit issued by Illinois EPA regulates the discharge. The NPDES permit sets limits that must be met at the discharge to the receiving stream.

Historically, these point sources have impacted water quality of the receiving streams, particularly during low flow conditions. Many municipal WWTPs have upgraded the facilities through grant and low-interest loan programs, thereby improving effluent quality and reducing impacts to the receiving stream.

Municipal point source effluents are typically regulated for ammonia nitrogen and biochemical oxygen demand (BOD). BOD is associated with oxygen demand. The higher the BOD, the more likely the effluent is to reduce the DO levels in the stream.

Phosphorous can be attributed to municipal point sources and can originate from domestic sources. Control of phosphorous entering the stream may reduce the amount of algal growth/chlorophyll "a" in the stream.

There are a total of 186 NPDES permits issued to dischargers in the Big Muddy River basin. A total of nine WWTPs discharge to the Big Muddy River mainstem, all downstream of Rend Lake. Four of these dischargers are considered major municipal dischargers (design average flow greater than one million gallons per day) (Muir et al. 1997). The point sources specific to the Big Muddy River N12 and Kinkaid Lake watersheds are discussed in Section 5.

4.4.2 Agriculture

The southern Illinois area is largely agriculture land use. Row crop agriculture is the largest single category land use in the basin. Agricultural land uses potentially contribute sediment, TSS, nutrients, and BOD loads to the water resource loading. The amount that is contributed is a function of the soil type, slope, crop management,

precipitation, total amount of cropland, and the distance to the water resource (D.B. Muir, R.L. Hite, M.M. King, and M.R. Matson 1995).

Erosion of the land and streambanks carries sediment to the streams and lakes, resulting in higher levels of BOD, which impacts DO concentrations, TSS, and siltation. This can also be caused by livestock on pastures and feedlots. Wastes from livestock can enter streams, adding to the ammonia nitrogen loading and impact DO.

4.4.3 Resource Extraction

Resource extraction consists of both active mining and abandoned mine lands. Runoff and discharges from mines can contain sulfates, salinity/total dissolved solids (TDS)/ chlorides, metals, TSS, and can affect the pH of the stream or lake. There are currently 47 permitted coal mines with 169 authorized discharges in the Big Muddy River basin. In addition, 1,177 inactive or abandoned mines have been identified. There are 4 pre-law inactive coal mines located in the Big Muddy River segment N12 Watershed and no permitted mines within the Kinkaid Lake Watershed. Mining is most concentrated in Beaucoup Creek, Galum Creek, Little Muddy River, Pond Creek, Hurricane Creek, and Rend Lake watersheds (Muir et al. 1997).

Drainage from the mines can be impacted by contact with exposed soil, spoil piles, or pumped water from pits. Acid mine drainage occurs when water and oxygen come in contact with iron pyrite material. This combination makes ferrous iron and sulfuric acid, creating acidic runoff and impacting the stream pH. Although acid mine drainage may come from active mines, most acid mine drainage entering streams is from abandoned mine lands.

4.4.4 Contaminated Sediments

Sediments are carried to streams, lakes, and reservoirs during runoff conditions and are generally deposited in streambeds or lake bottoms. Constituents contained in sediment may include nutrients, which can impact BOD loads, and metals. Both agricultural lands and urban areas contribute to the nutrient loading in the sediment.

Suspended sediments settle out to stream bottoms during periods of low flow. During periods of high flow, sediments are resuspended and carried downstream to be deposited in another location. Once the sediment reaches a lake or reservoir, the sediments are deposited and typically accumulate in these areas. The source of the contaminated sediment can therefore be located much farther upstream than the location detected.

Contaminated sediments can slowly leach contaminants to the water column, thereby being a continual source of impact to the water body. Phosphorous is commonly released from sediment into the water column especially when anoxic conditions persist.

4.4.5 Urban Runoff/Storm Sewers

Urban areas in the Big Muddy River Watershed constitute a small percentage of land use in the watershed; however, polluted runoff from urban sections can be significant. Runoff from urban areas reaches streams or lakes either by sheet flow runoff or through storm sewer discharges. The runoff can originate from any number of areas including highways; roadways; parking lots; industrial, commercial, or residential areas; or undeveloped lands. Phosphorous, which can influence BOD loads, can originate from fertilizer use, natural phosphorous levels in sediment, and from sanitary waste where combined sewer overflows are present.

Section 5
Big Muddy River Watershed Data Review

5.1 Existing Data Review

The following data sources were reviewed for model selection and analysis:

- mapping data
- topography data
- flow data
- precipitation data
- temperature data
- evaporation data
- existing water quality data
- land use
- soil data
- cropping practices
- reservoir characteristics
- point sources
- dairy and animal confinement locations
- septic systems

5.1.1 Mapping Data

USGS quadrangle maps (scale 1:24,000) were collected for the watershed in paper and electronic form. These were utilized for base mapping.

5.1.2 Topography Data

A Digital Elevation Model (DEM) was used to delineate watersheds in a geographic information system (GIS) for Kinkaid Lake and Big Muddy River impaired segment N12. A DEM is a digital representation of the landscape as a GIS-compatible grid in which each grid cell is assigned an elevation. DEMs of 90-meter resolution were downloaded from the *BASINS* database (USEPA 2002a) for watershed delineation. GIS watershed delineation defines the boundaries of a watershed by computing flow directions from elevations and locating elevation peaks on the DEM. The GIS-delineated watershed was checked against USGS 7.5-minute topographic maps to ensure agreement between the watershed boundaries and natural topographic boundaries. Figure 5-1 at the end of this section shows the location of historic flow and water quality gages for the Kinkaid Lake segment RNC and Big Muddy River segment N12 Watersheds and the boundaries for each watershed. The watershed boundaries define the area investigated for causes of impairments in each segment. Purple areas in Figure 5-1 represent features of the topographic maps that have been updated through aerial photography but have not been field verified.

The watershed for segment N12 only represents the area that drains directly to segment N12. Beaucoup Creek converges with the main stem of the Big Muddy River directly

upstream of segment N12. The Big Muddy River segment directly downstream of segment N12 is also listed as full support. Sources of impaired constituents in Beaucoup Creek segment NC07 (upstream of segment N12) will be addressed separately. Therefore, the sources of impairments in segment N12 will focus on areas draining directly to the segment.

5.1.3 Flow Data

Analyses of the Kinkaid Lake and Big Muddy River Watersheds require an understanding of flow into Kinkaid Lake and through the Big Muddy River segment N12. A gage is located in segment N12; however, no gage for the tributaries to Kinkaid Lake exists. Therefore, the drainage area ratio method, represented by the following equation, was used to estimate flows into the lake.

$$Q_{gaged}\left(\frac{Area_{ungaged}}{Area_{gaged}}\right) = Q_{ungaged}$$

where Q_{gaged} = streamflow of the gaged basin
$Q_{ungaged}$ = streamflow of the ungaged basin
$Area_{gaged}$ = area of the gaged basin
$Area_{ungaged}$ = area of the ungaged basin

The assumption behind the equation is that the flow per unit area is equivalent in watersheds with similar characteristics. Therefore, the flow per unit area in the gaged watershed times the area of the ungaged watershed will result in a flow for the ungaged watershed.

USGS gage 05595820 (Casey Fork at Mt. Vernon, Illinois) was chosen as an appropriate gage from which to compute flow into Kinkaid Lake. Gage 05595820 captures flow from a drainage area of 77 square miles in an upstream section of the Casey Fork Watershed, which is about 50 miles northeast of the Kinkaid Lake Watershed. Daily streamflow data for the gage were downloaded from the USGS National Water Inventory System (NWIS) for the entire period of record from October 1, 1985 to September 30, 2000 (USGS 2002a). Figure 5-2 at the end of this section shows the average monthly flows over the period of record into Kinkaid Lake calculated from the drainage area ratio method using gage 05595820.

USGS gage 05599500 (Big Muddy River at Murphysboro, Illinois) is located at the downstream end of segment N12 as shown in Figure 5-1. Gage 05599500 captures flow from a drainage area of approximately 2,169 square miles. Daily streamflow data for the gage were downloaded from the USGS NWIS for the entire period of record from January 1, 1972 to September 30, 2000 (USGS 2002a). Figure 5-3 at the end of this section shows the seasonal patterns of streamflow through segment N12 over the period of record. Flows are higher in the spring months of March through May. For Big Muddy River segment N12, average monthly flows range from 403 to 4,180 cubic feet per second (cfs) with a mean annual flow of 2,080 cfs. The 7Q10 flow

(lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years) is typically utilized as the critical low flow for NPDES permitting and is estimated to 55 cfs for segment N12 (ISWS 2000).

5.1.4 Precipitation, Temperature, and Evaporation Data

Two sites with historical temperature and precipitation data were identified in Jackson County through the NCDC database. The data from gage 1265 were used for analysis because the recent dataset was more complete than the data set from gage 5983. Fifteen months of data were missing from gage 1265 over the period from 1985 to 2001. Missing data were supplemented with data from the gage in neighboring Williamson County. Table 5-1 lists the station details for the Jackson County and Williamson County gages (NCDC 2002).

Table 5-1 Historical Precipitation Data for the Big Muddy River Watershed (NCDC 2002)

NCDC Gage Number	Station Location (Name)	Period of Record
5983	Jackson County (Murphysboro 2SW)	1948 to present
1265	Jackson County (Carbondale Sewage Plant)	1970 to present
5342	Williamson County (Marion 4NNE)	1948 to present

Table 5-2 Average Monthly Precipitation in Jackson County from 1985 to 2001

Month	Average Precipitation (inches)
January	3.2
February	3.2
March	3.6
April	4.5
May	4.9
June	5.3
July	3.0
August	3.5
September	3.5
October	3.1
November	4.8
December	3.5
Total	**46**

Table 5-2 shows the average monthly precipitation of the dataset developed for Jackson County for the years 1985 to 2001. The average annual precipitation over the same period is approximately 46 inches.

Pan evaporation data is available through the Illinois State Water Survey (ISWS) website at nine locations across Illinois (ISWS 2002). The Carlyle station was chosen for its proximity to the 303(d)-listed water bodies and stream segments in southern Illinois and the completeness of the dataset as compared to other stations. The Carlyle station is approximately 60 miles northeast of the Kinkaid Lake and Big Muddy River Watersheds. The average monthly pan evaporation for the years 1980 to 2001 at the Carlyle station was downloaded from the ISWS website and summed to produce an average annual pan evaporation of 44.2 inches. Actual evaporation is typically less than pan evaporation, so the average annual pan evaporation was multiplied by 0.75 to calculate an average annual evaporation of 33.2 inches (ISWS 2002).

5.1.5 Water Quality Data

Twelve historic water quality stations exist within the Kinkaid Lake and Big Muddy River segment N12 watersheds and are presented in Table 5-3. This table provides the

location, station identification number, and the agency that collected the water quality data. Location and station identification number are also shown in Figure 5-1.

Table 5-3 Historic Water Quality Stations in the Big Muddy River Watershed

Location	Station Identification Number	Data Collection Agency
Big Muddy River	N12	Illinois EPA Division of Water Pollution Control
Big Muddy River	05599500	USGS
Kinkaid Lake	05599540 RNC-1	USGS Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-2	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-3	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-4	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-5	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-6	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-7	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-8	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-9	USEPA Region 5 Data

The impaired water body segments in the Big Muddy River Watershed were presented in Section 2. For Kinkaid Lake, segment RNC, there are 10 historic water quality stations. For Big Muddy River segment N12 there are two historic water quality stations listed in Table 5-3 and shown in Figure 5-1. The Kinkaid Lake stations beginning with "RN" have a concurrent period of record. Stations RN-A08-C-1 and 05590540 are positioned in the same place in Kinkaid Lake and have overlapping periods of record. The two stations in segment N12 are also located in the same place, but have different sampling periods. Table 5-4 summarizes available historic water quality data since 1990 from the USEPA *Storage and Retrieval (STORET)* database associated with impairments discussed in Section 2 for segments RNC and N12. Stations RNC-5 through RNC-9 are not included in Table 5-4 because their periods of record ended prior to 1990. Illinois volunteer lake monitoring data was not utilized in modeling efforts.

Table 5-4 Summary of Constituents Associated with Potential Impairments for Big Muddy River Segments N12 and RNC (USEPA 2002b and Illinois EPA 2002)

Sample Location and Parameter	Period of Record Examined for Samples	Number of Samples
Big Muddy River Segment N12; Sample Location 05599500		
Manganese	1/9/90-4/24/97	51
Sulfates	1/9/90-4/24/97	65
pH	1/9/90-4/24/97	102
DO	1/9/90-4/24/97	102
Big Muddy River Segment N12; Sample Location N12		
Manganese	10/27/97-9/6/00	27
Sulfates	11/20/97-9/6/00	25
pH	10/27/97-9/6/00	27
DO	10/27/97-9/6/00	27
Kinkaid Lake Segment RNC; Sample Location 05599540, RNC-1, RNC-2, RNC-3, RNC-4		
05599540		
pH	1/08/90-8/28/97	70
RNC-1		
pH	4/30/90-10/11/01	52
RNC-2		
pH	4/30/90-10/11/01	25
RNC-3		
pH	4/30/90-10/11/01	25
RNC-4		
PH	4/30/90-10/11/01	25

5.1.5.1 Kinkaid Lake Water Quality Data

There are four active water quality stations in Kinkaid Lake as shown in Figure 5-1 and listed in Table 5-4. The water quality station data for Kinkaid Lake were downloaded from the *STORET* online database for the years of 1977 to 1998 (USEPA 2002b). Data collected after 1998 were available from the Illinois EPA and were incorporated into the electronic database. The data summarized in this section include water quality data for impaired constituents in Kinkaid Lake as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

The constituents of concern in Kinkaid Lake are pH and mercury. The mercury TMDL will be addressed in a regional TMDL by USEPA and will not be addressed at the state level. The regional TMDL will focus on air deposition of mercury. USEPA's strategy for addressing persistent, bioaccumulative toxic chemicals (PBT) is a two-track approach. The "fast track" involves actions that can be implemented immediately, including pollution prevention and the "virtual elimination" project. The "science track" includes the study and assessment of the problems and solutions through modeling, monitoring, and emission inventories. The "virtual elimination" project, a cooperative Canadian – U.S. strategy to virtually eliminate persistent toxic substances in the Great Lakes Basin (the Bi-national Strategy), seeks to achieve quantifiable reduction goals between now and 2005 for specific toxic substances, including mercury (USEPA 2003). Mercury is addressed by USEPA with these strategies; therefore, Illinois EPA does not address it as part of this TMDL.

Constituents are sampled at various depths throughout Kinkaid Lake, and compliance with water quality standards is determined by the sample at a one-foot depth from the lake surface. This section discusses the one-foot depth samples of water quality constituents used in modeling efforts for Kinkaid Lake. The exception is chlorophyll "a," which was sampled at various depths at each water quality station and will be presented as an average over all sample depths. Modeling of the reservoir required use of phosphorus samples at all depths, which is discussed and presented in Section 7.3.3.2.

5.1.5.1.1 pH

The average pH measurements at one-foot depth for each year of available data after 1990 at each monitoring site in Kinkaid Lake are presented in Table 5-5. At station RNC-1, samples were taken at one-foot depth from the lake surface and at the lake bottom. Samples at stations RNC-2, RNC-3, and RNC-4 were only taken at a one-foot depth from the lake surface. The TMDL endpoints for pH are a minimum of 6.5 and a maximum of 9.0. The annual averages at all three stations and the annual lake averages are all within the endpoint limits, but individual measurements in 1991, 1994, and 2000 exceeded the upper limit. Specifically, the pH value at station RNC-3 on July 9, 1991 was 9.1, and on July 12, 1994, the pH value was 9.1 at RNC-1. On June 5, 2000 and August 2, 2000, the pH value measured was 9.2 at RNC-1 and RNC-3, respectively. At gage 05599540, three values were below the lower limit for pH. On September 25, 1991 and January 11, 1996, the pH was recorded as 6.3, and on December 14, 1995, the pH was recorded as 6.2.

Table 5-5 Average pH (s.u.) Values in Kinkaid Lake

Year	RNC-1 and 05599540	RNC-2	RNC-3	RNC-4	Lake Average
1990	7.7	8.2	8.1	7.5	7.9
1991	7.7	8.1	8.2	7.6	7.9
1992	7.4				7.4
1993	8.0				8.0
1994	8.2	8.3	8.4	8.1	8.2
1995	7.2				7.2
1996	7.1				7.1
1997	7.7	7.9	7.9	7.4	7.7
2000	8.3	8.3	8.5	8.2	8.3

Fluctuations in pH can be correlated to photosynthesis from algae. Plants and algae use carbon dioxide (CO_2) during photosynthesis, which causes pH levels to rise. The photosynthetic rate progressively decreases as the residual CO_2 concentration declines and ceases completely with the extinction of light. During the night, reaeration and respiration replenish CO_2 causing the pH levels to decrease overnight (Welch 1980). Chlorophyll "a" indicates presence of excessive algal or aquatic plant growth. Reducing total phosphorus is likely to reduce algal growth thus resulting in attainment of the pH standard. Therefore, the relationship between pH, chlorophyll "a," and total phosphorus in Kinkaid Lake was investigated. The correlation between pH and chlorophyll "a" is expected to indicate a direct relationship between the two constituents. Likewise, the correlation between chlorophyll "a" and total phosphorus is

expected to indicate a direct relationship. These relationships would suggest that controlling phosphorus will decrease chlorophyll "a" concentrations, which will in turn control the pH. This hypothesis is supported by Wetzel who asserts that photosynthesis and respiration are major influences on pH (1983).

5.1.5.1.2 Total Phosphorus

The average total phosphorus concentrations at one-foot depth for each year of available data from 1990 to 2000 at each monitoring site in Kinkaid Lake are presented in Table 5-6. At station RNC-1, samples were taken at a one-foot depth from the lake surface and at the lake bottom. Samples at stations RNC-2 and RNC-3 were only taken at a one-foot depth from the lake surface. The water quality standard for total phosphorus is less than or equal to 0.05 mg/L at one-foot depth. Additionally, multiple samples taken at one-foot depth since 1990 do violate the TMDL endpoint for phosphorus. It is apparent from Table 5-6 that concentrations at Station RNC-4 repeatedly violate the phosphorus standard. The raw data for all sample depths are contained in Appendix A.

Table 5-6 Average Total Phosphorus Concentrations (mg/L) in Kinkaid Lake at One-foot Depth (USEPA 2002b and Illinois EPA 2002)

Year	RNC-1 and 05599540	RNC-2	RNC-3	RNC-4	Lake Average
1990	0.06	0.01	0.02	0.09	0.05
1991	0.02	0.02	0.03	0.10	0.04
1992	0.02				0.02
1993	0.02		0.03		0.02
1994	0.03	0.02	0.04	0.14	0.06
1995	0.02				0.02
1996	0.03				0.03
1997	0.02	0.03	0.04	0.13	0.06
1998	0.03				0.03
2000	0.01	0.01	0.02	0.05	0.03

Phosphorus exists in water in either a particulate phase or a dissolved phase. Particulate matter includes living and dead plankton, precipitates of phosphorus, phosphorus adsorbed to particulates, and amorphous phosphorus. The dissolved phase includes inorganic phosphorus and organic phosphorus. Phosphorus in natural waters is usually found in the form of phosphates (PO_4 and PO_3). Phosphates can be in inorganic or organic form. Inorganic phosphate is phosphate that is not associated with organic material. Types of inorganic phosphate include orthophosphate and polyphosphates. Orthophosphate is sometimes referred to as "reactive phosphorus." Orthophosphate is the most stable kind of phosphate and is the form used by plants or algae. There are several forms of phosphorus that can be measured. Total phosphorus is a measure of all the forms of phosphorus, dissolved or particulate, that are found in a sample. Soluble reactive phosphorus is a measure of orthophosphate, the filterable (soluble, inorganic) fraction of phosphorus, the form directly taken up by plant cells.

5.1.5.1.3 Chlorophyll "a"

The average chlorophyll "a" concentrations for each year of available data from 1990 to 2001 at each active monitoring site in Kinkaid Lake are presented in Table 5-7. There was no chlorophyll "a" data available at station 05599540. The raw data for all sample depths are contained in Appendix A.

Table 5-7 Average Chlorophyll "a" Concentrations (µg/L) in Kinkaid Lake (USEPA 2002b and Illinois EPA 2002)

Year	RNC-1	RNC-2	RNC-3	RNC-4	Lake Average
1990	9.8	13.6	14.5	32.7	17.6
1991	9.0	10.5	17.1	43.1	19.9
1994	19.1	23.4	24.3	52.1	29.7
1997	13.2	19.4	27.5	48.9	27.3
1998	21.9				21.9
2000	18.4	12.7	16.4	38.0	21.4

5.1.5.1.4 Tributary Data

There is no water quality data available for the tributaries to Kinkaid Lake. The primary tributaries to Kinkaid Lake are Kinkaid Creek and Little Kinkaid Creek. Tributary water quality data along with flow information would be useful in assessing contributing loads from the watersheds to help differentiate between external loading and internal loading. External loads are those loadings from the watershed, such as nonpoint source runoff and point sources. Internal loads are caused by low DO conditions near lake sediments, which promote re-suspension of phosphorus from the sediments into the water column. External versus internal loads will be discussed further in Section 7.4.

5.1.5.2 Big Muddy River Water Quality Data

There is one active and one historic water quality station in Big Muddy River segment N12 as shown in Figure 5-1. The water quality station data for segment N12 were downloaded from the *STORET* online database for the years of 1990 to 1998 (USEPA 2002b). Data collected after 1998 were available from the Illinois EPA and were incorporated into the electronic database. The data summarized in this section include water quality data for impaired constituents in the Big Muddy River segment N12 as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

5.1.5.2.1 Manganese and Sulfates

Table 5-8 summarizes historical manganese and sulfates data since 1990 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for impaired segments in the Big Muddy River Watershed. The raw historical water quality data are contained in Appendix A. For impairments on segment N12, the average of the data sets do not exceed the water quality standard for either manganese and sulfates. The historical water quality samples were also taken during months with historically varying flow conditions.

Table 5-8 Summary of Constituents Associated with Potential Impairments for the Big Muddy River Segment N12

Sample Location and Parameter	Endpoint (mg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum
Big Muddy River Segment N12; Sample Location 05599500					
Manganese	1.0	1/9/90-4/24/97; 51	0.6	2.5	0.1
Sulfates	500	1/9/90-4/24/97; 65	237	660	59
Big Muddy River Segment N12; Sample Location N12					
Manganese	1.0	10/27/97-9/6/00; 27	0.6	1.9	0.2
Sulfates	500	11/20/97-9/6/00; 24	285	653	68

Figures 5-4 and 5-5 (at the end of this section) show concentrations of manganese and sulfates, respectively, with corresponding flows in segment N12. Figures 5-4 and 5-5 exclude samples taken between October 1993 and September 1995 because flow data was unavailable for those months. The flow for each sample date was compared to the monthly average flow shown in Figure 5-3 for the month the sample was taken. Based on this analysis, about 75 percent of manganese samples and 88 percent of sulfates samples were taken at below average flow conditions. This suggests that most historical samples were taken under low flow conditions in segment N12 of the Big Muddy River Watershed. Analysis of impaired sample dates showed that more than half of the impaired samples were taken at below average flows.

5.1.5.2.2 DO and TOC

Table 5-9 summarizes the available historic DO and total organic carbon (TOC) data since 1990 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for Big Muddy River segment N12 (raw data contained in Appendix A). TOC data are presented here because they are used in the DO analysis. The average DO concentration for segment N12 is above the water quality standard of 6.0 mg/L (16 hours of any 24-hour period), but the minimum values observed are less than the water quality standard of 6.0 mg/L.

Table 5-9 Existing DO and TOC Water Quality Data and TMDL Endpoints

Sample Location and Parameter	Endpoint (mg/L)	Period of Record Examined and Number of Data Points	Mean (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Big Muddy River Segment N12; Sample Location 05599500					
DO	6.0 (16 hours of any 24-hour period)	1/9/90-4/24/97; 102	8.7	20.8	3.7
Big Muddy River Segment N12; Sample Location N12					
DO	6.0 (16 hours of any 24-hour period)	10/27/97-9/6/00; 25	7.7	12.4	4.7
TOC	–	10/27/97-9/6/00; 2	5.6	5.6	5.5

Historical flow data were presented in Section 5.1.3. The flow values during the historical sampling events for DO that had corresponding TOC measurements are presented in Table 5-10. The flow for each sample date was compared to the monthly average flow shown in Figure 5-3 for the month the sample was taken. Based on this comparison, the September 6, 2000 sample was taken at below average flows, and the

July 24, 2000 sample was taken at above average flows. Low flow values within the stream segment result in slow-moving waters, which could decrease the amount of aeration occurring in the stream. In addition, the day with DO impairment (September 6, 2000) occurred in a typically warm weather month. Elevated stream temperatures affect the aquatic environment by limiting the concentration of DO in the water column. For example, the DO concentration for 100 percent air saturated water at sea level is 14.6 mg O_2/L at 0 degrees Celsius (°C) (32°F) and decreases to 8.6 mg O_2/L at 25°C (77°F) (Brown and Brazier 1972).

Table 5-10 DO Sampling Events and Associated Flow Values

Sample Location	Date	Flow (cfs)	DO (mg/L)
Big Muddy River (N12)	7/24/00	2,060	7.9
Big Muddy River (N12)	9/6/00	400	4.7

5.1.5.2.3 pH and TDS

Table 5-11 summarizes the available historic pH data from 1990 to 2001 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for Big Muddy River segment N12 (raw data contained in Appendix A). Although the segment is not impaired for TDS, the data are used in the pH calculations. The average pH concentration for the segment is within the water quality boundaries of 6.5 and 9.0, but the minimum value observed is less than the water quality standard of 6.5.

Table 5-11 Existing pH and TDS Water Quality Data and TMDL Endpoints

Sample Location and Parameter	Endpoint (mg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum
Big Muddy River Segment N12; Sample Location 05599500					
pH	6.5 - 9	1/9/90-4/24/97; 102	7.4	8.8	6.4
TDS	1,000	1/9/90-2/29/96; 16	620	2,010	197
Big Muddy River Segment N12; Sample Location N12					
pH	6.5 - 9	10/27/97-9/6/00; 25	7.1	8.1	6.4
TDS	1,000	7/24/00-9/6/00; 2	356	487	225

Figure 5-6 shows a histogram of pH values in Segment N12 of the Big Muddy River. This histogram illustrates that, based on historic data, three percent of the measured pH values in segment N12 violated the pH standard. The last violation occurred in August of 1998.

5.1.6 Land Use

The Illinois Natural Resources Geospatial Clearinghouse distributes the Critical Trends Assessment Land Cover Database of Illinois. This database represents 23 land use classes created by satellite imagery captured between 1991 and 1995. The data were published in 1996 and are distributed by county in grid format for use in GIS. The GIS-delineated watershed for Kinkaid Lake and Big Muddy River segment N12 were used to obtain the land use from the Critical Trends Assessment Land Cover grid. Tables 5-12 and 5-13 list the land uses contributing to the Kinkaid Lake Watershed and the segment N12 watershed, as well as each land use area and percent of total area.

Table 5-12 Critical Trends Assessment Land Uses in Kinkaid Lake (IDNR 1996)

Land Use	Acres	Percent of Area
Deciduous Forest	21,597	56%
Rural Grassland (pastureland, grassland, waterways, buffer strips, CRP land, etc.)		
Pasture	2,977	8%
Grassland	5,953	16%
Row Crop (corn, soybeans, and other tilled crops)	3,576	9%
Open Water	2,703	7%
Small Grains (wheat, oats, etc.)	751	2%
Coniferous Forest	461	1%
Forested Wetlands	368	1%
Urban (high and medium density)	101	0%
Shallow Water Wetlands	61	0%
Shallow Marsh/Wetlands	27	0%
Urban Grassland	17	0%
Deep Marsh	7	0%
Barren Land	5	0%
Cattle Feedlot	6	0%
Total	38,610	100%

*Subclasses of rural grassland were estimated by the Jackson County NRCS (2002a)

Table 5-13 Land Use for Segment N12 Watershed

Land Use	Area (Acres)	Percent of Total
Deciduous	7,164	39%
Rural Grassland	5,175	28%
Row Crop	1,989	11%
Urban Grassland	1,241	7%
Forested Wetland	813	4%
Medium Density	529	2.5%
Small Grains	491	2.5%
Orchard/Nurseries	297	2%
Open Water	292	2%
High Density	200	1%
Shallow Water/Wetlands	159	1%
Coniferous	27	0%
Shallow Marsh/Wetlands	16	0%
Low Density	11	0%
Swamp	3	0%
Deep Marsh	1	0%
Total	18,408	100%

Additional land use data were obtained from the Spatial Analysis Research Center's Cropland Data Layer to supplement the Critical Trends Assessment dataset. The data were requested from the National Agricultural Statistics Service (NASS) website for the years of 1999 and 2000 (NASS 2002). The Cropland Data Layer is also derived from satellite imagery, but the land use classes for crops are more detailed than those presented in the Critical Trends Assessment dataset. The detailing of crops in the Cropland Data Layer land use classes makes it a more accurate dataset for calculation of crop-related parameters. The dataset was also used to verify the land use obtained from the Critical Trends Assessment. Table 5-14 shows the cropland use classes of the

Cropland Data Layer and the Critical Trends Assessment classes to which they were applied.

Table 5-14 Comparison of Land Use Classes in the Kinkaid Lake Watershed

Cropland Data Layer Land Use Class	Critical Trends Assessment Land Use Class
Corn	Row Crop
Sorghum	Small Grains
Soybeans	Row Crop
Winter Wheat	Small Grains
Other Small Grains & Hay	Small Grains
Double-Cropped Winter Wheat/Soybeans	Half to Small Grains Half to Row Crops

5.1.7 Point Sources and Animal Confinement Operations

5.1.7.1 Coal Mines and Oil and Gas Fields

Acid mine drainage from coal mines could contribute to manganese and sulfates concentrations in a watershed. Data from the Illinois Natural Resources Geospatial Data Clearinghouse was reviewed for coal mines, oil fields, and non-coal mines within the Big Muddy River Watershed from the following references (full citation provided in Section 13):

- Chenoweth, Cheri, 1998, Areas Mined for the Springfield (No. 5) Coal in Illinois
- Stiff, Barbara J., 1997, Areas Mined for Coal in Illinois - Part 1
- Stiff, Barbara J., 1997, Areas Mined for Coal in Illinois - Part 2
- Coal Section, Illinois State Geological Survey, 1991, Point Locations of Active and Abandoned Coal Mines in Illinois
- Illinois Office of Mines and Minerals, 1998, Coal Mine Permits Boundaries in Illinois
- Staff, ISGS, 1996, Non-coal Underground Mines of Illinois
- Staff, ISGS, 1996, Non-coal Underground Mines of Illinois - Points
- Illinois State Geological Survey, not published, Oil and Gas Fields in Illinois

Figure 5-7 presents the findings from these databases for extraction operations in the Big Muddy River Watershed. Multiple coal mines were identified within the watershed and labeled on Figure 5-7. The mine names and dates of operation are listed in Appendix B. There are no permitted mines in this watershed, and a comparison of the existing and permitted mine databases suggests that non-permitted mines are likely abandoned or closed. No oil or gas fields or non-coal mines were located in the segment N12 Watershed; however, the non-coal mine database contains only 20 percent of the non-coal mines in Illinois due to the lack of a legal filing requirement.

Both Illinois EPA and IDNR Office of Mines and Minerals have responsibilities relating to the permitting of active coal mines and the regulation of mine drainage. Mine drainage is any groundwater, surface water, or rainwater that flows through, or in any way contacts an area affected by mining. Mine drainage from sites in Illinois are either non-acid drainage or acid drainage and can be classified as pre-law and post-law. Pre-law mines are those mines operated prior to 1977, which are abandoned and not permitted and are typically acid drainage mines (Muir et al. 1997).

Acid mine drainage is formed when three essential components combine: iron pyrite material, oxygen, and water. Pyritic material may come in several different forms, some of which are very stable and difficult to break down while others are very reactive and break down readily. Iron pyrite is commonly found associated with coal and coal refuse materials. As water contacts iron pyrite in the presence of oxygen, a chemical reaction occurs that forms ferrous iron and sulfuric acid. The ferrous iron then undergoes oxidation to form ferric iron. With the presence of ferrous iron, ferric iron, pyrite, oxygen, and water, several chemical reactions occur that produce additional acidity, further lowering the pH of the water. The formation of new acid is practically continuous when erosion of the refuse material exposes unreacted pyrite in the presence of oxygen and water. The negative impacts of acid mine drainage are high levels of dissolved solids, especially iron, sulfates, chlorides, and manganese associated with the mine drainage (Muir et al. 1997).

As mentioned previously, the sampling data for manganese and sulfates, shown in Figures 5-4 and 5-5, were taken primarily under low-flow conditions. The figures show a decrease in concentrations with increases in flow indicating that groundwater is the potential source of these constituents. If the source of manganese and sulfates were due to surface runoff, an increase in concentrations would be expected with increased flows. The absence of exceedences of the water quality standards for manganese or sulfates at higher flows in the figures supports the conclusion that manganese and sulfates could have leached into the groundwater from pools within the mine sites and be the source of manganese and sulfates concentrations in segment N12. In addition, no data are available to assess the natural background of manganese and sulfates in the watershed. Natural background concentrations typically are attributed to what occurs naturally in groundwater due to mineral conditions of the soils (Water Environment Research Foundation [WERF] 1997).

5.1.7.2 Animal Confinement Operations

The Illinois EPA provided a GIS shapefile illustrating the location of livestock facilities in the Big Muddy River Basin, which contains Kinkaid Lake and Big Muddy River segment N12. The Illinois EPA assessed the potential impact of each facility on water quality with regard to the size of the facility, the site condition and management, pollutant transport efficiency, and water resources vulnerability. Two livestock facilities (cattle feedlots) were identified in the Kinkaid Lake watershed as shown in Figure 5-8. One of the feedlots was determined to have no impact on the receiving waters, and the other was determined to have a slight impact on receiving waters. Three animal management operations were located in the segment N12 watershed; two are

designated as having no impact on receiving waters, and the third was not assessed. Figure 5-9 shows the animal management operations within the segment N12 Watershed.

5.1.7.3 Wastewater Treatment Plants

Table 5-15 lists the wastewater treatment facilities within the N12 watershed. No point sources were located within the Kinkaid Lake Watershed. Table 5-15 also provides information on whether there is potential for the facility to impact DO concentrations in Segment N12. With exception of the Carbondale Northwest Wastewater Treatment Plan, none of the facilities has the potential to impact DO concentrations in Segment N12. The facilities are either no discharge or discharge such little effluent that it is unlikely that they impact the Big Muddy River. The Carbondale Northwest Plant will be further discussed in Section 10.

Table 5-15 Wastewater Treatment Plants within N12 Watershed

Facility Name	NPDES Number	Potential to Impact DO Concentrations in N12
Lake Chautauqua Home	IL0045705	No
Fairway Motor Home Park	IL0045306	No
New Thompson Lake Fishing Club	IL0048569	No
Jackson Country Club	IL0038521	No
Fairway Vista Group	IL0061786	No
Paul Parrish Apartments	IL0048089	No
Green Tree Mobile Home Park	IL0036935	No
Happy Ours Mobile Home Park	IL0046299	No
Carbondale Northwest Wastewater Treatment Plant	IL0027871	Yes

5.1.8 Soil Data

State Soil Geographic (*STATSGO)* database data, created by the USDA – National Resource Conservation Service (NRCS) Soil Survey Division, are aggregated soil surveys for GIS use published for Illinois in 1994. The *STATSGO* shapefiles were downloaded by HUC from the USEPA *BASINS* website (USEPA 2002a). *STATSGO* data are presented as map units of soils in which each map unit has a unique code linking it to attribute tables listing percentages of soil types within a map unit, soil layer depths, hydrologic soil groups, and soil texture among other soil properties.

5.1.9 Cropping Practices

Tillage practices can be categorized as conventional till, reduced till, mulch-till, and no-till. The percentage of each tillage practice for corn, soybeans, and small grains by county are generated by the Illinois Department of Agriculture from County Transect Surveys. Data specific to the Kinkaid Lake Watershed were not available; however, the Jackson County NRCS office recommended percentages of each tillage practice for application to the Kinkaid Lake Watershed as shown in Table 5-16 (NRCS 2002a).

Table 5-16 Tillage Practices in the Kinkaid Lake Watershed (NRCS 2002a)

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	20%	0%	20%
Reduced Till	15%	10%	50%
Mulch-Till	15%	5%	10%
No-Till	50%	85%	20%

5.1.10 Reservoir Characteristics

Reservoir characteristics were obtained from GIS analysis, the Illinois EPA, the Kinkaid Lake watershed plan, and USEPA water quality data. The watershed plan for Kinkaid Lake lists a normal pool of 2,350 acres (Kinkaid Area Watershed Project, Inc. [KAWP] 2000). Illinois EPA originally estimated the surface area of Kinkaid Lake as 3,475 acres, resulting in a large discrepancy between this value and those obtained from the watershed plan and GIS. Based on recent studies in the watershed, the surface area of 2,350 acres from the watershed plan was used to validate the surface area of 2,402 acres obtained from GIS analysis. For modeling analyses, the area obtained through GIS analysis was scaled to equal the area from the resource plan.

The water quality dataset described in Section 5.1.5.1 was used to determine the average depth of Kinkaid Lake. On each date sampled for water quality constituents, the total depth at the site was measured. Table 5-17 lists the average depth calculated for each water quality site in Kinkaid Lake for each year of available data after 1990.

Table 5-17 Average Depths in Feet for Kinkaid Lake

Year	RNC-1	RNC-2	RNC-3	RNC-4	Lake Average
1990	55.9	42.3	6.5	6.5	27.8
1991	63.0	40.3	22.0	3.4	32.2
1992	80.4	15.2	13.8	4.3	28.4
1993	73.0	22.4	15.6	6.5	29.4
1994	60.0	35.7	24.7	4.0	31.1
1996	60.0	41.1	9.2	9.2	29.9
1997	57.9	40.2	27.4	9.4	33.7
1998	57.9	39.5	29.0	10.5	34.2
2000	51.3	39.4	26.8	10.2	31.9

Reservoir characteristics that were unavailable were flows into and out of the reservoir.

5.1.11 Septic Systems

Typically, septic systems near lake waters have greater potential for impacting water quality than systems near streams due to their proximity to the water body of concern. The number of septic systems within the watersheds could not be confirmed from available data sources. There were no residences observed near the lake during the site visit described in Sections 2.2 and 2.3. It is anticipated that failing septic systems are a negligible source of pollutant loads in this watershed.

5.1.12 Aerial Photography

Aerial photographs of the Big Muddy River Watershed were obtained from the Illinois Natural Resources Geospatial Data Clearinghouse. The photographs were used to supplement the USGS quadrangle maps when locating facilities.

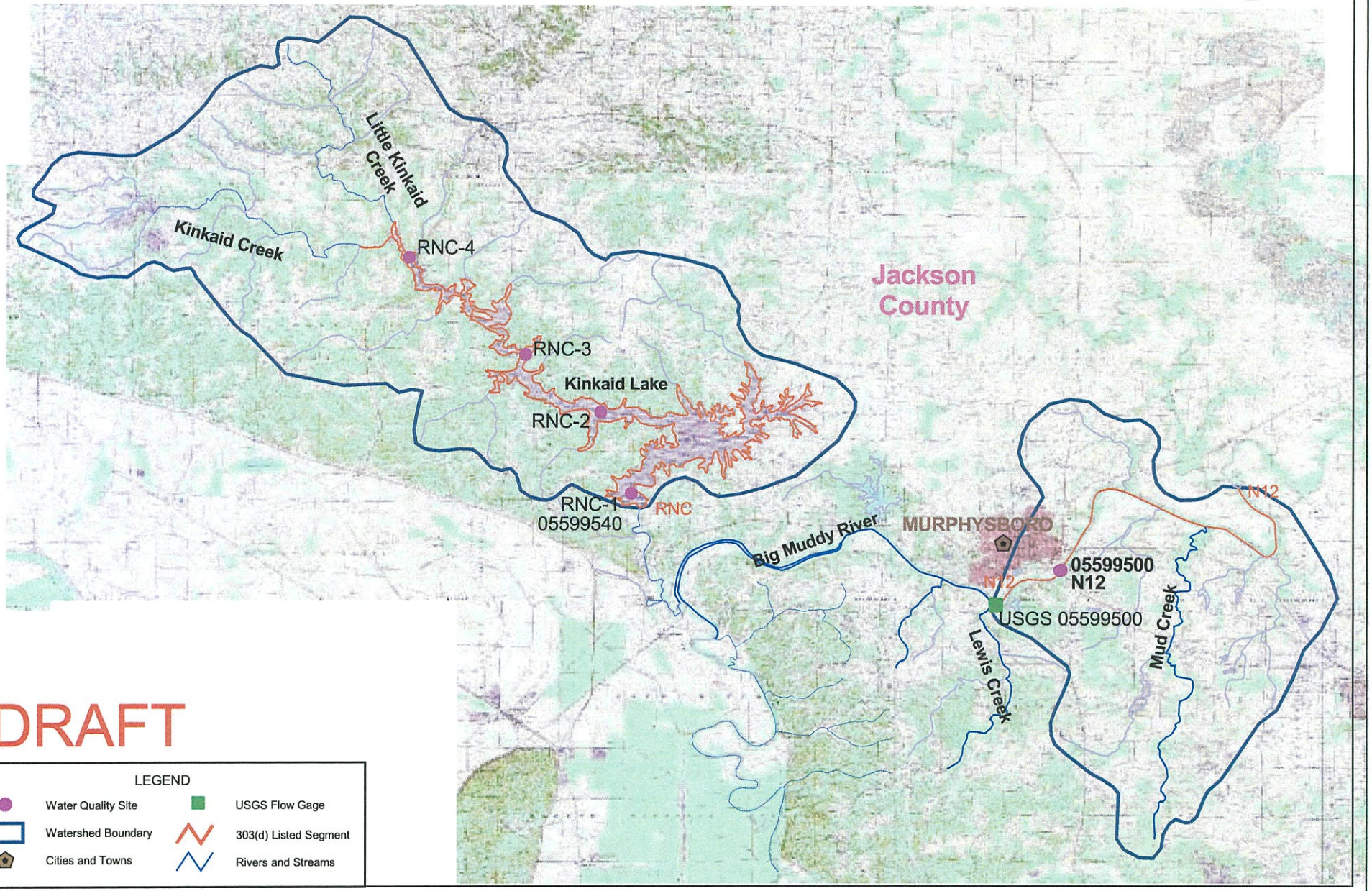


Figure 5-1
Big Muddy River #1 Watershed
Historic Flow and Water Quality Gages

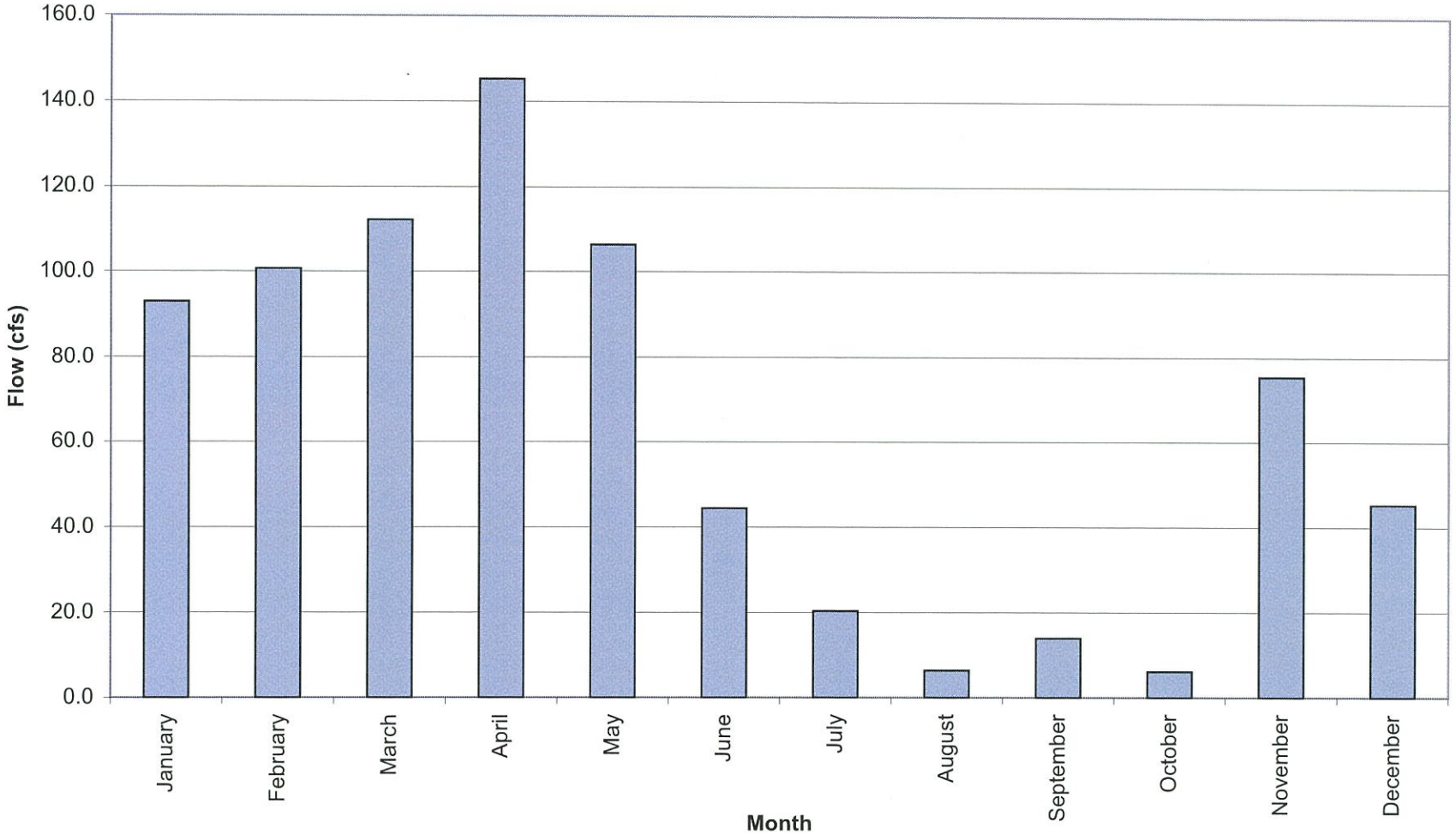
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Figure 5-2: Estimated Streamflow Upstream of Kinkaid Lake Calculated from Gage 05595820



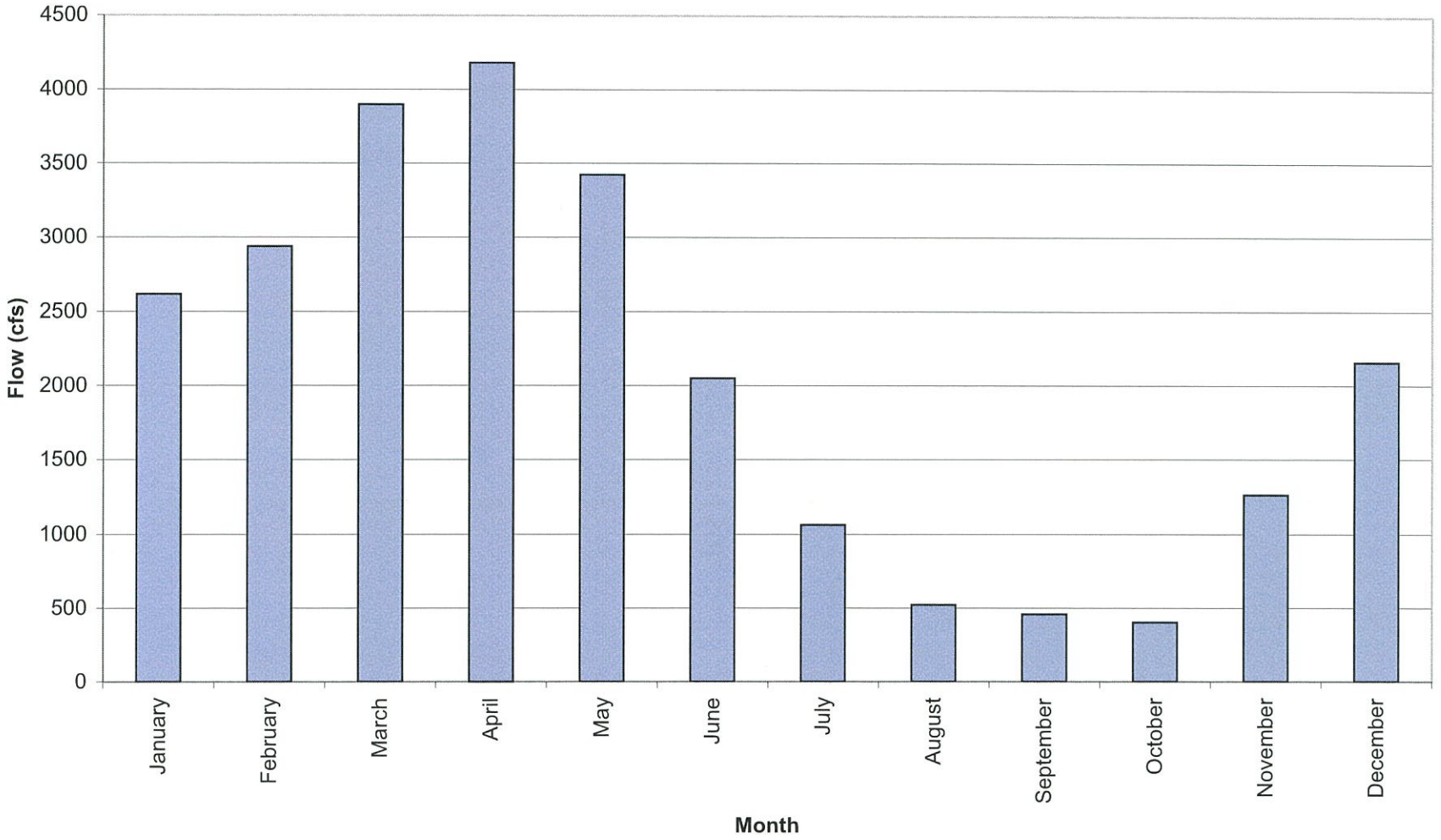
Period of Record
October 1, 1985 to September 30, 2000

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Figure 5-3: Flows in the Big Muddy River Segment N12
Gage 05599500



Period of Record
January 1, 1972 to September 30, 2000

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Figure 5-4 Manganese Concentrations and Flows in Big Muddy River Segment N12

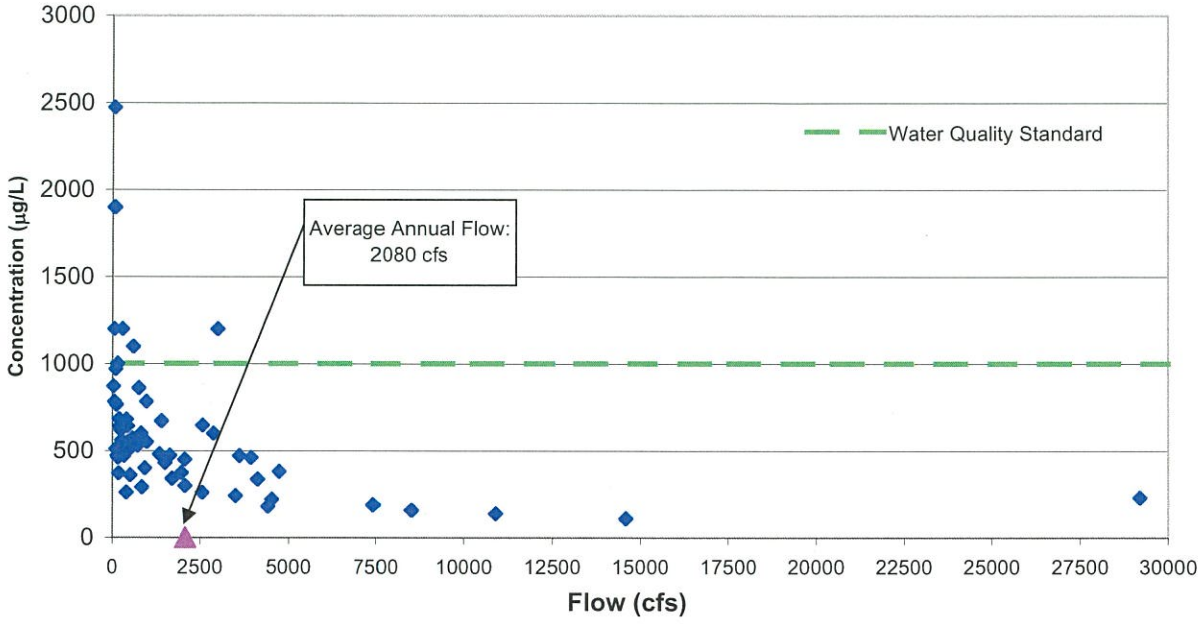
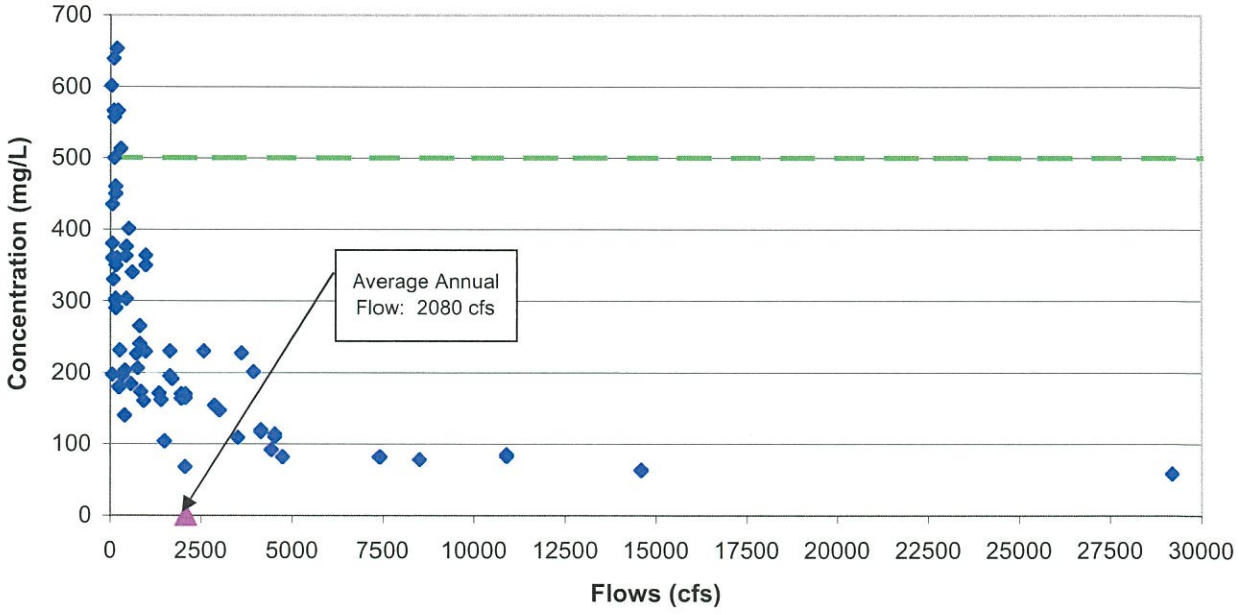
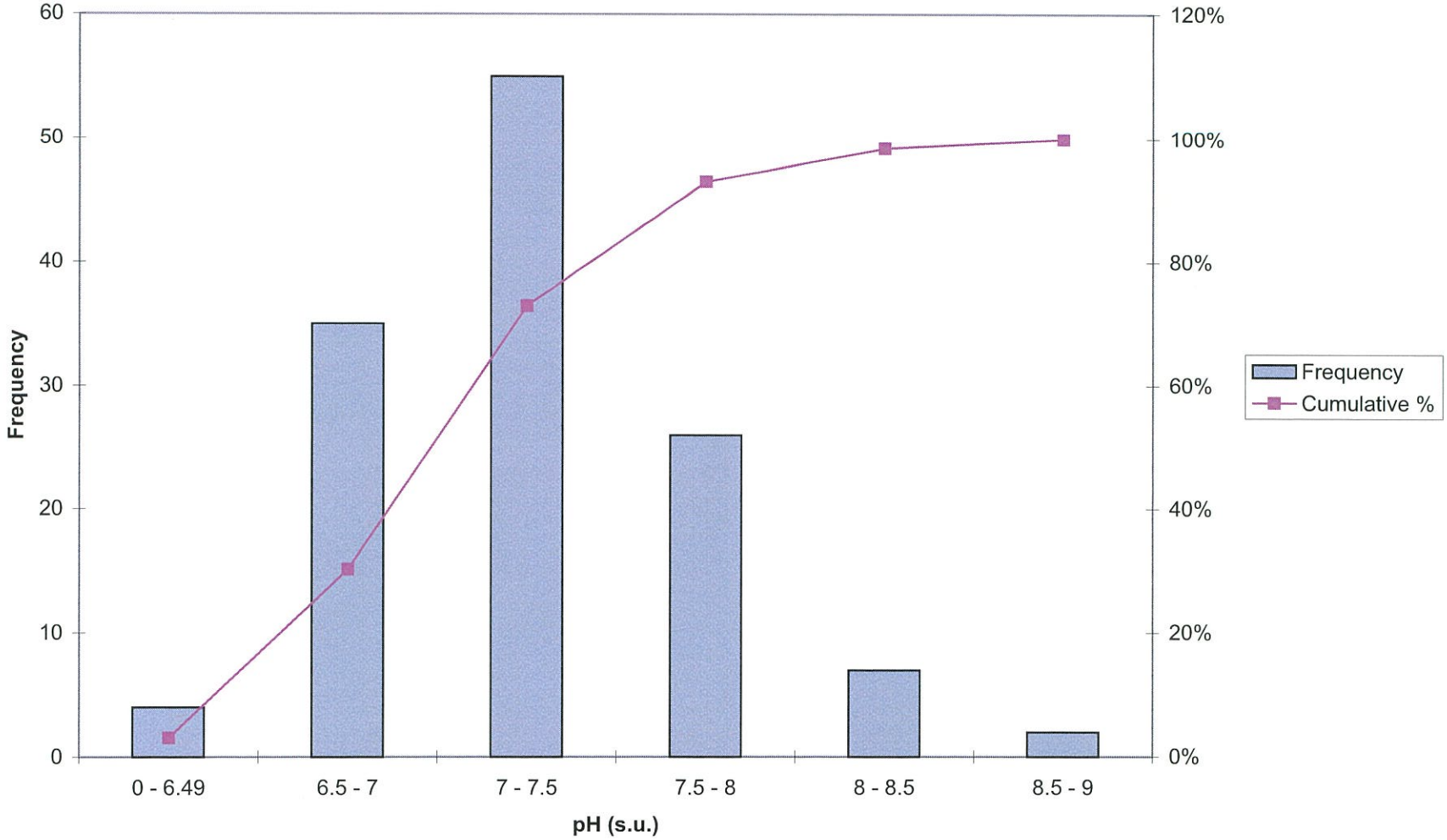


Figure 5-5: Sulfate Concentrations and Flows in Big Muddy River Segment N12



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Figure 5-6: pH Histogram for Segment N12 in the Big Muddy River



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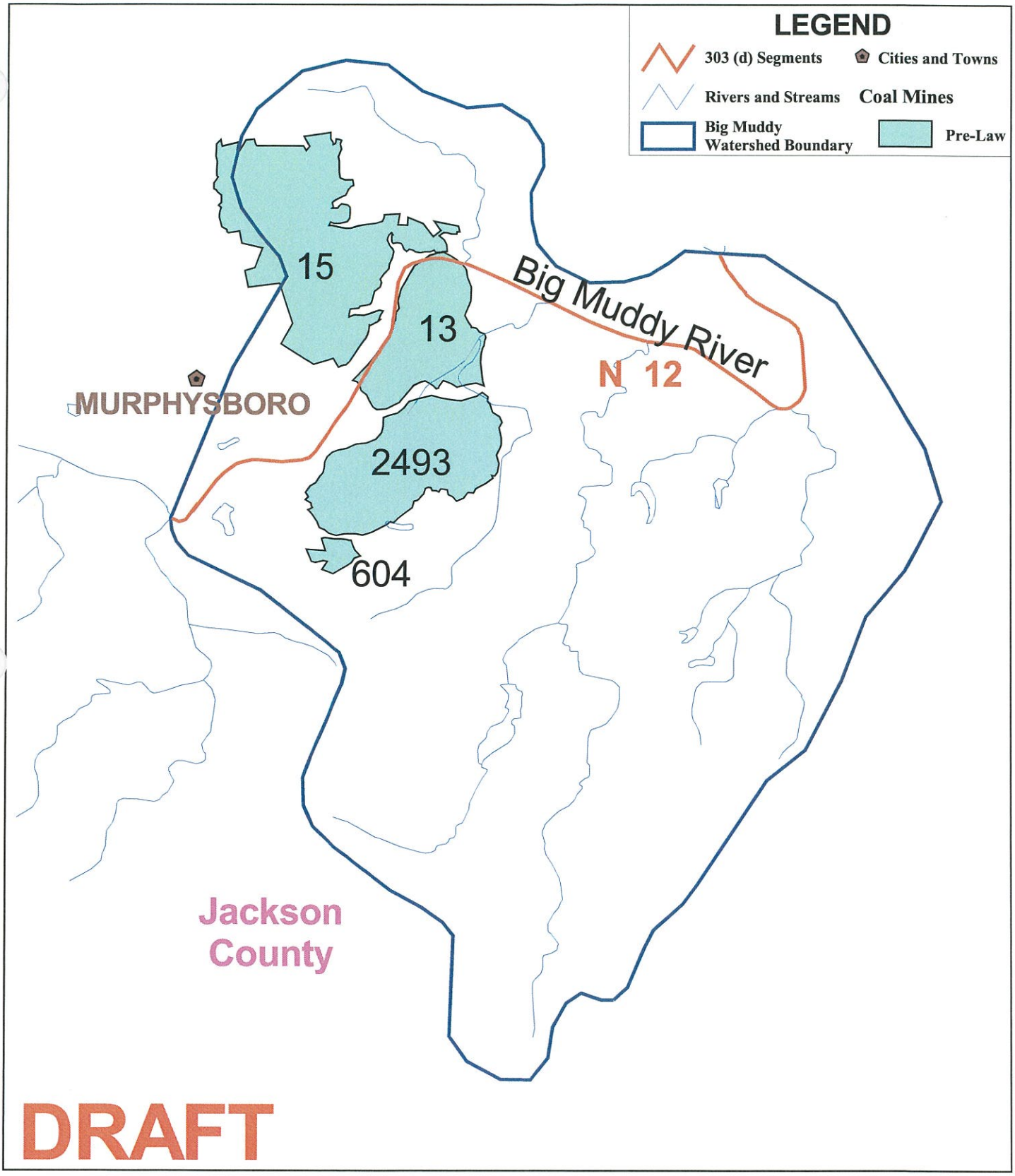


Figure 5-7
Coal Mines in the
Big Muddy River #1 Watershed
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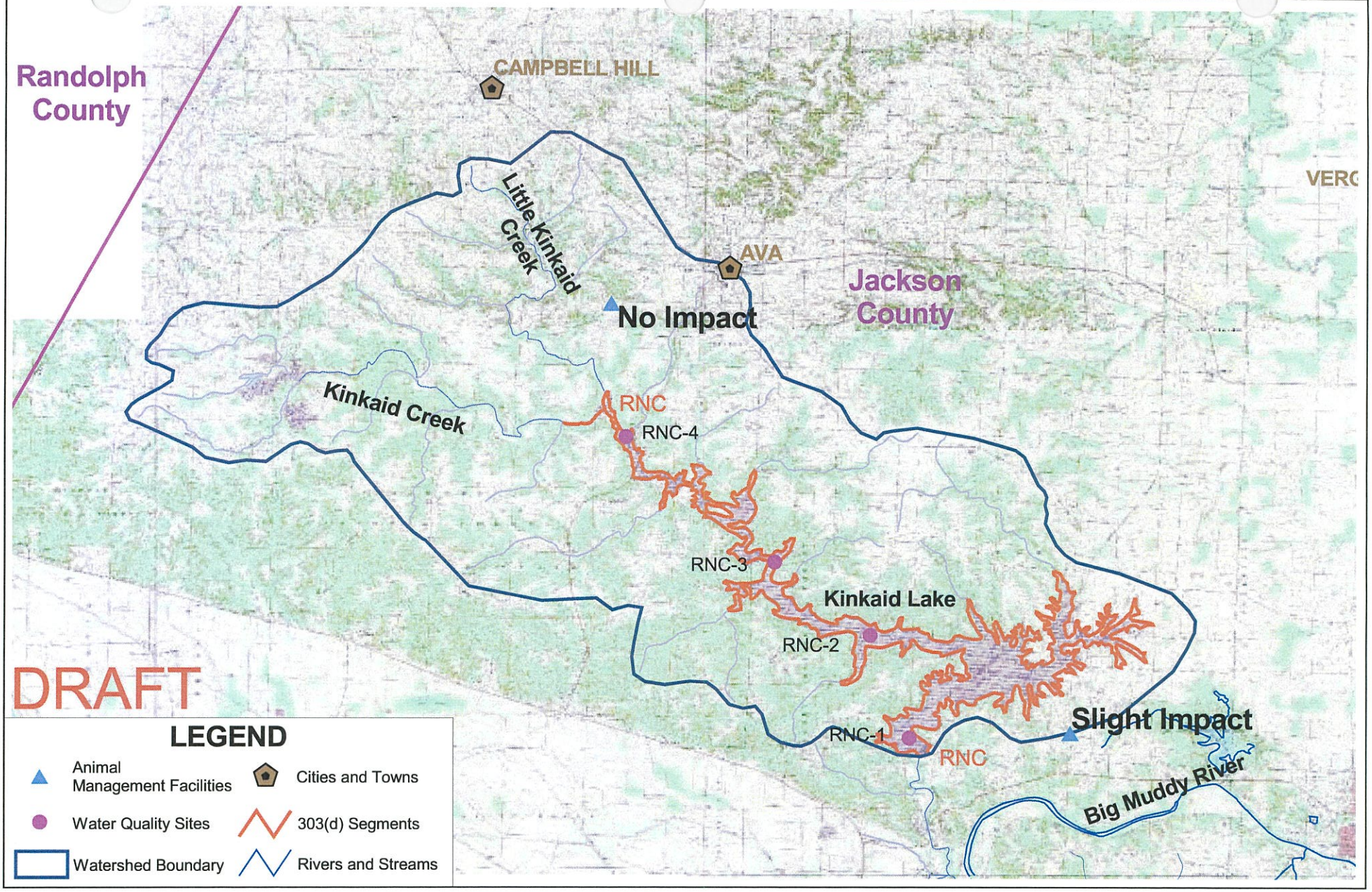


Figure 5-8
Animal Management Facilities in the
Kinkaid Lake Watershed

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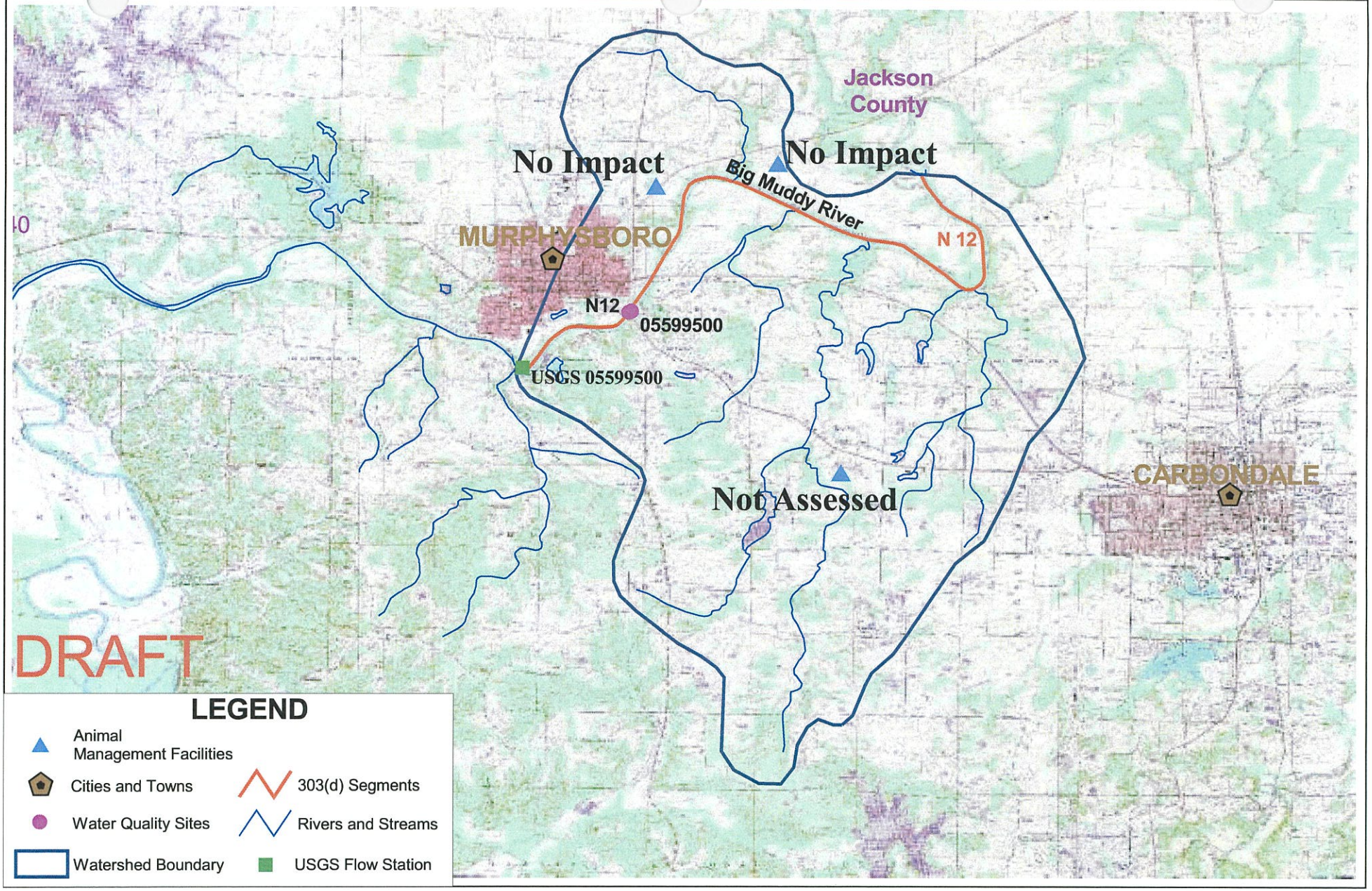


Figure 5-9
Animal Management Facilities in the
Big Muddy River #1 Watershed

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Section 6
Methodologies and Models to Complete TMDLs for the Big Muddy River

6.1 Set Endpoints for TMDLs

TMDLs are used to define the total amount of pollutants that may be discharged into a particular water body within any given day based on a particular use of that water body. Developing TMDLs must, therefore, account for both present and future stream users, habitat, flow variability, and current and future point and nonpoint pollutant loadings that may impact the water body. Defining a TMDL for any particular stream segment must take into account not only the science related to physical, chemical, and biological processes that may impact water body water quality, but must also be responsive to temporal changes in the watershed and likely influences of potential solutions to water quality impairments on entities that reside in the watershed.

Stream and lake water quality standards were presented in Section 4, specifically in Table 4-1. Biological data, such as the Index of Biotic Integrity (IBI) and the Macroinvertebrate Biotic Index (MBI), are used to support 305(b) and 303(d) listing decisions; however, TMDLs were not developed specifically to meet biological endpoints for the Big Muddy River Watershed. The endpoints presented in Section 4, which are chemical and physical endpoints of the following constituents, were targeted:

- stream segments: sulfates, pH, DO, manganese;
- lake segment: pH.

6.2 Methodologies and Models to Assess TMDL Endpoints

Methodologies and models were utilized to assess TMDL endpoints for the Big Muddy River Watershed. Model development is more data intensive than using simpler methodologies or mathematical relationships for the basis of TMDL development. In situations where only limited or qualitative data exist to characterize impairments, methodologies were used to develop TMDLs and implementation plans as appropriate.

In addition to methodologies, watershed and receiving water computer models are available for TMDL development. Most models have similar overall capabilities but operate at different time and spatial scales and were developed for varying conditions. The available models range between empirical and physically based. However, all existing watershed and receiving water computer models simplify processes and often include obviously empirical components that omit the general physical laws. They are, in reality, a representation of data.

Each model has its own set of limitations on its use, applicability, and predictive capabilities. For example, watershed models may be designed to project loads within annual, seasonal, monthly, or storm event time scales with spatial scales ranging from

large watersheds to small subbasins to individual parcels such as construction sites. With regard to time, receiving water models can be steady state, quasi dynamic, or fully dynamic. As the level of temporal and spatial detail increases, the data requirements and level of modeling effort increase.

6.2.1 Watershed Models

Watershed or loading models can be divided into categories based on complexity, operation, time step, and simulation technique. USEPA has grouped existing watershed-scale models for TMDL development into three categories based on the number of processes they incorporate and the level of detail they provide (USEPA 1997):

- simple models,
- mid-range models,
- detailed models.

Simple models primarily implement empirical relationships between physiographic characteristics of the watershed and pollutant runoff. A list of simple category models with an indication of the capabilities of each model is shown in Table 6-1. Simple models may be used to support an assessment of the relative significance of different nonpoint sources, guide decisions for management plans, and focus continuing monitoring efforts. Generally, simple models aggregate watershed physiographic data spatially at a large-scale and provide pollutant loading estimates on large time-scales. Although they can easily be adopted to estimate storm event loading, their accuracy decreases since they cannot capture the large fluctuations of pollutant concentrations observed over smaller time-scales.

Table 6-1 Evaluation of Watershed Model Capabilities - Simple Models (USEPA 1997)

Criteria		USEPA Screening[1]	Simple Method[1]	Regression Method[1]	SLOSS-PHOSPH[2]	Watershed	FHWA	WMM
Land Uses	Urban	○	◒	◒	–	◒	○[3]	●
	Rural	◒	–	○	◒	◒	○	●
	Point Sources	–	–	–	–	○	–	○
Time Scale	Annual	●	●	●	●	●	●	●
	Single Event	○	○	○	–	–	○	–
	Continuous	–	–	–	–	–	–	–
Hydrology	Runoff	–[4]	◒	–	–	–	○	○
	Baseflow	–	–	–	–	–	–	○
Pollutant Loading	Sediment	◒	◒	◒	◒	◒	–	–
	Nutrients	◒	◒	◒	◒	◒	◒	◒
	Others	○	◒	◒	–	◒	◒	◒
Pollutant Routing	Transport	–	–	–	–	–	–	–
	Transformation	–	–	–	–	–	–	○
Model Output	Statistics	–	–	–	–	◒	○	○
	Graphics	–	–	–	–	◒	–	○
	Format Options	–	–	–	–	◒	–	○
Input Data	Requirements	○	○	○	○	○	○	○
	Calibration	–	–	–	○	◒	–	◒
	Default Data	●	●	◒	◒	○	◒	◒
	User Interface	–	–	–	–	◒	○	◒
BMPs	Evaluation	○	○	–	○	◒	◒	◒
	Design Criteria	–	–	–	–	–	–	–
Documentation		●	●	●	●	●	●	◒

[1] Not a computer program
[2] Coupled with GIS
[3] Highway drainage basins
[4] Extended Versions recommended use of SCS-curve number method for runoff estimation

● High ◒ Medium ○ Low – Not Incorporated

Mid-range models attempt a compromise between the empiricism of the simple models and complexity of detailed mechanistic models. Mid-range models are designed to estimate the importance of pollutant contributions from multiple land uses and many individual source areas in a watershed. Therefore, they require less aggregation of the watershed physiographic characteristics than the simple models. Mid-range models may be used to define large areas for pollution migration programs on a watershed basis and make qualitative evaluations of BMP alternatives. A list of models within the mid-range category and their capabilities is shown in Table 6-2.

Table 6-2 Evaluation of Watershed Model Capabilities - Mid-Range Models (USEPA 1997)

Criteria		SITEMAP	GWLF	P8-UCM	Auto-QI	AGNPS	SLAMM
Land Uses	Urban	●	●	●	●	–	●
	Rural	●	●	–	–	●	–
	Point Sources	◒	◒	●	–	●	●
Time Scale	Annual	–	–	–	–	–	–
	Single Event	○	–	●	–	●	–
	Continuous	●	●	●	●	–	●
Hydrology	Runoff	●	●	●	●	●	●
	Baseflow	○	●	○	○	–	○
Pollutant Loading	Sediment	–	●	●	●	●	●
	Nutrients	●	●	●	●	●	●
	Others	–	–	●	●	–	●
Pollutant Routing	Transport	○	○	○	◒	●	◒
	Transformation	–	–	–	–	–	–
Model Output	Statistics	◒	○	–	–	–	○
	Graphics	◒	◒	●	–	●	○
	Format Options	●	●	●	○	●	●
Input Data	Requirements	◒	◒	◒	◒	◒	◒
	Calibration	○	○	○	◒	○	◒
	Default Data	●	●	◒	○	◒	◒
	User Interface	●	●	●	◒	◒	●
BMPs	Evaluation	○	○	●	◒	◒	◒
	Design Criteria	–	–	●	◒	◒	○
Documentation		●	●	●	◒	●	◒

● High ◒ Medium ○ Low – Not Incorporated

Detailed models use storm event or continuous simulation to predict flow and pollutant concentrations for a range of flow conditions. These models explicitly simulate the physical processes of infiltration, runoff, pollutant accumulation, instream effects, and groundwater/surface water interaction. These models are complex and were not designed with emphasis on their potential use by the typical state or local planner. Many of these models were developed for research into the fundamental land surface and instream processes that influence runoff and pollutant generation rather than to communicate information to decision-makers faced with planning watershed management (USEPA 1997). Although detailed or complex models provide a comparatively high degree of realism in form and function, complexity does not come without a price of data requirements for model construction, calibration, verification, and operation. If the necessary data are not available, and many inputs must be based upon professional judgment or taken from literature, the resulting uncertainty in predicted values undermine the potential benefits from greater realism. Based on the available data for the Big Muddy River Watershed, a detailed model could not be constructed, calibrated, and verified with certainty and the watershed model selection should focus on the simple or mid-range models.

6.2.1.1 Watershed Model Recommendation

The watershed model recommendation for Kinkaid Lake is the Generalized Watershed Loading Function (GWLF) model. No watershed models will be utilized for stream TMDLs as methodologies will be utilized for stream segments in the Big Muddy River Watershed. The GWLF model was chosen for the Kinkaid Lake TMDL based on the following criteria:

- ease of use and Illinois EPA familiarity
- compatible with pollutants of concern and existing data
- provide adequate level of detail for decision making

The GWLF manual estimates dissolved and total monthly phosphorus loads in streamflow from complex watersheds. Both surface runoff and groundwater sources are included, as well as nutrient loads from point sources and onsite wastewater disposal (septic) systems. In addition, the model provides monthly streamflow, soil erosion, and sediment yield values (Haith et al. 1996).

6.2.2 Receiving Water Quality Models

Receiving water quality models differ in many ways, but some important dimensions of discrimination include conceptual basis, input conditions, process characteristics, and output. Table 6-3 presents extremes of simplicity and complexity for each condition as a point of reference. Most receiving water quality models have some mix of simple and complex characteristics that reflect tradeoffs made in optimizing performance for a particular task.

Table 6-3 General Receiving Water Quality Model Characteristics

Model Characteristic	Simple Models	Complex Models
Conceptual Basis	Empirical	Mechanistic
Input Conditions	Steady State	Dynamic
Process	Conservative	Nonconservative
Output Conditions	Deterministic	Stochastic

The concept behind a receiving water quality model may reflect an effort to represent major processes individually and realistically in a formal mathematical manner (mechanistic), or it may simply be a "black-box" system (empirical) wherein the output is determined by a single equation, perhaps incorporating several input variables, but without attempting to portray constituent processes mechanistically.

In any natural system, important inputs, such as flow in the river, change over time. Most receiving water quality models assume that the change occurs sufficiently slowly so that the parameter (for example, flow) can be treated as a constant (steady state). A dynamic receiving water quality model, which can handle unsteady flow conditions, provides a more realistic representation of hydraulics, especially those conditions associated with short duration storm flows, than a steady-state model. However, the price of greater realism is an increase in model complexity that may be neither justified nor supportable.

The manner in which input data are processed varies greatly according to the purpose of the receiving water quality model. The simplest conditions involve conservative substances where the model need only calculate a new flow-weighted concentration when a new flow is added (conservation of mass). Such an approach is unsatisfactory for constituents such as DO or labile nutrients, such as nitrogen and phosphorus, which will change in concentration due to biological processes occurring in the stream.

Whereas the watershed nonpoint model's focus is the generation of flows and pollutant loads from the watershed, the receiving water models simulate the fate and transport of the pollutant in the water body. Table 6-4 presents the steady-state (constant flow and loads) models applicable for this watershed. The steady-state models are less complex than the dynamic models. Also, as discussed above, the dynamic models require significantly more data to develop and calibrate an accurate simulation of a water body.

Table 6-4 Descriptive List of Model Components - Steady-State Water Quality Models

Model	Water Body Type	Parameters Simulated	Process Simulated	
			Physical	Chemical/Biological
USEPA Screening Methods	River, lake/ reservoir, estuary, coastal	Water body nitrogen, phosphorus, chlorophyll "a," or chemical concentrations	Dilution, advection, dispersion	First order decay - empirical relationships between nutrient loading and eutrophication indices
EUTROMOD	Lake/reservoir	DO, nitrogen, phosphorus, chlorophyll "a"	Dilution	Empirical relationships between nutrient loading and eutrophication indices
BATHTUB	Lake/reservoir	DO, nitrogen, phosphorus, chlorophyll "a"	Dilution	Empirical relationships between nutrient loading and eutrophication indices
QUAL2E	Rivers (well mixed/shallow lakes or estuaries)	DO, CBOD, arbitrary, nonconservative substances, three conservative substances	Dilution, advection, dispersion	First order decay, DO-BOD cycle, nutrient-algal cycle
EXAMSII	Rivers	Conservative and nonconservative substances	Dilution, advection, dispersion	First order decay, process kinetics, daughter products, exposure assessment
SYMPTOX3	River/reservoir	Conservative and nonconservative substances	Dilution, advection, dispersion	First order decay, sediment exchange
STREAMDO	Rivers	DO, CBOD, and ammonium	Dilution	First order decay, BOD-DO cycle, limited algal component

6.2.2.1 Receiving Water Model Recommendation

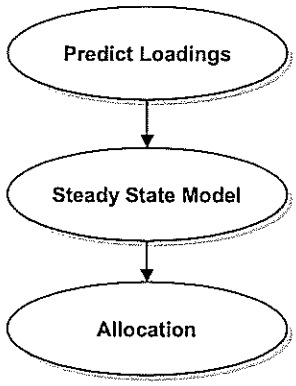
The receiving water model recommended for Kinkaid Lake is BATHTUB, which applies a series of empirical eutrophication models to reservoirs and lakes. The program performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network that accounts for advective and diffusive transport, and

nutrient sedimentation. Eutrophication-related water quality conditions are predicted using empirical relationships (USEPA 1997).

Because of the lack of spatial data sets for the stream segments within the Big Muddy River Watershed, methodologies based on the USEPA Screening Methods and Monte Carlo simulations will be utilized for stream TMDL development as discussed in the following section.

6.2.3 Kinkaid Lake TMDL

For Kinkaid Lake, a TMDL for pH will be completed using a watershed/receiving water model combination. The strategy for completing the watershed/receiving water model TMDL for Kinkaid Lake is shown in the schematic to the right. This strategy applies to constituents whose loads can be predicted using GWLF. This approach allows a linkage between source and endpoint resulting in an allocation to meet water quality standards. After loads are predicted, the BATHTUB model will be used to determine the resulting phosphorus concentrations within Kinkaid Lake. Model development is discussed further in Section 7.



Schematic 1
Strategy for Lake TMDL Modeling

6.2.4 Stream TMDLs for the Big Muddy River Watershed

Because of limited data available for watershed and receiving water model development for the Big Muddy River Watershed, TMDLs for the following constituents will be completed using methodologies: sulfates, pH, DO, and manganese. For DO, a Streeter-Phelps analysis based on the USEPA Screening Procedures was developed. This analysis is described in Section 8. For sulfates and manganese, a Monte Carlo simulation was conducted, and the description of this analysis is also contained in Section 8. For pH, an analysis based on recurrence interval and pH was created, and this discussion is also included in Section 8.

6.2.5 Calibration and Validation of Models

The results of loading and receiving water simulations are more meaningful when they are accompanied by some sort of confirmatory analysis. The capability of any model to accurately depict water quality conditions is directly related to the accuracy of input data and the level of expertise required to operate the model. It is also largely dependent on the amount of data available. Calibration involves minimization of deviation between measured field conditions and model output by adjusting parameters of the model. Data required for this step are a set of known input values along with corresponding field observation results. Validation involves the use of a second set of independent information to check the model calibration. The data used for validation should consist of field measurements of the same type as the data output from the model. Specific features such as mean values, variability, extreme values, or all predicted values may be of interest to the modeler and require testing. Models are

tested based on the levels of their predictions, whether descriptive or predictive. More accuracy is required of a model designed for absolute versus relative predictions. If the model is calibrated properly, the model predictions will be acceptably close to the field predictions.

The GWLF and BATHTUB models were calibrated based on existing data. As will be outlined in Section 7, the GWLF model was calibrated based on historical flow records. The calibration factors taken into account for the GWLF model were the recession constant and seepage constant. Water quality data on the tributaries to Kinkaid Lake were not available so the GWLF model could not be calibrated to tributary nutrient loads. Nutrient loads were based on literature values for Southern Illinois. GWLF model validation was not conducted, as the hydrology was calibrated based on 16 years of observed flow. Data collection activities needed to calibrate nutrient loads are outlined in Section 9 Implementation Plan. The calibration process for the BATHTUB model is also outlined in Section 7. For Kinkaid Lake, loads from a below normal, above normal, and dry precipitation year were taken from GWLF and entered into the BATHTUB model, which predicted average in-lake concentrations that were in turn compared to observed lake concentrations as the basis for calibration.

6.2.6 Seasonal Variation

Consideration of seasonal variation, such that water quality standards for the allocated pollutant will be met during all seasons of the year, is a requirement of a TMDL submittal. TMDLs must maintain or attain water quality standards throughout the year and consider variations in the water body's assimilative capacity caused by seasonal changes in temperature and flow (USEPA 1999). Seasonal variation for the Kinkaid Lake Watershed is discussed in Section 8 and for the Big Muddy River Watershed discussed in Section 11.

6.2.7 Allocation

Establishing a TMDL requires the determination of the LC of each stream segment. The models or methodologies were used to establish what the LC is for each segment for each pollutant. The next step was to determine the appropriate MOS for each segment. After setting the MOS, WLA of point sources and LA from the nonpoint sources were set.

The MOS can be set explicitly as a portion of the LC or implicitly through applying conservative assumptions in data analysis and modeling approaches. Data analyses and modeling limitations were taken into account when recommending a MOS. The allocation scheme (both LA and WLA) demonstrates that water quality standards will be attained and maintained and that the load reductions are technically achievable. The allocation is the foundation for the implementation and monitoring plan. Further discussion on the allocation is presented in Section 9.

6.2.8 Implementation and Monitoring

For the Big Muddy River Watershed, a plan of implementation was produced to support the developed TMDL. The plan of implementation has reasonable assurance of being achieved. The plan provides the framework for the identification of the actions that must be taken on point and nonpoint sources to achieve the desired TMDLs. The accomplishment of the necessary actions to reach these targets may involve substantial efforts and expenditures by a large number of parties within the watershed. Depending upon the specific issues and their complexity in the Big Muddy River Watershed, the time frame for achieving water quality standards has been developed.

The implementation plan delineates a recommended list of the sources of stressors that are contributing to the water quality impairments. The amount of the reduction needed from various sources to achieve the water quality limiting parameter was then delineated. For nonpoint sources, the use of BMPs is one way to proceed to get the desired reduction in loading. The effectiveness of various BMPs was factored into the modeling and methodologies to develop the range of options of BMPs to use. Associated with those BMPs is cost information, as available. Reductions from point services through waste stream management, pretreatment controls, and other structural and nonstructural programs were also identified as applicable. The implementation plan for the Big Muddy River Watershed is presented in Section 12.

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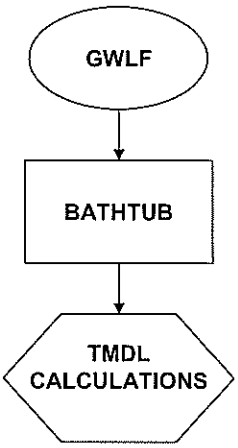
Section 7
Model Development for Kinkaid Lake

7.1 Basis for pH TMDL

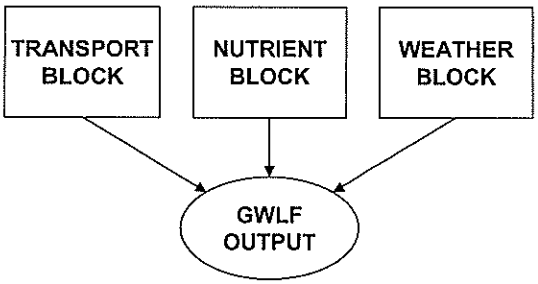
The relationships between pH, chlorophyll "a," and phosphorus were discussed in Section 5.1.5.1.1. Figures 7-1 and 7-2 show the relationship between chlorophyll "a" and pH at Kinkaid Lake stations RNC-1 and RNC-3, respectively. The relationships are only provided at these two locations because samples at stations RNC-2 and RNC-4 did not show exceedences of the pH standard. As explained in Section 5.1.5.1.1, the figures are expected to show an increase with pH as chlorophyll "a" increases. Increased chlorophyll "a" concentrations may also lead to low pH values as the CO_2 decreases during respiration. The relationship between chlorophyll "a" and phosphorus at stations RNC-1 and RNC-3 are shown in Figures 7-3 and 7-4, respectively. Likewise, these figures are expected to show a direct relationship between the constituents. The relationships presented in Figures 7-1 through 7-4 provide general trends between model constituents and represent the data available from sampling. The general relationships shown in Figures 7-1 through 7-4 suggest that controlling total phosphorus will decrease chlorophyll "a" concentrations, which will in turn bring pH into the range required for compliance with water quality standards. The TMDL will be based on the existing relationships with the knowledge that a larger data set would result in a more robust TMDL. It is therefore recommended that a TMDL endpoint of 0.05 mg/L for total phosphorus for Kinkaid Lake be utilized so that the pH standard is achieved.

7.2 Model Overview

The models used for the TMDL analysis of Kinkaid Lake were GWLF and BATHTUB. These models require input from several sources including online databases, GIS-compatible data, and hardcopy data from various agencies. This section describes the existing data reviewed for model development, model inputs, and model calibration and verification.



Schematic 1 Models used for Kinkaid Lake TMDL calculation.

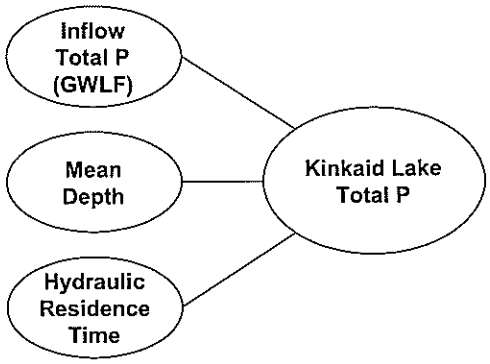


Schematic 2 GWLF Model.

Schematic 1 shows how the GWLF model and BATHTUB model are utilized in calculating the TMDL. The GWLF model predicts phosphorus loads from the watershed. These loads are then inputted in the BATHTUB model to assess resulting phosphorus concentrations. The GWLF model outlined in Schematic 2 shows how GWLF predicts phosphorus loads from the watershed. The transport

block of the GWLF model uses the Universal Soil Loss Equation to determine erosion in the watershed. The transport block also calculates runoff based on the SCS Curve Number equation. The nutrient block allows the model user to input concentrations of phosphorus contained in the soil and in the dissolved phase for runoff. These two blocks, in conjunction with the weather block, predict both solid and dissolved phosphorus loads.

Schematic 3 shows how, by using total phosphorus concentrations predicted from GWLF, the resulting in-lake total phosphorus concentrations can be predicted. The BATHTUB model uses empirical relationships between mean reservoir depth, total phosphorus inputted into the lake, and the hydraulic residence time to determine in-reservoir concentrations.



Schematic 3
BATHTUB Model Schematic.

7.3 Model Development and Inputs

The ability of the GWLF and BATHTUB models to accurately reflect natural processes depends on the quality of the input data. The following sections describe the selection, organization, and use of existing data as input to the GWLF and BATHTUB models and outline assumptions made in the process.

Due to the size of the Kinkaid Lake Watershed and the multiple tributaries contributing to the lake, the watershed area was divided into four subwatersheds for accurate representation in the GWLF model. Flows within each of the subbasins were calculated from gage 05595820 with the drainage area ratio method presented in Section 5.1.3. To model Kinkaid Lake accurately in BATHTUB, the lake was divided in four sections surrounding each of the three monitoring stations.

7.3.1 Watershed Delineation

Prior to developing input parameters for the GWLF or BATHTUB models, a watershed for Kinkaid Lake was delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation indicates that Kinkaid Lake captures flows from a watershed of approximately 60.3 square miles, which is consistent with the drainage area of 60.5 square miles reported in the watershed plan (KAWP 2000). The flow through the lake is primarily from northeast to southwest. Figure 7-5 at the end of this section shows the location of each water quality station in Kinkaid Lake, the boundary of the GIS-delineated watershed contributing to Kinkaid Lake, the four subbasins used in GWLF modeling, and the division of the lake for BATHTUB modeling purposes.

7.3.2 GWLF Inputs

GWLF requires input in the form of three data files that represent watershed parameters, nutrient contributions, and weather records. Each data file will be discussed in the following sections. The input files and actual values used for each parameter are listed in Appendix C. The GWLF manual is contained in Appendix D.

DEMs of 30-meter resolution were downloaded from the USGS National Elevation Dataset for development of GWLF model parameters discussed in this section (USGS 2002b).

7.3.2.1 Transport Data File

The transport data file provides watershed parameters including land use characteristics, evapotranspiration and erosion coefficients, groundwater and streamflow characteristics, and initial soil conditions. Table 7-1 presents each transport file input parameter and its source. Those requiring further explanation are discussed in the next section.

Table 7-1 Data Needs for GWLF Transport File (Haith et al. 1996)

Input Parameter	Source
Land Use	Critical Trends Assessment Database, GIS
Land Use Area	GIS
Curve Number	*STATSGO*, GIS, Critical Trends Assessment Database, TR-55 Manual, WMM Manual
KLSCP	*STATSGO*, GIS, DEM, GWLF Manual pages 34 and 35, NRCS
Evapotranspiration Cover Coefficient	GWLF Manual page 29
Daylight Hours	GWLF Manual page 30
Growing Season	GWLF Manual Recommendation page 54
Erosivity Coefficient	GWLF Manual pages 32 and 37
Sediment Delivery Ratio	GIS, GWLF Manual page 33
5-day Antecedent Rain and Snow	GWLF Manual Recommendation page 37
Initial Unsaturated Storage	GWLF Manual Recommendation page 30
Initial Saturated Storage	GWLF Manual Recommendation page 37
Recession Constant	Calibrated
Seepage Constant	Calibrated
Initial Snow	GWLF Manual Recommendation page 37
Unsaturated Available Water Capacity	GWLF Manual Recommendation page 37

7.3.2.1.1 Land Use

Land use for the Kinkaid Lake Watershed was extracted from the Critical Trends Assessment Database grid for Jackson County in GIS. Within the transport input file, each land use must be identified as urban or rural. The land uses were presented in Table 5-12.

Individually identifying each field of crops or urban community in GWLF would be time intensive, so each land use class was aggregated into one record for GIS and GWLF representation. For example, the area of each row crop field was summed to provide a single area for row crops. Additionally, the parameters for each row crop field were averaged to provide a single parameter for the row crop land use. Details of the parameter calculation are contained in the remainder of this section.

GWLF computes runoff, erosion, and pollutant loads from each land use, but it does not route flow over the watershed. For example, the model does not recognize that runoff may flow from a field of corn over grassland and then into the river. The model assumes all runoff from the field of corn drains directly to the stream. Therefore, the location of each land use is irrelevant to the model allowing each land use class to be aggregated into a single record.

To provide accurate modeling in GWLF, the rural grassland land use class, presented in Table 5-12, was separated into two subclasses of pasture and grassland based on the recommendation of the Jackson County NRCS (2002a). The GWLF model requires nutrient runoff concentrations for each land use, and the two subclasses of rural grassland have varying concentrations. The area of each subclass was estimated from the GIS-derived rural grassland area and suggested percentages of each subclass by the Jackson County NRCS (2002a).

Due to the detailing of crops, the Cropland Data Layer land use classes, presented in Table 5-14, were used to generate evapotranspiration cover coefficients, cropping management factors, and to verify the land use obtained from the Critical Trends Assessment. Land uses used in GWLF correspond to land uses in the Critical Trends Assessment, so calculations based on the Cropland Data Layer land use classes were typically weighted by area to match the Critical Trends Assessment classes. Details of the calculations are presented in later sections and Appendix E.

7.3.2.1.2 Land Use Area

GIS was used to summarize the area of each aggregated land use in square meters as well as acres and hectares. Area in hectares was input for each land use in the transport data file.

7.3.2.1.3 Curve Number

The curve number, a value between zero and 100, represents the ability of the land surface to infiltrate water, which decreases with increasing curve number. The curve number is assigned with consideration to hydrologic soil group and land use. The hydrologic soil group, represented by the letters A through D, denotes how well a soil drains. A well-drained, sandy soil would be classified as a type A soil, whereas clay would be classified as a type D soil. This property is identified in the *STATSGO* attribute table for each soil type.

Assigning curve numbers to a large area with multiple soil types and land uses was streamlined using the GIS *ArcView* project, CRWR-PrePro (Olivera 1998), developed at the University of Texas at Austin. This process was used to develop a curve number grid. Scripts in the project intersect shapefiles of land use and soil with the *STATSGO* attribute table to create a grid in which each cell contains a curve number based on the combination.

The transport data file requires that a single curve number be associated with each land use. To accomplish this, the curve number in each grid cell was averaged over each aggregated land use area. Details of the GIS process are provided in Appendix E.

7.3.2.1.4 KLSCP

GWLF uses the Universal Soil Loss Equation, represented by the following equation (Novotny and Olem 1994), to calculate soil erosion.

$$A = (R)(K)(LS)(C)(P)$$

where A = calculated soil loss in tons/ha for a given storm or period
R = rainfall energy factor
K = soil erodibility factor
LS = slope-length factor
C = cropping management factor
P = supporting practice factor

The combined coefficient, KLSCP, is required as input to GWLF for each rural land use. The development of each factor will be discussed in the next sections. GWLF calculates the rainfall energy factor (R) with precipitation and a rainfall erosivity coefficient that will be discussed in Section 7.3.2.1.5.

Soil Erodibility Factor (K). The soil erodibility factor, K, represents potential soil erodibility. The *STATSGO* soils representation in GIS is by map unit, which incorporates multiple soil types (and K-values) in each unit, but the *STATSGO* attribute table lists the K factor for each soil type. Using this column, a weighted K factor was developed for each GIS map unit. Details of this process are provided in Appendix E.

Topographic Factor (LS). The topographic, or LS, factor represents the contribution to erosion from varying topography. This factor is independent of soil type, but dependent on land use and land surface elevations, requiring use of the DEM. Multiple equations and methodologies are used to calculate the LS factor and for this application we used methodology outlined in the *TMDL USLE* software package (USEPA 2001). The LS factor was calculated with a series of equations that compute intermediate values of slope steepness, runoff length, and rill to interill erosion before combining them into the LS factor. This process was also performed with GIS analyses to automate computational tasks. Details of the GIS computation are provided in Appendix E.

Cropping Management Factor (C). The cropping management factor, C, represents the influence of ground cover, soil condition, and management practices on erosion. The Jackson County NRCS office provided a table of C factors for various crops and tillage practices (NRCS 2002a). The table is included as Appendix F. The NRCS office also estimated the percentage of each tillage practice for corn, soybeans, and small grains in the Kinkaid Lake Watershed (NRCS 2002a). Although the percentage of each tillage practice is known, the specific locations in the watershed to which these practices are applied were unknown, so a weighted C-factor was created for these

7.3.2.2 Nutrient Data File

The nutrient input file contains information about dissolved phosphorus and nitrogen from each rural land use, solid-phase phosphorus and nitrogen from urban runoff, solid-phase nutrient concentrations in the soil and groundwater, and any point source inputs of phosphorus or nitrogen.

All solid-phase nutrient concentrations from runoff for Kinkaid Lake were obtained from the GWLF manual. Figure B-4 (page 39 of Appendix D) was utilized for determining solid-phase phosphorus concentrations in the soil. A mid-range value of 0.07 percent phosphate was selected and then converted to 700 parts per million (ppm) using the relationship 0.1 percent = 1,000 ppm. Phosphate is composed of 44 percent phosphorus, so the 700 ppm phosphate was multiplied by 0.44 to obtain a value of 308 ppm phosphorus in the sediment. This solid-phase phosphorus concentration was multiplied by the recommended enrichment ratio of 2.0 and therefore a total solid-phase concentration of 616 ppm was utilized for modeling purposes. The enrichment ratio represents the ratio of phosphorus in the eroded soil to that in the non-eroded soil. Specific soil phosphorus data is not available, so the GWLF manual recommended enrichment ratio of 2.0 was used. Dissolved phosphorus concentrations in the runoff from each agricultural land use were obtained from page 41 of the GWLF manual with the exception of grassland under the rural grassland land use and concentrations from animal management facilities. The grassland dissolved phosphorus concentration was estimated from the dissolved phosphorus concentration for pasture. Grassland is assured to have less animals, and therefore less animal waste, than pasture land, so the concentration was reduced for hayland. The selection of dissolved phosphorus concentrations will be confirmed in Section 7.4.1. The runoff phosphorus concentration from the feedlots and animal management areas were obtained from Novotny and Olem with a range of 4 to 15 mg/L (1994). The concentrations used to model the animal management areas were dependent on the impact each facility had on the receiving waters as recorded in the GIS file discussed in Section 5.1.7. One feedlot was identified in the Kinkaid Lake Watershed as potentially having a slight impact on water quality and one facility was identified as potentially having no impact on water quality in the receiving stream. The animal management facilities in the Kinkaid Lake Watershed were assigned dissolved phosphorus concentrations of 4 and 5.5 mg/L for the no impact and slight impact facilities, respectively, because these are at the lower end of the literature range.

Table 7-5 Dissolved Phosphorus Concentrations in Runoff from the Kinkaid Lake Watershed

Land Use	Dissolved Phosphorus (mg/L)
Row Crop	0.26
Small Grains	0.30
Rural Grasslands	
Pasture	0.25
Grassland	0.15
Deciduous Forest	0.009
Coniferous Forest	0.009
Animal Management Facility	4.5 - 15
Barren Land	0.008
Urban-High Density	0.01

Table 7-5 lists the land uses in the Kinkaid Lake Watershed and associated runoff phosphorus concentrations used in the GWLF model. It should be noted that although the majority of dissolved phosphorus concentrations in Table 7-5 exceed the endpoint of 0.05 mg/L of total phosphorus, once the surface runoff reaches Kinkaid Lake or its tributaries, it mixes with water already in the stream or lake and the

concentration decreases. Therefore, it cannot be concluded without analysis that constituents with dissolved concentrations above the endpoint for total phosphorus are responsible for water quality impairments.

The GWLF manual suggests nutrient concentrations in groundwater based on the percentage of agricultural versus forestlands. These percentages were calculated from the land use areas in the watershed, and the appropriate groundwater concentrations were selected from the GWLF manual, page 41. The percentage of agricultural lands in each subbasin and their corresponding groundwater dissolved phosphorus concentrations are provided in Table 7-6.

Table 7-6 Percentage of Agricultural and Forest Lands and Groundwater Phosphorus Concentrations in the Kinkaid Lake Watershed (Haith et al. 1996)

Subbasin	Agriculture	Forest	Dissolved Phosphorus (mg/L)
1	42%	55%	0.015
2	20%	72%	0.012
3	7%	77%	0.012
4	34%	45%	0.015

7.3.2.3 Weather Data File

The weather data file is a text file of daily precipitation and temperature and was compiled from weather data presented in Section 5.1.4. An excerpt of the weather data file is recorded in Appendix C. The precipitation data are used in GWLF to determine runoff, erosion, and evapotranspiration, and temperature data are used to compute potential evaporation and snowmelt.

7.3.3 BATHTUB Inputs

BATHTUB has three primary input interfaces: global, reservoir segment(s), and watershed inputs. The individual inputs for each of these interfaces are described in the following sections and the data input screens are provided in Appendix C.

Multiple simulations of the BATHTUB model were run to investigate variations in total phosphorus concentrations in a wet, normal, and dry year of precipitation to bracket conditions for calibration. The first step in choosing the wet, normal, and dry years was to calculate average annual precipitation. BATHTUB models lake concentrations based on a water year (October to September), so the precipitation data presented in Section 5.1.4 were averaged to coincide with the water year. Table 7-7 shows these annual and average annual precipitation values in Jackson County. Each water year was then

Table 7-7 Annual Precipitation in Jackson County

Model Year	Precipitation (inches)
1986	52
1987	35
1988	43
1989	47
1990	48
1991	41
1992	43
1993	54
1994	44
1995	46
1996	57
1997	49
1998	45
1999	40
2000	51
Average	**46**

classified as wet, dry, or normal based on a comparison to the average water year precipitation of 46 inches. Another consideration in selecting the years for simulation was determining which years coincided with the collection dates of in-lake total phosphorus concentrations at the water quality stations within recent years. With these criteria, the only years available for modeling Kinkaid Lake are 1994, 1997, and 2000. Based on Table 7-7, 1994 is designated as the normal year and 1997 and 2000 are both designated as wet years.

7.3.3.1 Global Inputs

Global inputs represent atmospheric contributions of precipitation, evaporation, and atmospheric phosphorus. Precipitation was discussed in the previous section and is shown in Table 7-7 for the model years 1994, 1997, and 2000. An average annual evaporation was determined from pan evaporation data as discussed in Section 5.1.4. The default atmospheric phosphorus deposition rate suggested in the BATHTUB model was used in absence of site-specific data, which is a value of 30 kilograms per kilometer squared per year (kg/km^2-yr) (USACE 1999b).

7.3.3.2 Reservoir Segment Inputs

The data included as segment inputs represents reservoir characteristics in BATHTUB. These data were used in BATHTUB simulations and for calibration targets. The calibration targets are observed water quality data summarized in Section 5.1.5.1.

Kinkaid Lake was modeled as four segments in BATHTUB to represent the lake characteristics around each water quality station, so an average annual value of total phosphorus was calculated for each site for input of observed data. The lake segments are shown in Figure 7-5 at the end of this section. The averages of total phosphorus sampled at one-foot depth were presented in Table 5-6; however, the BATHTUB model calculates an average lake concentration. Therefore, total phosphorus samples at all depths were averaged to provide targets for the BATHTUB model. Table 7-8 shows the average annual total phosphorus concentrations for all sample depths at each station in Kinkaid Lake for the years modeled. As mentioned in Section 5.1.5.1.2, station RNC-1 had samples taken at one-foot depth from the surface and at the lake bottom, whereas stations RNC-2, RNC-3, and RNC-4 were only sampled at one-foot depth. The raw data for all sample depths are contained in Appendix A.

Table 7-8 Average Total Phosphorus Concentrations in Kinkaid Lake (mg/L) over All Depths

Year	RNC-1	RNC-2	RNC-3	RNC-4	Lake Average
1994	0.03	0.02	0.04	0.14	0.05
1997	0.04	0.03	0.04	0.13	0.06
2000	0.03	0.01	0.02	0.05	0.03

Other segment inputs include lake depth, lake length, and depth to the metalimnion. The lake depth was represented by the averaged data from the water quality stations shown in Table 5-16. The lake length was determined in GIS, and the depth to the metalimnion was estimated from a chart of temperature versus depth. The charts are presented in Appendix G.

7.3.3.3 Tributary Inputs

Tributary inputs to BATHTUB are drainage area, flow, and total phosphorus (dissolved and solid-phase) loading. The drainage area of each tributary is equivalent to the basin or subbasin it represents, which was determined with GIS analyses. For the Kinkaid Lake Watershed, the four subbasins modeled in GWLF represent tributary inputs. Loadings were calculated with the monthly flow and total phosphorus concentrations obtained from GWLF output. The monthly values were summed over the water year for input to BATHTUB. To obtain flow in units of volume per time, the depth of flow was multiplied by the drainage area and divided by one year. To obtain phosphorus concentrations, the nutrient mass was divided by the volume of flow.

7.4 Model Calibration and Verification

The GWLF model was calibrated prior to BATHTUB calibration. The GWLF model for the Kinkaid Lake Watershed was calibrated to flow data, as tributary phosphorus concentrations were not available. Nutrient concentrations entered into the GWLF model were calibrated based on response occurring in the BATHTUB model. Therefore, the nutrient block of the GWLF model and the BATHTUB model were calibrated together to reach agreement with observed data in Kinkaid Lake.

7.4.1 GWLF Calibration

The GWLF model must run from April to March to coincide with the soil erosion cycle. GWLF does not retain erodible sediment between model years, so the model year must begin after the previous year's sediment has been washed off. The model assumes that the soil erosion cycle begins with spring runoff events in April and that erodible soil for the year has been washed off by the end of winter for the cycle to begin again the following April. GWLF generates monthly outputs including precipitation, flow, runoff and nutrient mass per watershed, and annual outputs including precipitation, flow, runoff, and nutrient mass per land use. These outputs are part of the input for the BATHTUB model.

Instream nutrient data was not available for model calibration, so GWLF was only calibrated to flow. The monthly average flow output from GWLF was compared to the monthly average streamflow calculated from USGS gage 05595820 with the drainage area ratio method presented in Section 5.1.3. The model flow was calibrated visually through the recession constant and seepage constant. Visual calibration is a subjective approach to model calibration in which the modeler varies inputs to determine the parameter combination that looks like the best fit to the observed data (Chapra 1997). According to the GWLF manual, an acceptable range for the recession constant is 0.01 to 0.2. No range suggestions are provided for the seepage constant. Figure 7-6 (at the end of this section) shows the comparison between the two flows for subbasin 1 of Kinkaid Lake. The GWLF model for Kinkaid Lake was visually calibrated with a resulting recession constant of 0.15 and a seepage constant of 0.15 in each subbasin. Once calibrated, the model output data could properly be included as BATHTUB inputs. The GWLF model was not validated as flow was calibrated by visually

comparing 16 years of observed flow. The summary output from GWLF for each subbasin is included in Appendix C.

Although instream nutrient concentrations are not available for the tributaries to Kinkaid Lake, Clean Lakes Studies have been conducted by the Illinois EPA on various Illinois lake watersheds, which do provide instream nutrient data for lake tributaries including dissolved and total phosphorus. A Clean Lake Study was conducted on Kinkaid Lake during the summer of 2003. The dissolved and total phosphorus concentrations predicted by GWLF for tributaries to the Kinkaid Lake subbasins were compared to the measured dissolved and total phosphorus concentrations from tributaries to lakes observed in the Clean Lakes studies as shown in Figure 7-7.

Table 7-9 shows the comparison between dissolved and total phosphorus in watersheds from Clean Lakes Studies and in the Kinkaid Lake Watershed. The dissolved phosphorus concentration in Subbasin 3 in the Kinkaid Lake Watershed was too low to be calculated by GWLF, so it is assumed to be negligible and presented as zero concentration.

Table 7-9 Percentage of Dissolved Phosphorus to Total Phosphorus Concentrations in Clean Lake Study Watersheds and the Kinkaid Lake Watershed

Watershed	Site	Mean Dissolved Phosphorus (mg/L)	Mean Total Phosphorus (mg/L)	Dissolved / Total Phosphorus
Nashville City	ROO 02	0.68	0.89	0.76
Paradise	RCG 02	0.06	0.07	0.87
Raccoon	RA 02	0.30	0.46	0.66
	RA 03	0.21	0.29	0.71
	RA 04	0.46	0.63	0.73
	RA 05	0.07	0.22	0.30
Lake Lou Yeager	A	0.06	0.13	0.46
	B	0.15	0.16	0.92
	C	0.05	0.25	0.20
	D	0.13	0.17	0.78
	E	0.06	0.12	0.46
	F	0.17	0.20	0.87
	G	0.33	0.41	0.79
	H	0.33	0.35	0.93
	I	0.13	0.14	0.96
Kinkaid	1	0.06	0.18	0.31
	2	0.01	0.10	0.12
	3	0.0	0.07	–
	4	0.03	0.10	0.26

The ratio of dissolved to total phosphorus in the Kinkaid Lake subbasins is within the range of ratios represented by the Clean Lakes Studies, except for Subbasin 2, which is below the low end of the range.

7.4.2 BATHTUB Comparison with Observed Data

The BATHTUB model's response to changes in the GWLF nutrient block were compared to known in-lake concentrations of total phosphorus and chlorophyll "a" for each year of simulation. These known concentrations were presented in Tables 5-6 and 5-7. The BATHTUB manual defines the limits of total phosphorus calibration factors as 0.5 and 2.0.The calibration factor accounts for sedimentation rates, and the limits were determined by error analysis calculations performed on test data sets (USACE 1999). The calibration limits for chlorophyll "a" are not defined in the BATHTUB manual.

The GWLF model was set at a total phosphorus soil concentration of 660 ppm based on comparison with observed data in the BATHTUB model. As part of the comparison process, the watershed was also modeled with a total phosphorus soil concentration of 440 ppm to perform a sensitivity analysis on soil phosphorus. Decreasing the total soil phosphorus concentration shows little impact on the estimated in-lake concentrations (Table 7-10). The calibration factor range for total phosphorus modeling in BATHTUB is 0.5 to 2 and use of the 616-ppm total phosphorus in the soil falls within this accepted range. Table 7-10 also shows what calibration factors for chlorophyll "a" would be required so that estimated concentrations would match observed concentrations. The columns labeled *target* in Table 7-10 represent the average observed in-lake concentrations. The results of the modeling sensitivity analyses are contained in Appendix H.

Table 7-10 Kinkaid Lake Calibration Sensitivity Analysis

Year	In-Lake Target Total Phosphorus (mg/L)	In-Lake Estimated Total Phosphorus (mg/L)	% of Total Loads from Internal Loading Required to Meet Target	Phosphorus Calibration Factor	In-Lake Target Chlorophyll "a" (µg/L)	In-Lake Estimated Chlorophyll "a" (µg/L)	Chlorophyll "a" Calibration Factor
Soil Total Phosphorus 440 ppm							
1994	0.04	0.04	0	1.0	23.6	14.6	1.6
1997	0.05	0.04	0	1.4	19.9	9.9	2.0
2000	0.03	0.04	0	0.6	18.9	12.4	1.5
Soil Total Phosphorus 616 ppm							
1994	0.04	0.03	0	1.2	23.6	13.1	1.8
1997	0.05	0.03	0	1.6	19.9	9	2.2
2000	0.03	0.04	0	0.7	18.9	11.2	1.7

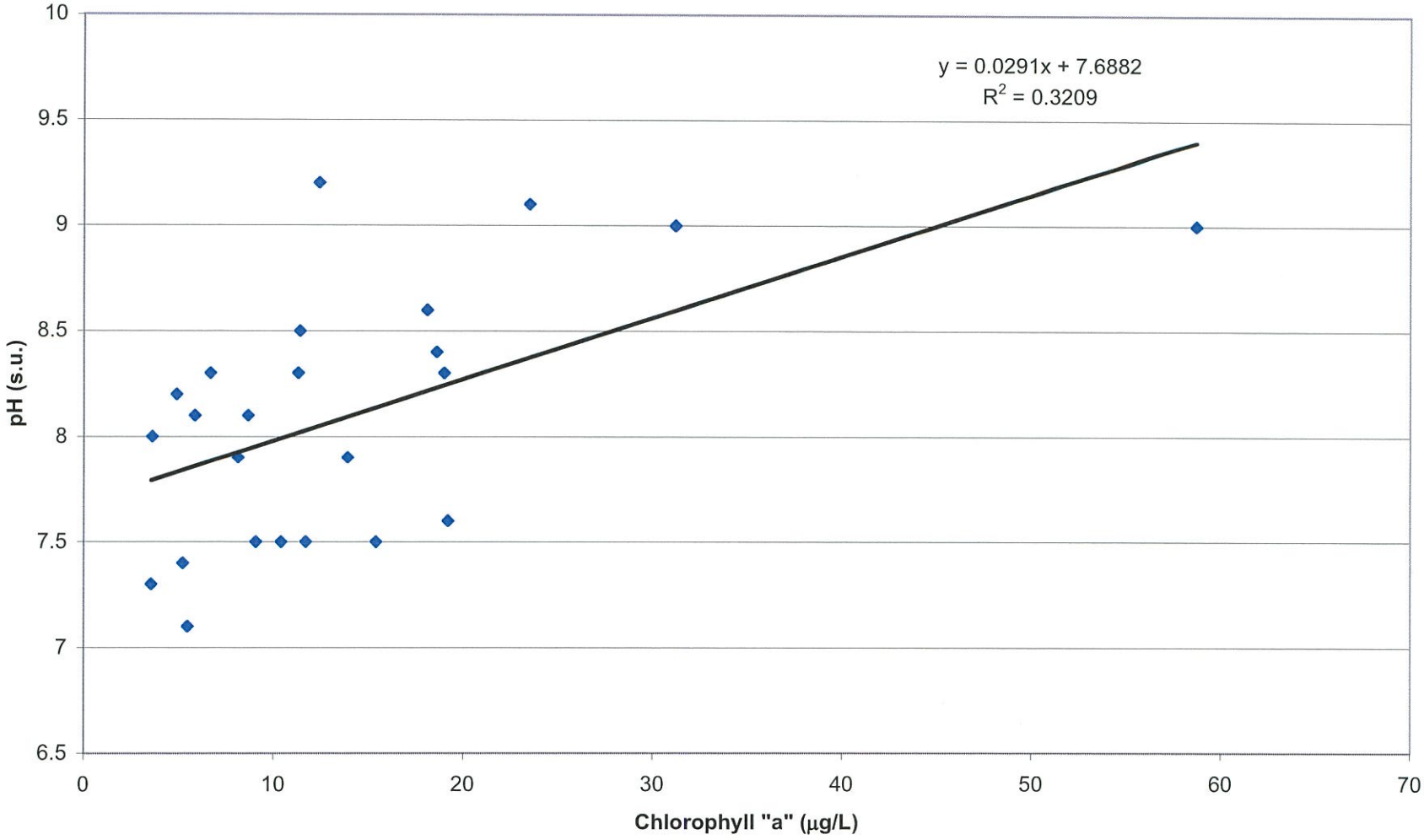
A robust calibration and validation of Kinkaid Lake could not be completed because the following information was not available: observed nutrient concentrations in tributaries to the lake, site-specific data on internal cycling rates, reservoir outflow rates, and nutrient concentrations in reservoir releases. The analysis presented in Table 7-10 is therefore considered a preliminary calibration. However, BATHTUB modeling results indicate a fair estimate between predicted and observed values for the years modeled based on error statistics calculated by the BATHTUB model and should be sufficient for estimating load reductions required in the watershed. BATHTUB calculates three measures of error on each output concentration. If the absolute value

of the error statistic is less than 2.0, the modeled output concentration is within the 95 percent confidence interval for that constituent (USACE 1999b). A robust calibration and validation of Kinkaid Lake will be possible if data collection activities outlined in the future monitoring in Section 9 Implementation are implemented.

Based on modeling results, it appears that internal cycling is not occurring in Kinkaid Lake. The BATHTUB manual notes that internal cycling can be significant in shallow prairie reservoirs and provides Lake Ashtabula (approximately 42 feet deep) as an example (USACE 1999b and 2003). Table 5-17 notes a depth of approximately 62 feet for Kinkaid Lake, which places it outside of the category of shallow reservoir making it appropriate that internal cycling is not occurring in modeled results. Literature sources suggest that internal loading for deeper, more stratified lakes could be in the range of 10 to 30 percent of total loadings and that values for shallower reservoirs could be much higher (Wetzel 1983).

Because the modeling of the Kinkaid Lake changes based on annual loadings and climatic conditions, a validation of the model could not be completed. The model was calibrated for three climatic conditions, which will be the basis for the TMDL analysis presented in Section 8. The preliminary calibrated model was used to estimate the amount of load reductions needed from the watershed to meet water quality standards.

Figure 7-1: Relationship between pH and Chlorophyll "a" at Kinkaid Lake Station RNC-1

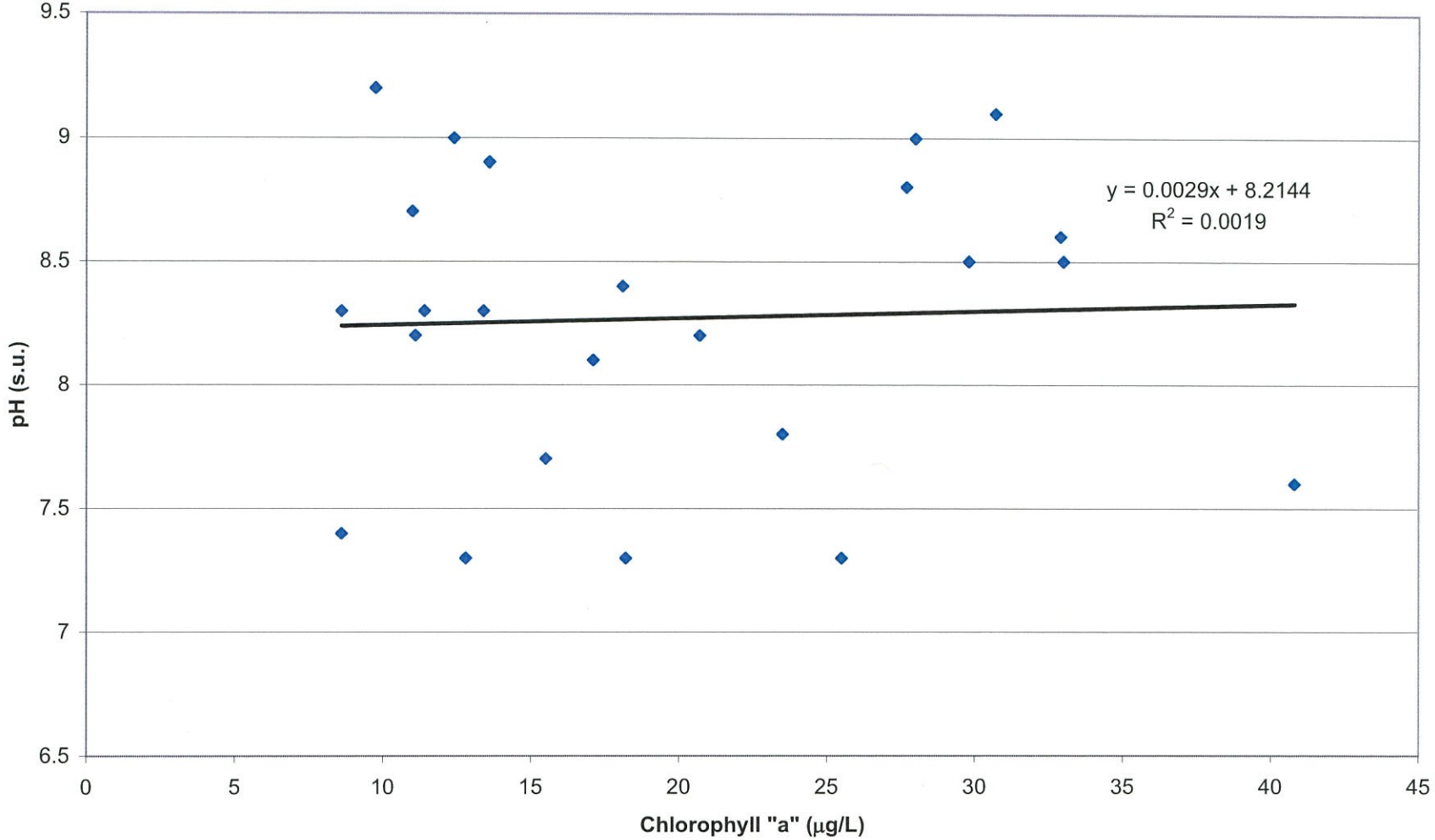


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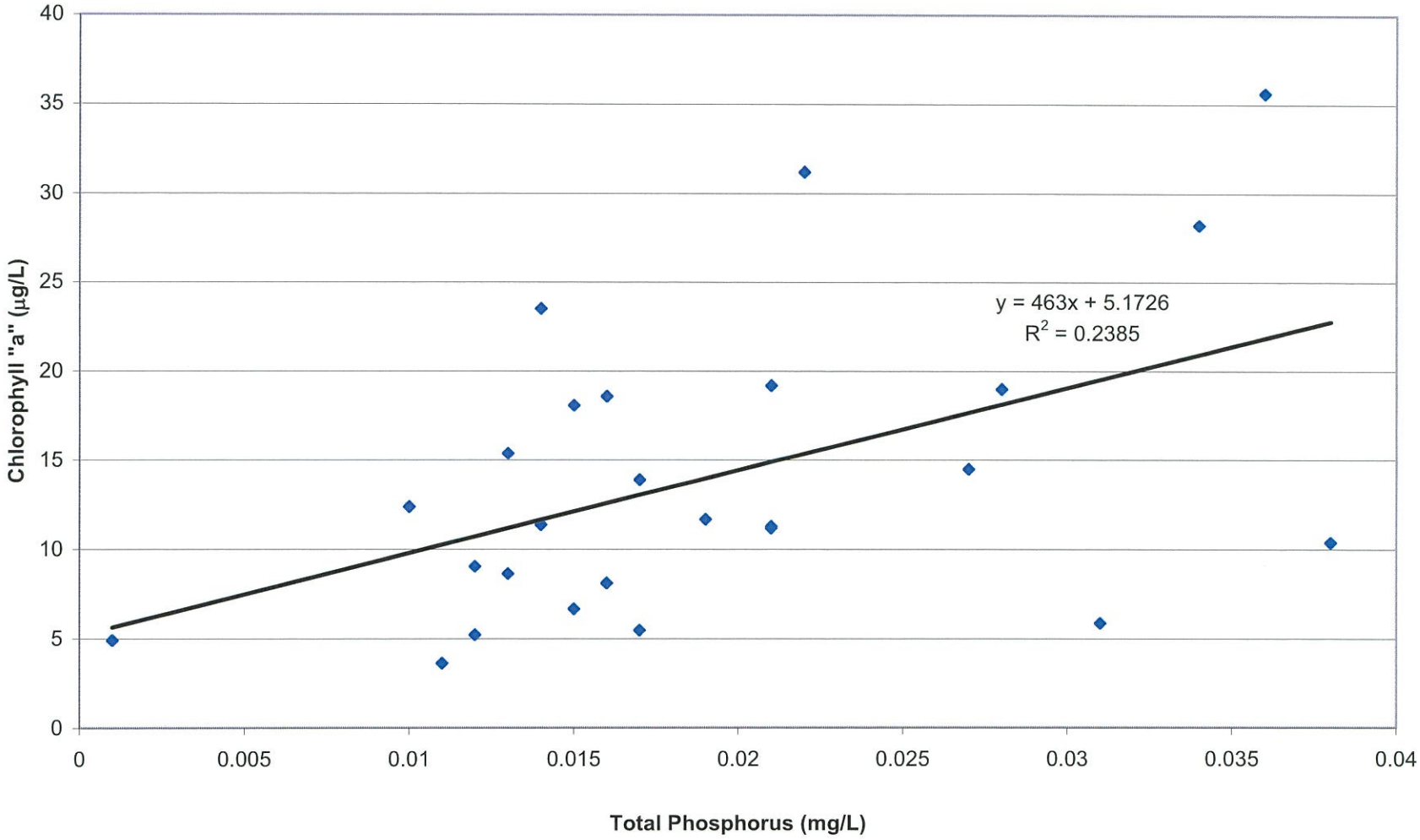
Figure 7-2: Relationship between pH and Chlorophyll "a" at Kinkaid Lake Station RNC-3



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Figure 7-3: Relationship between Total Phosphorus at One-Foot Depth and Chlorophyll "a" at Kinkaid Lake Station RNC-1

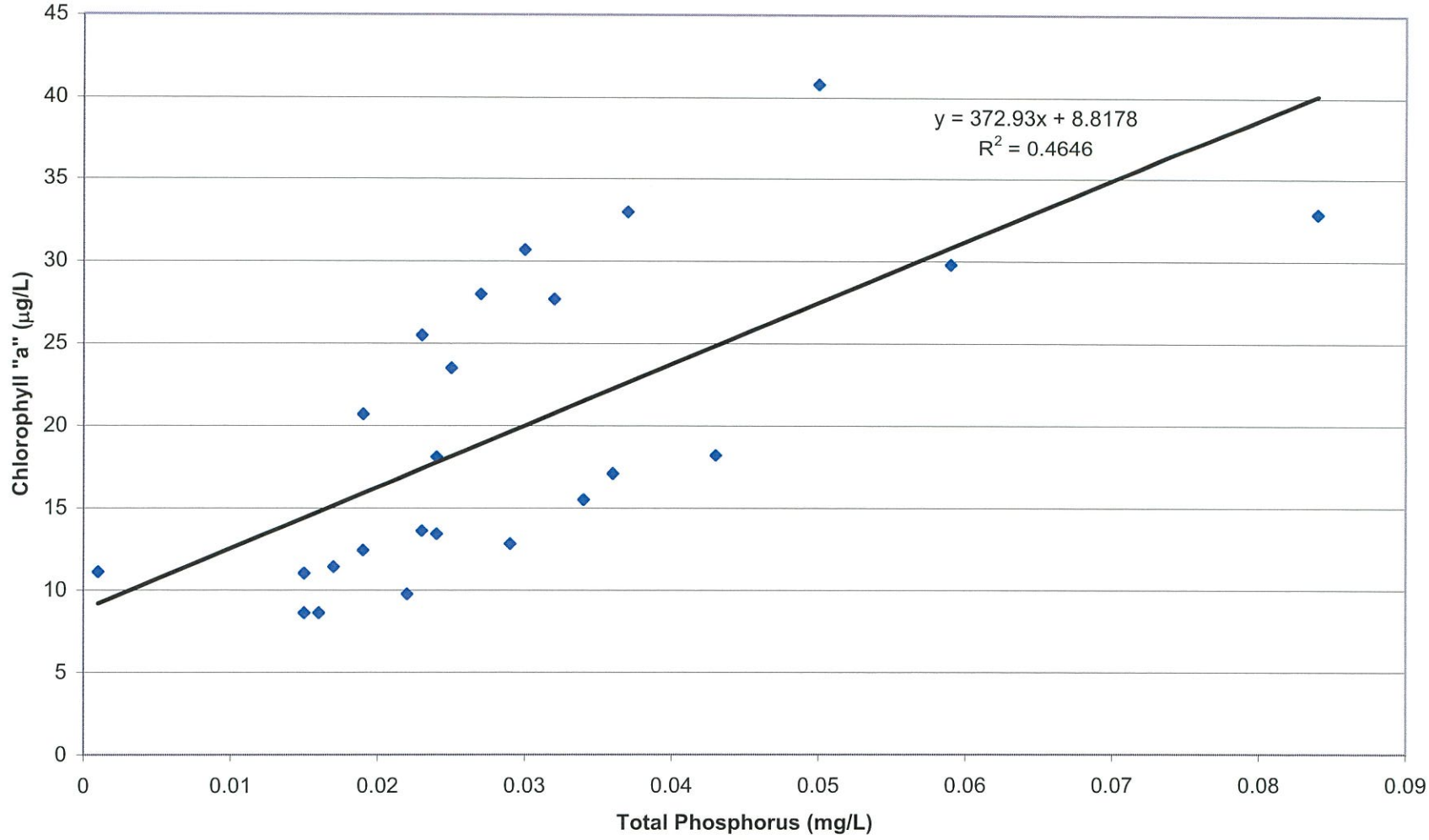


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Figure 7-4: Relationship between Total Phosphorus at One-Foot Depth andChlorophyll "a" at Kinkaid Lake Station RNC-3



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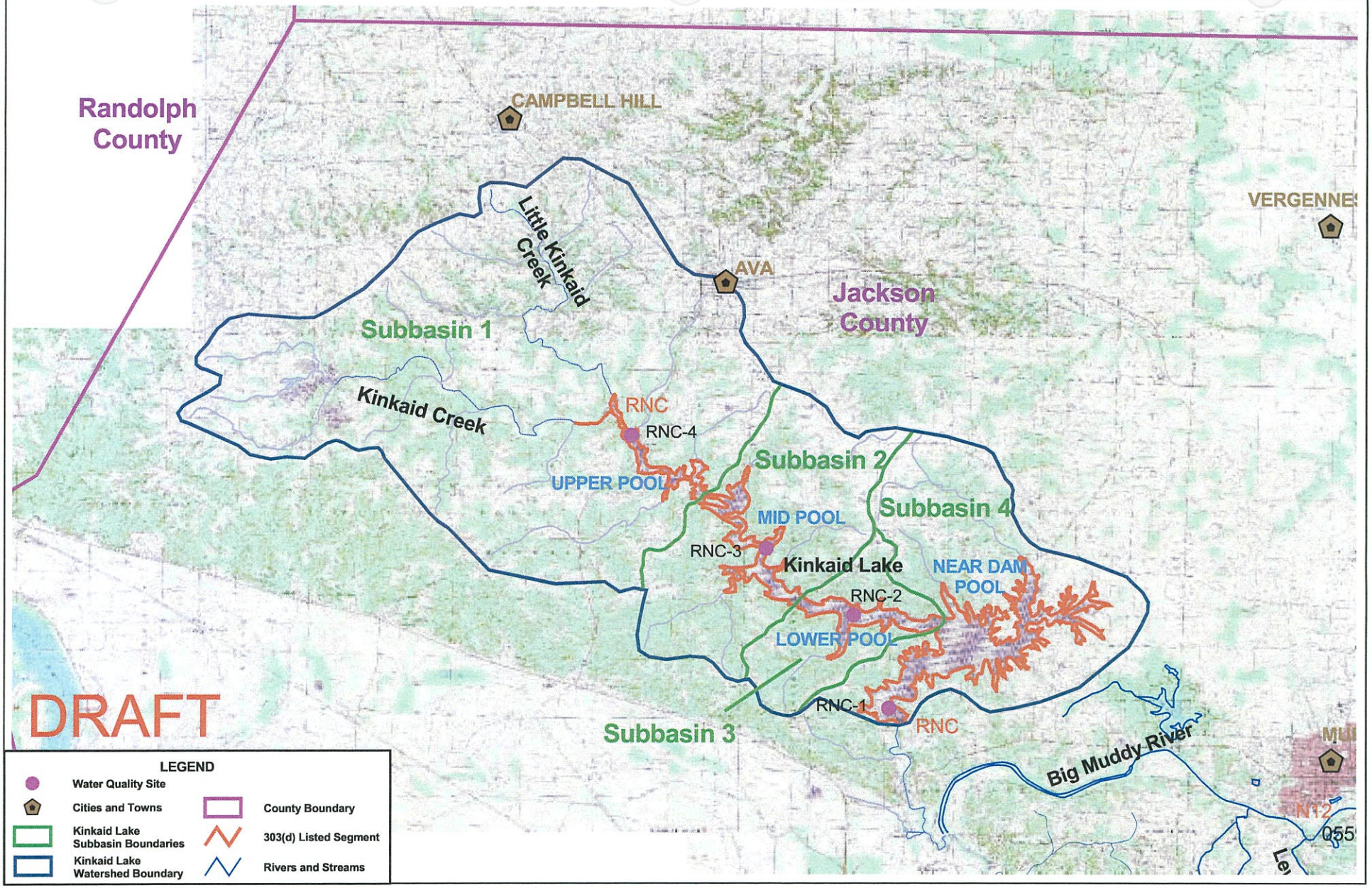


Figure 7-5
Kinkaid Lake Watershed, Historic Sampling Locations, and Modeling Divisions

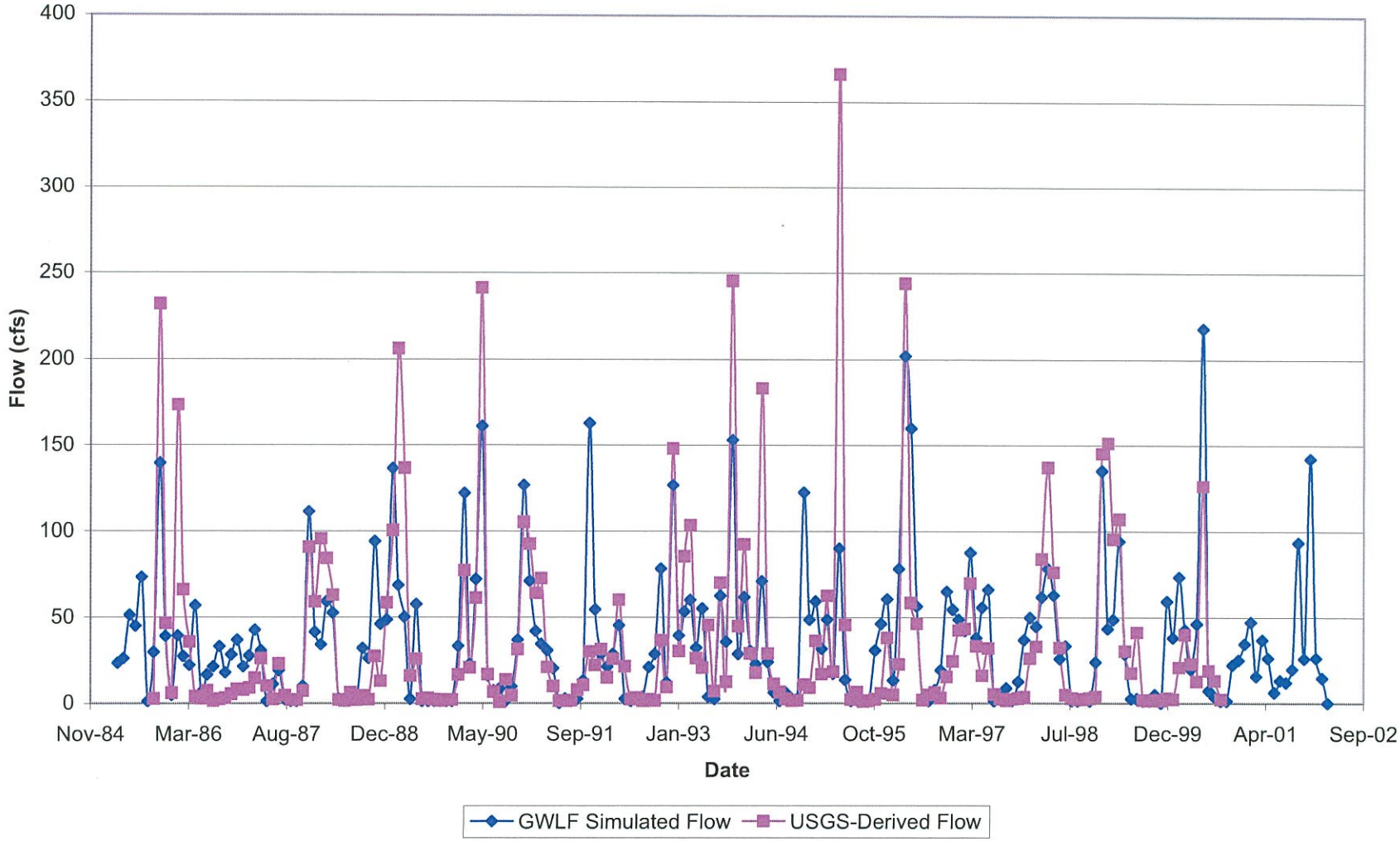
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Figure 7-6: Kinkaid Lake Inflows
Subbasin 1 Monthly Flow Comparison

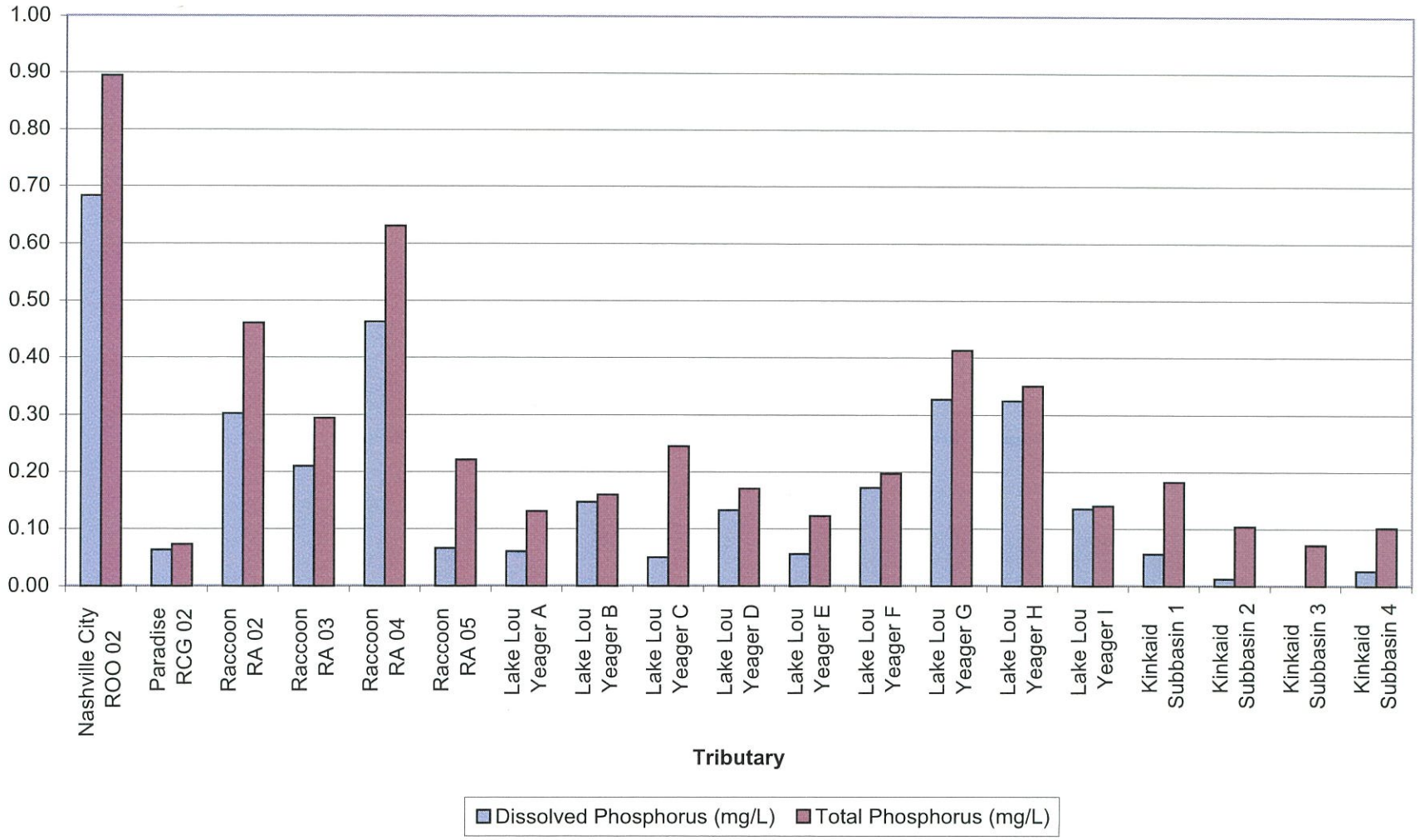


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Figure 7-7: Dissolved and Total Phosphorus Concentrations Measured in Clean Lake Study Tributaries and Estimated for Tributaries to Kinkaid Lake



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Section 8
Total Maximum Daily Load for Kinkaid Lake Watershed

8.1 TMDL Endpoints for Kinkaid Lake

The desired in-lake water quality standard for pH is between 6.5 and 9 and less than or equal to 0.05 mg/L for total phosphorus. Tables 5-5, 5-6, ad 5-7 summarized the average pH, total phosphorus, and chlorophyll "a" concentrations sampled in the Kinkaid Lake Watershed. As noted in Section 5.1.5.1.1, all observed in-lake averages meet these targets, but individual samples violate the TMDL endpoints. The range of pH values is set to prevent eutrophic conditions in Kinkaid Lake and maintain aquatic life. Phosphorus is a concern as nuisance plant growth and algal concentrations in many freshwater lakes are enhanced by the availability of phosphorus.

8.2 Pollutant Sources and Linkages

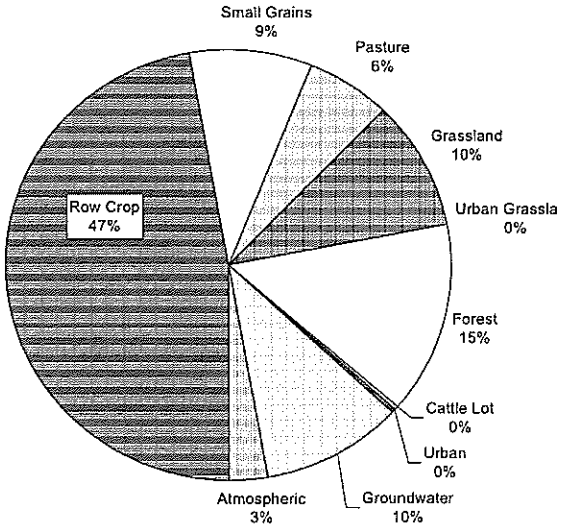
The TMDL for pH in Kinkaid Lake is dependent on a relationship between pH, chlorophyll "a," and phosphorus as explained in Sections 5.1.5.1.1 and 7.1. Relationships between phosphorus, chlorophyll "a," and pH were determined, but it is recognized that they only represent general trends.

Although Kinkaid Lake is not listed for phosphorus, sample concentrations do exceed the endpoint of 0.05 mg/L for total phosphorus in the most upstream pool. This TMDL is based on the assumption that trends in Kinkaid Lake will follow those observed in literature where the control of phosphorus results in acceptable pH values. The remainder of this section focuses on reductions in phosphorus to control pH.

Pollutant sources and their linkages to Kinkaid Lake were established through the GWLF and BATHTUB modeling techniques described in Section 7. Pollutant sources of phosphorus include nonpoint source runoff from agriculture. Atmospheric deposition is another potential source of loads. The predicted phosphorus loads from GWLF and BATHTUB modeling and their sources are presented in Table 8-1. The mean loads presented in Table 8-1 will be used in the overall TMDL calculation for the amount of reductions that need to occur in the Kinkaid Lake Watershed.

Table 8-1 Modeled Total Phosphorus Load by Source

Land Use	1994 (normal)		1997 (wet)		2000 (wet)		Mean	
	lb/yr	Percent	lb/yr	Percent	Lb/yr	Percent	lb/yr	Percent
Row Crop	6,949	45%	9,276	47%	15,215	49%	10,480	47%
Small Grains	1,306	8%	1,707	9%	2,813	9%	1,942	9%
Rural Grassland								
Pasture	933	6%	1,101	6%	2,036	7%	1,357	6%
Grassland	1,446	9%	1,817	9%	3,241	10%	2,168	10%
Urban Grassland	0	0%	0	0%	27	0%	9	0%
Forest	2,006	13%	2,835	14%	4,795	16%	3,212	15%
Cattle Feedlot	23	0%	28	0%	54	0%	35	0%
Urban	70	0%	28	0%	27	0%	41	0%
Groundwater	2,262	15%	2,395	12%	2,223	7%	2,293	10%
Atmospheric	628	4%	628	3%	628	2%	628	3%
Total	**15,623**	**100%**	**19,815**	**100%**	**31,059**	**100%**	**22,165**	**100%**



The majority of the predicted phosphorus load is from agricultural nonpoint sources as shown in the pie chart to the right. The loads represented in Table 8-1 and the pie chart were entered into the BATHTUB model as explained in Section 7 to determine resulting in-lake total phosphorus concentration in mg/L. As explained in Section 7, these loads result in in-lake concentrations that exceed the total phosphorus target of 0.05 mg/L at the most upstream water quality site. The TMDL explained throughout the remainder of this section will examine how much the external loads need to be reduced in order to meet the total phosphorus water quality standard of 0.05 mg/L in Kinkaid Lake.

8.3 Allocation

As explained in Section 1, the TMDL for Kinkaid Lake will address the following equation:

$$\mathbf{TMDL = LC = \Sigma WLA + \Sigma LA + MOS}$$

where: LC = Maximum amount of pollutant loading a water body can receive without violating water quality standards

WLA = The portion of the TMDL allocated to existing or future point sources

LA = Portion of the TMDL allocated to existing or future nonpoint sources and natural background

MOS = An accounting of uncertainty about the relationship between pollutant loads and receiving water quality

Each of these elements will be discussed in this section as well as consideration of seasonal variation in the TMDL calculation.

8.3.1 Loading Capacity

The loading capacity of Kinkaid Lake is the pounds per year of total phosphorus that can be allowed as input to the lake and still meet the water quality standard of 0.05 mg/L total phosphorus. The allowable phosphorus loads that can be generated in the watershed and still maintain water quality standards was determined with the models that were set up and calibrated as discussed in Section 7. To accomplish this, the loads presented in Table 8-1 were reduced by a percentage and entered into the BATHTUB model until the water quality standard of 0.05 mg/L total phosphorus was met in Kinkaid Lake. Only loads modeled from Subbasin 1 were reduced because this subbasin has the most impact on water quality at site RNC-4, which had observed phosphorus concentrations greater than 0.05 mg/L. Table 8-2 shows the allowable phosphorus loading determined for 1994, 1997, and 2000 by reducing modeled inputs to Kinkaid Lake through GWLF and BATHTUB. The output files to BATHTUB showing the results of the load reductions for 1994, 1997, and 2000 are contained in Appendix I.

Table 8-2 Allowable Total Phosphorus Load by Model Year for Kinkaid Lake

Model Year	Phosphorus (lb/yr)
1994	8,109
1997	10,697
2000	23,145
Mean	13,983

The allowable pounds per year resulting from the modeling show the effects of varying climatic conditions observed during these years. Therefore, an average value of these years was set as the target loading to meet the in-lake water quality standards of 0.05 mg/L.

The modeled total phosphorus and chlorophyll "a" concentrations resulting from the allowable loads are presented in Table 8-3. The pH values associated with the phosphorus and chlorophyll "a" concentrations shown in Table 8-3 were determined from the relationships provided in Figures 7-1 through 7-4. Only results at stations RNC-1 and RNC-3 are shown because, as mentioned previously, these are the only stations with samples that exceeded the pH standard. This analysis shows that violations of the pH water quality standard should be avoided. Therefore, the TMDL for Kinkaid Lake will focus on phosphorus as explained throughout the remainder of this section.

Table 8-3 Predicted Total Phosphorus, Chlorophyll "a," and pH Values in Kinkaid Lake

Year	Total Phosphorus (mg/L)	Chlorophyll "a" (µg/L)	pH (s.u.)
1994 (RNC-1)	0.02	16.6	8.2
1994 (RNC-3	0.02	13.1	8.3
1997 (RNC-1)	0.03	11.9	8.0
1997 (RNC-3	0.03	18.2	8.3
2000 (RNC-1)	0.02	19.1	8.2
2000 (RNC-3)	0.03	15.5	8.3

As discussed previously, modeled loads to the most upstream segment of Kinkaid Lake were reduced to attain a total phosphorus concentration of 0.05 mg/L, which in turn reduced modeled concentrations in downstream segments of the lake. Therefore, the values in Table 8-3 are much lower than the water quality standard, although the modeled concentrations in the most upstream segment are just below the phosphorus standard of 0.05 mg/L.

8.3.2 Seasonal Variation

A season is represented by changes in weather; for example, a season can be classified as warm or cold as well as wet or dry. Seasonal variation is represented in the Kinkaid Lake TMDL as conditions were modeled on an annual basis and by taking 15 years of daily precipitation data when calculating run-off through the GWLF model. This takes into account the seasonal effects the reservoir will undergo during a given year. Since the various pollutant sources are expected to contribute loadings in different quantities during different time periods (e.g., atmospheric deposition year round, spring run-off loads), the loadings for this TMDL will focus on average annual loadings rather than specifying different loadings by season. In addition, three data sets (wet, dry, average) were examined to assess the effects of varying precipitation on loading to the reservoir and resulting in-lake concentrations.

8.3.3 Margin of Safety

The MOS can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. The MOS for the Kinkaid Lake TMDL should be based on a combination of both. Model inputs were selected from the GWLF manual when site-specific data were unavailable. These default input values are assumed to be conservative, which implicitly includes a MOS in the modeling effort. Because the default input values are not site-specific, they are assumed more conservative and therefore a MOS can be implicitly assumed. Default input values include:

- Sediment delivery ratio – using literature value is assumed conservative as cropping practices have changed within Illinois since ratio was developed in 1975.
- Soil phosphorus concentration – phosphorus concentrations in the soil were not available therefore literature values were assumed conservative as the mid-point of the range of suggested literature range was used as a starting point for analyses.

In addition, averaging of a normal and dry year is assumed to be conservative and part of the implicit MOS.

Due to uncertainty with nutrient model inputs as explained in Section 7.4, an explicit MOS of 5 percent is also recommended. Due to unknowns regarding estimated versus actual measurements of loadings to the lake, an explicit MOS is included. The 5 percent MOS is appropriate based upon the generally good agreement between the GWLF loading model and observed flows, and in the BATHTUB water quality model and observed values in Kinkaid Lake (Section 7.4). Since these models reasonably

reflect the conditions in the watershed, a 5 percent MOS is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. The MOS can be reviewed in the future as new data is developed.

8.3.4 Waste Load Allocation

There are no point sources in the watershed; therefore, no WLA is recommended at this time.

8.3.5 Load Allocation and TMDL Summary

Table 8-4 shows a summary of the TMDL for Kinkaid Lake. On average, a total reduction of 43 percent of total phosphorus loads to Kinkaid Lake would result in compliance with the water quality standard of pH values between 6.5 and 9 based on modeling efforts.

Table 8-4 TMDL Summary for Total Phosphorus in Kinkaid Lake

LC (lb/yr)	WLA (lb/yr)	LA (lb/yr)	MOS (lb/yr)	Reduction Needed (lb/yr)	Reduction Needed (percent)
13,983	0	13,283	700	8,882	40%

Table 8-5 shows the respective reductions needed from atmospheric loads and nonpoint sources in the watershed to meet the TMDL. The reduction of atmospheric loads is zero because atmospheric contributions cannot be controlled by watershed management measures. An approximate 41 percent reduction of nonpoint sources from the watershed would be necessary to meet the load allocation presented in Table 8-4. Methods to meet these targets will be outlined in Section 9.

Table 8-5 Sources for Total Phosphorus Reductions

Source	Current Load (lb/yr)	Load Reduction (lb/yr)	Percent Reduction
Atmospheric	628	0	0%
Nonpoint Sources	21,537	8,882	41%

Section 9
Implementation Plan for Kinkaid Lake

9.1 Implementation Actions and Management Measures

As discussed in Sections 7.1 and 8.2, the TMDL for Kinkaid Lake is based on relationships between pH, chlorophyll "a," and phosphorus. The remainder of this section focuses on reductions in phosphorus to control pH. It was determined that reductions in phosphorus to the TMDL endpoint of 0.05 mg/L will result in pH concentrations that meet the water quality standard. Therefore, this implementation plan focuses on measures that will reduce phosphorus.

Phosphorus loads in the Kinkaid Lake Watershed originate from external sources, such as croplands. The annual averages of data collected during sampling of Kinkaid Lake indicate that only the upstream portion of Kinkaid Lake is impaired for phosphorus (detailed in Section 7). Land use for the entire watershed illustrates that 70 percent of the agricultural practices occur in the portion of the watershed upstream of Kinkaid Lake, which supports the data. Hence, implementation measures focus on the watershed area located upstream of Kinkaid Lake (subbasin 1 in Figure 7-5). However, the TMDL endpoints and load reductions apply to the entire Kinkaid Lake Watershed.

From modeling estimates, external loads from nonpoint source runoff from agricultural crops potentially account for 56 percent of the loading to Kinkaid Lake, and forest land, both deciduous and coniferous, accounts for approximately 15 percent of the nonpoint source phosphorus loaded to the lake. Grassland and pasture land account for approximately 16 percent of the modeled load, and the remaining 14 percent are contributed by atmospheric and groundwater loads. To achieve the 41 percent reduction for the load allocations established in Section 8 (Table 8-4), management measures must address nonpoint source loading through sediment and surface runoff controls. Phosphorus sorbs readily to soil particles and controlling sediment load into the reservoir helps control phosphorus loadings.

The pH level in lakes is tied to the plant, animal, and nutrient cycles of the lake. Plants and algae use CO_2 during photosynthesis, which causes pH levels to rise. The photosynthetic rate progressively decreases as the residual CO_2 concentration declines and ceases completely with the extinction of light. During the night, reaeration and respiration replenish CO_2 causing the pH levels to decrease overnight (Welch 1980). Plant and algae growth tend to increase significantly with the addition of phosphorus to the lake; therefore, the success of controlling pH levels in Kinkaid Lake is linked to the control of nonpoint source phosphorus loads.

Implementation actions, management measures, or BMPs are used to control the generation or distribution of pollutants. BMPs are either structural, such as wetlands, sediment basins, fencing, or filter strips; or managerial, such as conservation tillage, nutrient management plans, or crop rotation. Both types require good management to be effective in reducing pollutant loading to water resources (Osmond et al. 1995).

It is generally more effective to install a combination of BMPs or a BMP system. A BMP system is a combination of two or more individual BMPs that are used to control a pollutant from the same critical source. In other words, if the watershed has more than one identified pollutant, but the transport mechanism is the same, then a BMP system that establishes controls for the transport mechanism can be employed. (Osmond et al. 1995).

Implementation actions and management measures are described for each phosphorus source located in the upper Kinkaid Lake Watershed. Nonpoint sources include agricultural practices, such as cropland and a cattle feedlot.

9.1.1 Nonpoint Source Phosphorus and pH Management

The sources of nonpoint source pollution in subbasin 1 of the Kinkaid Lake Watershed consist of agricultural cropland and a cattle feedlot, although the feedlot in the upper watershed was designated as having no impact on the receiving waters. BMPs evaluated for treatment of these nonpoint sources are:

- conservation tillage practices,
- wetlands,
- filter strips,
- nutrient management.

Total phosphorus originating from cropland is most efficiently treated with a combination of no-till or conservation tillage practices and grass filter strips. Wetlands located upstream of the reservoir potentially provide further reductions in total and dissolved phosphorus in runoff from croplands and cattle operations. Nutrient management focuses on source control of nonpoint source contributions to Kinkaid Lake.

9.1.1.1 Conservation Tillage Practices

For the Kinkaid Lake Watershed, conservation tillage practices could help reduce nutrient loads in the lake. Nonpoint source runoff from 3,200 acres of row crops and small grain agriculture in subbasin 1 were estimated to contribute 27 percent of the phosphorus load to Kinkaid Lake. Total phosphorus loading from cropland is controlled through management BMPs, such as conservation tillage. Conservation tillage maintains at least 30 percent of the soil surface covered by residue after planting. Crop residuals or living vegetation cover on the soil surface protect against soil detachment from water and wind erosion. Conservation tillage practices can remove up to 45 percent of the dissolved and total phosphorus from runoff and approximately 75 percent of the sediment. Additionally, studies have found around 93 percent less erosion occurred from no-till acreage compared to acreage subject to moldboard plowing (North Carolina State University [NCSU] 2000). It is estimated that conventional till currently accounts for 20 percent of corn, 0 percent of soybean, and 20 percent of small grain tillage practices in Jackson County, and these percentages were assumed to apply to the Kinkaid Lake Watershed as well. To achieve the reductions needed, erosion control through conservation tillage could reduce

phosphorus loads. The watershed's modeled erosion rate from row crop and small grains average 10.5 tons/acre/year. To achieve a 19 percent reduction in phosphorus load, the erosion rate for the watershed would need to be reduced to 8.5 tons/acre/year. Similarly, the C-factors for corn, soybeans, and small grains would need to be reduced from 0.21, 0.08, and 0.13 to 0.17, 0.06, and 0.10, respectively.

9.1.1.2 Wetlands

The use of wetlands as a structural control is most applicable to nutrient reduction from agricultural lands in subbasin 1 of Kinkaid Lake. Therefore this section only focuses on the subbasin 1 watershed. Wetlands are an effective BMP for sediment and phosphorus control because they:

- prevent floods by temporarily storing water, allowing the water to evaporate or percolate into the ground,
- improve water quality through natural pollution control such as plant nutrient uptake,
- filter sediment,
- slow overland flow of water thereby reducing soil erosion (USDA 1996).

To treat loads from agricultural runoff from subbasin 1, which is estimated to contribute approximately 27 percent of the current total phosphorus load to Kinkaid Lake, a wetland system could be constructed on the upstream end of the reservoir. Treatment of sediment and phosphorus from agricultural runoff could be accomplished through a combination of no-till practices, wetlands, and filter strips.

While constructed wetlands have been demonstrated to effectively reduce nitrogen and sediment, literature shows mixed results for phosphorus removal. Studies have shown that artificial wetlands designed and constructed specifically to remove pollutants from surface water runoff have removal rates for suspended solids of greater than 90 percent, for total phosphorus of 0 to 90 percent, and for nitrogen species from 10 to 75 percent (Johnson, Evans, and Bass 1996; Moore 1993; USEPA 1993; Kovosic et al. 2000). In some cases, wetlands can be sources of phosphorus. Over the long term, it is generally thought that wetlands are neither sources nor sinks of phosphorus (Kovosic et al. 2000).

Efficiency of pollutant removal in wetlands can be addressed in the design and maintenance of the constructed wetland. Location, hydraulic retention time and space requirements should be considered in design. To maintain removal efficiency, sheet flow should be maintained and substrate should be monitored to assess whether the wetland is operating optimally. Sediment or vegetation removal may be necessary if the wetland removal efficiency is lessened over a period of time (USEPA 1993; NCSU 1994).

Guidelines for wetland design suggest a wetland to watershed ratio of 0.6 percent for nutrient and sediment removal from agricultural runoff. Since a wetland to treat

agricultural runoff from the 22,275-acre upper Kinkaid Lake Watershed would need to be approximately 134 acres based on these recommendations, it is recommended to build a wetland system composed of a series of wetlands on different tributaries around the basin to achieve the 134 acres of wetlands for treatment (Denison and Tilton 1993).

9.1.1.3 Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment, to Kinkaid Lake Watershed. Filter strips implemented along stream segments slow and filter nutrients and sediment out of runoff and provide bank stabilization decreasing erosion and deposition. Additionally, filter strips mitigate nutrient loads to lakes. The following paragraphs focus on the implementation of filter strips in subbasin 1 of the Kinkaid Lake Watershed. Finally, design criteria and size selection of filter strips are detailed.

Grass and riparian buffer strips filter out nutrients and organic matter associated with sediment loads to a water body. Reduction of nutrient concentrations, specifically phosphorus, in Kinkaid Lake will reduce the amount of algal growth in the lake system, which can cause more significant diurnal pH fluctuations from photosynthesis. Filter strips reduce nutrient and sediment loads to lakes by establishing ground depressions and roughness that settles sediment out of runoff and providing vegetation to filter nutrients out of overland flow. As much as 75 percent of sediment and 45 percent of total phosphorus can be removed from runoff by a grass filter strip (NCSU 2000). In addition, filter strips should be harvested periodically so that removal rate efficiencies over extended periods of time remain high (USEPA 1993).

Filter strip widths for the Kincaid Lake TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 9-1 outlines the guidance for filter strip flow length by slope (NRCS 1999). Based on this guidance, two filter strips were examined for the basin. Based on slope, the southern tributary would need a filter strip with 72 feet on each side of the tributary for a length of 902 feet. The northern tributary would need a filter strip that encompassed 108 feet on each side of the tributary for a length of 1,017 feet.

Filter strip widths for the Kinkaid Lake TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 9-1 outlines the guidance for filter strip flow length by slope (NRCS 1999).). Based on slope estimates near tributaries within the watershed, filter strips widths of 90 to 234 feet could be incorporated in locations throughout the watershed. The total acreage examined was 107 acres.

Table 9-1 Filter Strip Flow Lengths Based on Land Slope

Percent Slope	0.5%	1.0%	2.0%	3.0%	4.0%	5.0% or greater
Minimum	36	54	72	90	108	117
Maximum	72	108	144	180	216	234

The filter strip lengths and widths presented above are used to calculate an approximation of BMP costs in Section 9.2.2.6 and should only be used as a guideline for watershed planning. It is recommended that landowners evaluate their land near streams and lakes and create or extend filter strips according to the NRCS guidance presented in Table 9-1. Programs available to fund the construction of these buffer strips are discussed in Section 9.2.

9.1.1.4 Nutrient Management

Nutrient management could result in reduced phosphorus and nitrogen loads to Kinkaid Lake. Crop management of nitrogen and phosphorus can be accomplished through Nutrient Management Plans, which focus on increasing the efficiency with which applied nutrients are used by crops, thereby reducing the amount available to be transported to both surface and groundwater. In the past, nutrient management focused on application rates designed to meet crop nitrogen requirements but avoid groundwater quality problems created by excess nitrogen leaching. This results in buildup of soil phosphorus above amounts sufficient for optimal crop yields. Illinois, along with most Midwestern states, demonstrates high soil test phosphorus in greater than 50 percent of soil samples analyzed (Sharpley et al. 1999).

The overall goal of phosphorus reduction from agriculture should increase the efficiency of phosphorus use by balancing phosphorus inputs in feed and fertilizer with intakes of crops and animal produce as well as managing the level of phosphorus in the soil. Reducing phosphorus loss in agricultural runoff may be brought about by source and transport control measures, such as filter strips or grassed waterways. The Nutrient Management Plans account for all inputs and outputs of phosphorus to determine reductions. Elements of a Nutrient Management Plan include:

- Plan summary
- Manure summary, including annual manure generation, use, and export
- Nutrient application rates by field and crop
- Summary of excess manure utilization procedures
- Implementation schedule
- Manure management and stormwater BMPs

In Illinois, Nutrient Management Plans have successfully reduced phosphorus application to agricultural lands by 36-lb/acre. National reductions range from 11- to 106-lb/acre, with an average of 35-lb/acre (NCSU 2000).

9.1.2 Implementation Actions and Management Measures Summary

9.1.2.1 Kinkaid Lake Watershed

To meet the reductions outlined in Section 8 for Kinkaid Lake, 41 percent of phosphorus loaded from nonpoint source pollution would need to be reduced to meet the TMDL target of a total phosphorus concentration less than 0.05-mg/L. The GWLF model was used to model the following practices to estimate achievable reductions in total phosphorus:

- Conservation tillage
- Nutrient management (reduction of total phosphorus in sediment by 20 percent)
- Filter strips

These practices were only applied to subbasin 1 because reductions are only required in the upper pool of Kinkaid Lake. The modeling effort showed that filter strips do not provide much total phosphorus reduction, most likely due to routing constraints of the GWLF model as discussed in Section 7.3.2.1.1 and the small magnitude of area available for filter strip development.

Table 9-2 Summary of Total Phosphorus Load Reductions

Management Measure	Potential Percent Reduction
Nutrient Management Practices	10%
Conservation Tillage Practices	11%
Filter Strips*	22%
Wetland*	5%

* Literature Value

Reductions of external loads by conservation tillage, nutrient management, filter strips, and wetlands are summarized in Table 9-2. Wetlands were not modeled with GWLF because wetland performance is a result of placement in the watershed, and GWLF does not recognize spatial data due to routing constraints of the model. The lower bound of the literature value was used due to studies that have shown the long-term effectiveness of phosphorus removal in wetlands is negligible.

A combination of implementing these external load reduction practices would allow the Kinkaid Lake Watershed to meet its total goal of reducing phosphorus loads by 44 percent. Section 9.2 outlines planning level costs and programs available to help with cost sharing so that this goal can be achieved.

9.2 Reasonable Assurance

Reasonable assurance means that a demonstration is given that nonpoint source reductions in this watershed will be implemented. It should be noted that all programs discussed in this section are voluntary. The discussion in Section 9.1 provided a means for obtaining the reductions necessary. The remainder of this section discusses programs available to assist with funding of implementing practices and also an estimate of costs to the watershed for implementing these practices.

9.2.1 Available Programs

Approximately 24 percent of the Kinkaid Lake Watershed is classified as rural grassland (pasture land, Conservation Reserve Program [CRP], waterways, buffer strips, etc.), row crop, and small grains land. There are several voluntary conservation programs established through the 2002 U.S. Farm Bill, which encourage landowners to implement resource conserving practices for water quality and erosion control purposes. These programs would apply to crop fields and rural grasslands that are presently used as pasture land. Each program is discussed separately in the following paragraphs.

9.2.1.1 Illinois Department of Agriculture and Illinois EPA Nutrient Management Plan Project

The Illinois Department of Agriculture (IDA) and Illinois EPA are presently co-sponsoring a cropland Nutrient Management Plan project in watersheds that have or are developing a TMDL. Under this project, 4,327 acres of cropland have been targeted in the Kinkaid Lake Watershed. This voluntary project will supply incentive payments to producers to have Nutrient Management Plans developed and implemented. Additionally, if sediments or phosphorus have been identified as a cause for impairment in the watershed, then traditional erosion control practices will be eligible for cost-share assistance through the Nutrient Management Plan project as well.

9.2.1.2 Conservation Reserve Program (CRP)

This voluntary program encourages landowners to plant long-term resource-conserving cover to improve soils, water, and wildlife resources. CRP is the USDA's single largest environmental improvement program and one of its most productive and cost-efficient. It is administered through the Farm Service Agency (FSA) by USDA's Commodity Credit Corporation (CCC). The program was initially established in the Food Security Act of 1985. The duration of the contracts under CRP range from 10 to 15 years.

Eligible land must be one of the following:

1. Cropland that is planted or considered planted to an agricultural commodity two of the five most recent crop years (including field margins). Must be physically and legally capable of being planted in a normal manner to an agricultural commodity.

2. Certain marginal pastureland enrolled in the Water Bank Program.

The CCC bases rental rates on the relative productivity of soils within each county and the average of the past three years of local dry land cash-rent or cash-rent equivalent. The maximum rental rate is calculated in advance of enrollment. Producers may offer land at the maximum rate or at a lower rental rate to increase likelihood of offer acceptance. In addition, the CCC provides cost-share assistance for up to 50 percent of the participant's costs in establishing approved conservation practices. CCC also encourages restoration of wetlands by offering a one-time incentive payment equal to 25 percent of the costs incurred. This incentive is in addition to the 50 percent cost share provided to establish cover (USDA 1999).

Finally, CCC offers additional financial incentives of up to 20 percent of the annual payment for certain continuous sign-up practices. Continuous sign-up provides management flexibility to farmers and ranchers to implement certain high-priority conservation practices on eligible land. The land must be determined by NRCS to be eligible and suitable for any of the following practices:

- Riparian buffers
- Filter strips

- Grass waterways
- Shelter belts
- Field windbreaks
- Living snow fences
- Contour grass strips
- Salt tolerant vegetation
- Shallow water areas for wildlife
- Eligible acreage within an USEPA-designated wellhead protection area (FSA 1997)

9.2.1.3 Wetlands Reserve Program (WRP)

WRP is a voluntary program that provides technical and financial assistance to eligible landowners to restore, enhance, and protect wetlands. The goal of WRP is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. At least 70 percent of each project area will be restored to the original natural condition, to the extent practicable. The remaining 30 percent of each area may be restored to other than natural conditions. Landowners have the option of enrolling eligible lands through permanent easements, 30-year easements, or restoration cost-share agreements. The program is offered on a continuous sign-up basis and is available nationwide. WRP offers landowners an opportunity to establish, at minimal cost, long-term conservation and wildlife habitat enhancement practices and protection. It is administered through the NRCS (2002b).

The 2002 Farm Bill reauthorized the program through 2007. Increasing the acreage enrollment cap to 2,275,000 acres with an annual enrollment of 250,000 acres per calendar year. The program is limited by the acreage cap and not by program funding. Since the program began in 1985, the average cost per acre is $1,100 in restorative costs and the average project size is 177 acres. The costs for each enrollment option follow in Table 9-3 (USDA 1996).

Table 9-3 Costs for Enrollment Options of WRP

Option	Permanent Easement	30-year Easement	Restoration Agreement
Payment for Easement	100% Agricultural Value	75% Agricultural Value	NA
Payment Options	Lump Sum	Lump Sum	NA
Restoration Payments	100% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements

9.2.1.4 Environmental Quality Incentive Program (EQIP)

EQIP is a voluntary USDA conservation program for farmers and private landowners engaged in livestock or agricultural production who are faced with serious threats to soil, water, and related natural resources. It provides technical, financial, and educational assistance primarily in designated "priority areas." Priority areas are defined as watershed, regions, or areas of special environmental sensitivity that have significant soil, water, or natural resource related concerns. The program goal is to maximize environmental benefits per dollar expended and provides "(1) flexible

technical and financial assistance to farmers and ranchers that face the most serious natural resource problems; (2) assistance to farmers and ranchers in complying with Federal, State, and tribal environmental laws, and encourage environmental enhancement; (3) assistance to farmers and ranchers in making beneficial, cost-effective changes to measures needed to conserve and improve natural resources; and (4) for the consolidation and simplification of the conservation planning process." As of 2001, 379,000 acres have been protected in Illinois using EQIP (NRCS 2002d,e).

Landowners, with the assistance of a local NRCS or other service provider, are responsible for development of a site-specific conservation plan, which addresses the primary natural resource concerns of the priority area. Conservation practices include but are not limited to erosion control, filter strips, buffers, and grassed waterways. If the plan is approved by NRCS, a five- to 10-year contract that provides cost-share and incentive payments is developed.

Cost-share assistance may pay landowners up to 75 percent of the costs of conservation practices, such as grassed waterways, filter strips, manure management, capping abandoned wells, and other practices important to improving and maintaining the health of natural resources in the area. Total incentive and cost-share payments are limited to $10,000 per person per year and $50,000 over the life of the contract.

9.2.1.5 Conservation Practices Program

The Conservation Practices Program (CPP) is a 10-year program. The practices consist of waterways, water and sediment control basins (WASCOBS), pasture/hayland establishment, critical area, terrace system, no-till system, diversions, and grade stabilization structures. The CPP is State funded through the Department of Agriculture. There is a project cap of $5,000 per landowner and costs per acre vary significantly from project to project.

9.2.1.6 Wildlife Habitat Incentives Program (WHIP)

WHIP is a voluntary program that encourages the creation of high quality wildlife habitat of national, state, tribal, or local significance. WHIP is administered through NRCS, which provides technical and financial assistance to landowners for development of upland, riparian, and aquatic habitat areas on their property. NRCS works with the participant to develop a wildlife habitat development plan that becomes the basis of the cost-share agreement between NRCS and the participant. Most contracts are five to 10 years in duration, depending upon the practices to be installed. However, longer term contracts of 15 years or greater may also be funded. Under the agreement:

- The landowner agrees to maintain the cost-shared practices and allow NRCS or its agent access to monitor its effectiveness.
- NRCS agrees to provide technical assistance and pay up to 75 percent of the cost of installing the wildlife habitat practices. Additional financial or technical assistance may be available through cooperating partners (NRCS 2002c).

The FSA administers the CRP. NRCS administers the EQIP, WRP, and WHIP. Local NRCS and FSA contact information in Jackson County are listed in the Table 9-4 below.

Table 9-4 Local NRCS and FSA Contact Information

Contact	Address	Phone
Local NRCS Office		
W. Scott Martin	1213 N. 14th Street, Murphysboro, Illinois 62966	618-684-3064 x3
Local FSA Office		
Murphysboro Service Center	1213 N. 14th Street, Murphysboro, Illinois 62966	618-684-3471

9.2.2 Cost Estimates of BMPs

Cost estimates for different BMPs and individual practice prices such as filter strip installation are detailed in the following sections. Table 9-5 outlines the cost of implementation measures per acre. Finally, an estimate of the total order of magnitude costs for implementation measures in the Kinkaid Lake Watershed are presented in Section 9.2.2.6 and Table 9-6.

9.2.2.1 Wetland

The price to establish a wetland is site specific. In general, the cost to construct a wetland includes creation of wetland hydrology, site preparation for planting, shrub or tree planting, and labor costs. The average project cost to establish a wetland in Jackson County is $1,280/acre. It should be noted that the larger the wetland acreage to be established the more cost-effective the project.

9.2.2.2 Filter Strips and Riparian Buffers

Jackson County NRCS estimates an average cost per acre to install and maintain a grass filter strip with a 10-year life span at $90/acre. This price quote accounts for seeding and mowing every other year to remove woody sprouts. A riparian buffer strip established with bare root stock has a life span of 10-years and an installation cost of $384/acre.

9.2.2.3 Nutrient Management Plan – NRCS

Generally, agricultural land in Jackson County is comprised of cropland; therefore, nutrient management concentrates on nitrogen, phosphorus, potassium, lyme, and pest management residuals. The Nutrient Management Program in Jackson County consists of soil testing every three years using University of Illinois Guidelines and site specific recommendations for fertilizer application based on determined credits and realistic crop yields. The service averages $10/acre.

9.2.2.4 Nutrient Management Plan – IDA and Illinois EPA

The costs associated with development of Nutrient Management Plans co-sponsored by the IDA and the Illinois EPA is estimated as $5/acre paid to the producer and

$2/acre for a third party vendor who develops the plans. The total plan development cost is estimated at $7/acre.

9.2.2.5 Conservation Tillage

Conservation tillage is assumed to include tillage practices that preserve at least 30 percent residue cover of the soil after crops are planted. The installation cost for conservation tillage is $17/acre, and the average annual cost for maintaining conservation tillage is $17.35/acre/year (NCSU 2000).

9.2.2.6 Planning Level Cost Estimates for Implementation Measures

Cost estimates for different implementation actions are presented in Table 9-5. The column labeled *Program or Sponsor* lists the financial assistance program or sponsor available for various BMPs. The programs represented in the table are the WRP and the CRP.

Table 9-5 Cost Estimate of Various BMP Measures in Jackson County

Source	Program or Sponsor	BMP	Life Span	Installation Mean $/acre	Maintenance $/ac/yr
Nonpoint	WRP	Wetland	10	$1,280	$128.00
	CRP	Grass Filter Strips	10	$90	$9.00
	CRP	Riparian Buffer	10	$384	$38.40
	NRCS	Nutrient Management Plan		$10	
	IDA and Illinois EPA	Nutrient Management Plan		$7	
	CRP	Conservation Tillage	1	$17	$17.35

A total order of magnitude cost for implementation measures in the watershed was estimated to be $266,000. The total cost is calculated as the number of acres over which a BMP or structural measure is applied by the cost per acre. Table 9-6 summarizes the number of acres each measure is applied to in the basin and the corresponding cost. The acreages reported in Table 9-6 are a preliminary estimate in order to provide an overall understanding of cost of implementation in the watershed. The total only represents capital costs and annual maintenance costs. These do not represent the costs of operating the measure over its life cycle. The IDA and Illinois EPA sponsored nutrient management plan is applied to all cropland acres in the Kinkaid Lake Watershed, whereas the costs for conservation tillage were only developed for Subbasin 1.

Table 9-6 Cost Estimate of Implementation Measures for Kinkaid Lake Watershed

BMP	Treated Acres	Capital Costs		Maintenance Costs	
		Mean $/acre	Watershed $	$/ac/yr	Watershed $/yr
Wetland on River	134	$1,280	$172,000	$128.00	$17,000
Grass Filter Strips	107	$90	$10,000	$9.00	$1,000
Nutrient Management Plan	4,327	$7	$30,000		
Conservation Tillage	3,200	$17	$54,000	$17.35	$56,000
Total			**$266,000**		**$74,000**

9.3 Monitoring Plan

The purpose of the monitoring plan for Kinkaid Lake is to assess the overall implementation of management actions outlined in this section. This can be accomplished by conducting the following monitoring programs:

- Track implementation of management measures in the watershed
- Estimate effectiveness of management measures
- Continue ambient monitoring of Kinkaid Lake
- Tributary monitoring

Tracking the implementation of management measures can be used to address the following goals (NCSU 2000):

- Determine the extent to which management measures and practices have been implemented compared to action needed to meet TMDL endpoints
- Establish a baseline from which decisions can be made regarding the need for additional incentives for implementation efforts
- Measure the extent of voluntary implementation efforts
- Support workload and costing analysis for assistance or regulatory programs
- Determine the extent to which management measures are properly maintained and operated

Estimating the effectiveness of the BMPs implemented in the watershed could be completed by monitoring before and after the BMP is incorporated into the watershed. Additional monitoring could be conducted on specific structural systems such as a constructed wetland. Inflow and outflow measurements could be conducted to determine site-specific removal efficiency.

Illinois EPA monitors Kinkaid Lake from April through October approximately every three years. Continuation of this monitoring will assess in-lake water quality as improvements in the watershed are completed. This data will also be used to assess whether water quality standards in the reservoir are being attained. Additionally, Illinois EPA conducted a Clean Lakes Study on Kinkaid Lake, which would provide instream nutrient data for Kinkaid Lake tributaries including dissolved and total phosphorus, during the summer of 2003.

Tributary monitoring is needed to better assess the contribution of internal loading to Kinkaid Lake. By having further knowledge on actual contributions from external loads, a better estimate of internal loads could occur. Along with this tributary monitoring, a stage discharge relationship could be developed with the reservoir spillway so that flows into the reservoir could be paired with tributary water quality data to determine total phosphorus load from the watershed. Data on the different

forms of phosphorus (dissolved, total, or orthophosphate) would also be beneficial to better assess reservoir response to phosphorus loading.

9.4 Implementation Time Line

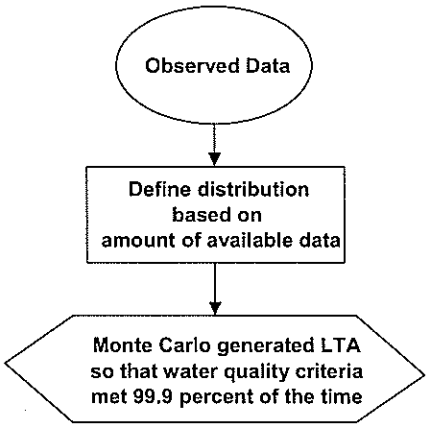
Implementing the actions outlined in this section for the Kinkaid Lake Watershed should occur in phases and the effectiveness of the management actions should be assessed as improvements are made. It is assumed that it may take up to five years to secure funding for actions needed in the watershed and five to seven years after funding to implement the measures. Once improvements are implemented, it may take Kinkaid Lake 10 years or more to reach the water quality standard target of 0.05 g/L for total phosphorus and associated targets between 6.5 and 9 for pH (Wetzel 1983). In summary, to meet water quality standards in Kinkaid Lake may take up to 20 years to complete.

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Section 10
Methodology Development for the Big Muddy River Watershed

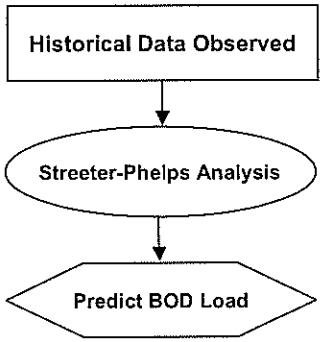
10.1 Methodology Overview

Methodologies were utilized in the TMDL analysis of the Big Muddy River segment N12. For manganese and sulfates, a Monte Carlo simulation was utilized to estimate a long-term average instream concentration needed to meet water quality standards. Investigation of DO required a Streeter-Phelps analysis.



Schematic 1

The schematic to the left shows how the Monte Carlo analysis was utilized to analyze manganese and sulfates. A distribution based on existing data is inputted in the Monte Carlo simulation program. This distribution is based on the amount of existing data available. Using this defined distribution, the computer simulation program randomly generates values to determine what long-term average (LTA) would be needed so that water quality criteria are met 99.9 percent of the time or so that water quality criteria are exceeded less than once every three years. The TMDL for manganese and sulfates will be based on this LTA. The randomly generated values generated by the Monte Carlo simulation are available in Appendix J.



Schematic 2

The Streeter-Phelps analysis was conducted as illustrated in the schematic to the right. Observed data were utilized to set up a Streeter-Phelps analysis to predict stream coefficients that would be required to result in observed DO concentrations. This Streeter-Phelps analysis was based on USEPA's Screening Procedures (Mills et al. 1985). The 5-day biochemical oxygen demand (BOD_5) load and reaeration coefficient (k_a) utilized in the Streeter-Phelps analysis were examined in the TMDL for DO for segment N12.

The procedure used to develop the TMDL for pH was based on an analytical procedure (Kentucky Department of Environmental Protection [KDEP] 2001). The procedure calculates a maximum allowable hydrogen ion loading in the water column to maintain pH standards.

10.2 Watershed Delineation

A watershed for the area contributing directly to Big Muddy River segment N12 was delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation suggests that segment N12 captures flows from a directly contributing watershed of approximately 28 square miles. Figure 10-1 at the end of this section shows the location of the water quality stations in the Big Muddy River segment N12 and the boundary of the GIS-delineated watershed contributing to the segment N12.

10.3 Methodology Development and Results

This section discusses the methodologies utilized to examine manganese, sulfates, DO, and pH levels in the Big Muddy River Watershed.

10.3.1 Monte Carlo Analysis Development and Results

For each constituent exceeding water quality standards, the available data was analyzed and an appropriate distribution was chosen to represent the data. A lognormal distribution, defined as a distribution of a random variables whose logarithm is normally distributed, was chosen to analyze segment N12 since sufficient data for this site was available to utilize this distribution.

Each constituent was evaluated separately using @RISK, which is a Microsoft® *Excel* add-in for the Monte Carlo analysis. The @RISK analysis package performed 10,000 iterations to determine the required percent reduction such that the water quality criteria would be met at least 99.9 percent of the time. The 99.9 percent of time value matches the Illinois EPA's 303(d) listing criteria of less than once in a three-year allowable excursion of water quality standards. For each simulation, the required percent reduction is:

$$PR = \text{maximum } \{0, (1-Cc/Cd)\}$$

where: PR = Required percent reduction for the current iteration
Cc = Water quality criterion in mg/L
Cd = Randomly generated pollutant source concentration in mg/L based on the lognormal distribution

An allowable LTA instream concentration was determined for each impaired constituent. The Monte Carlo simulation analysis is designed to identify a LTA value that will meet the water quality criterion for that parameter 99.9 percent of the time. The Monte Carlo simulation was run using 10,000 iterations with the triangular distribution. For each iteration, a concentration, Cd, is randomly generated according to a specified distribution determined by observed data. For each concentration generated, a percent reduction was calculated, if necessary, to meet water quality criteria. The mean concentration value is multiplied by the inverse of the required percent reduction to compute the long-term daily average concentration that needs to be met to achieve the water quality standard.

The overall percent reduction required is the 99.9th percentile value of the probability distribution generated by the 10,000 iterations, so that the allowable LTA concentration is:

LTA = Mean * (1 - PR99.9)

10.3.1.1 Monte Carlo Results for Big Muddy River Segment N12

Manganese values in Segment N12 ranged from 0.1 to 2.5 mg/L and sulfates values ranged from 59 to 660 mg/L as shown in Table 5-8. Two of the output model concentrations are significant to the TMDL analysis of segment N12. The first is the average concentration calculated from the triangular distribution of the observed data. The second concentration is the LTA, which represents the average concentration that should be observed over the long term to ensure that the water quality standard is exceeded fewer than once every three years. Table 10-1 shows the average concentration calculated from the distribution utilized in the Monte Carlo analysis and the LTA concentration needed so that water quality standards will be achieved in Big Muddy River segment N12. Calculation details are presented in Appendix E.

Table 10-1 LTA Manganese and Sulfates Concentrations Required to Meet Water Quality Standards in Big Muddy River Segment N12

Constituent	Average Concentration Calculated from Distribution (mg/L)	LTA Concentration (mg/L)
Manganese	0.6	0.2
Sulfates	247	104

Table 10-1 shows that the concentration required to meet water quality reductions, the LTA, is lower than the observed average concentration for manganese and sulfates; therefore, the TMDL for segment N12 requires that a load reduction be made for manganese and sulfates based upon the available data. The TMDL will be discussed in Section 11.

10.3.2 DO Analysis Development and Results

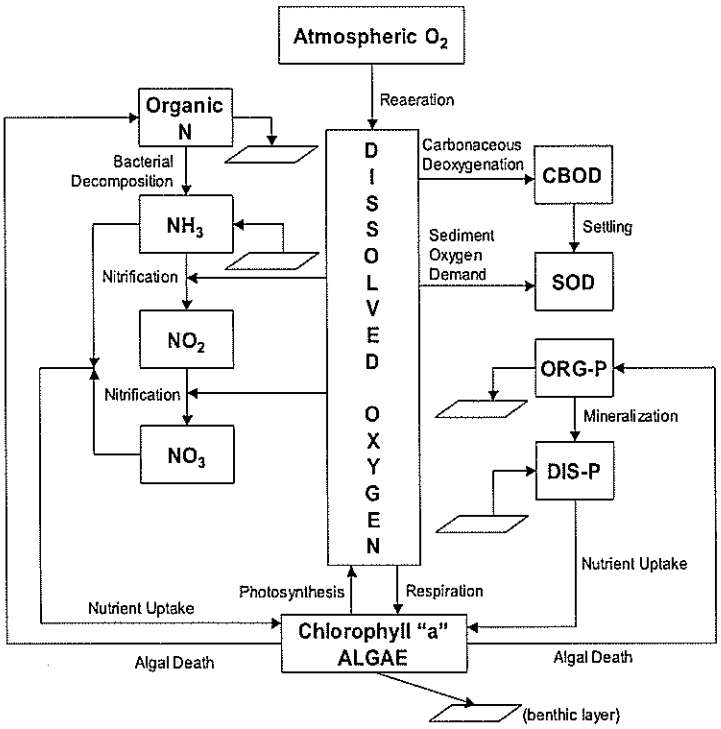
A Streeter-Phelps analysis was utilized for investigation of DO in the Big Muddy River segment N12 Watershed. Data availability useful for analyzing DO for this watershed is described in Table 10-2. The historic water quality data were investigated from 1990 to 2000.

Table 10-2 Data Availability from 1990 to 2000

Model Parameter	Historic data available (yes/no)
Flow	Yes
Stream Temperature	Yes
DO	Yes
5-Day Carbonaceous Biochemical Oxygen Demand ($CBOD_5$)	No
BOD_5	No
Total Nitrogen	No
Total Organic Carbon	Yes
Ammonia	Yes
Nitrate + Nitrite	Yes
Total Kjeldahl Nitrogen	Yes
Total Phosphorus	Yes
Dissolved Phosphorus	Yes
Orthophosphate	Yes
pH	Yes
20-Day Carbonaceous Biochemical Oxygen Demand ($CBOD_{20}$)	No
Daily Minimum And Maximum DO	No
Chlorophyll "a"	No
Stream Depth	Yes

The lack of various constituent samples from historic data sites in the Big Muddy River Watershed limits the modeling tools available for DO. Therefore, a Streeter-Phelps analysis was developed to examine the DO relationship with BOD_5 in the Big Muddy River. The diagram on the following page shows the interactions of DO with different processes within the water column of the stream (USEPA 1997b). The consumers of DO include:

- Deoxygenation of biodegradable organics whereby bacteria and fungi (decomposers) utilize oxygen in the bioxidation-decomposition process
- Sediment oxygen demand (SOD), where oxygen is utilized by organisms inhabiting the upper layers of the bottom sediment deposits
- Nitrification, in which oxygen is utilized during oxidation of ammonia and organic nitrogen to nitrates
- Respiration by algae and aquatic vascular plants that use oxygen during night and early morning hours to sustain their living processes

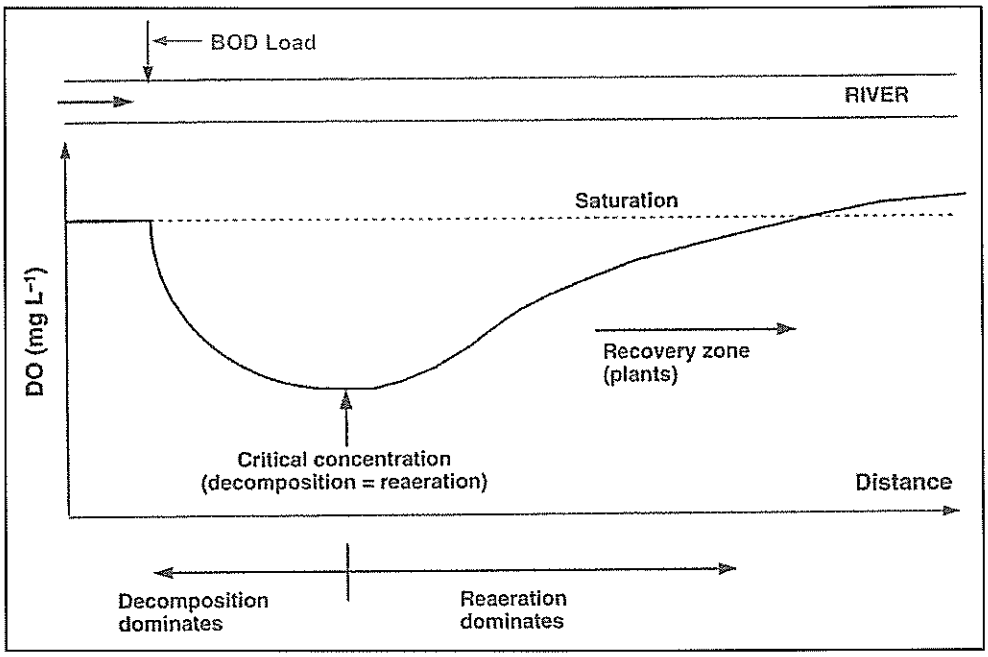


Major oxygen sources are:

- Atmospheric reaeration, where oxygen is transported from the air into the water through turbulence at the air-water interface
- Photosynthesis, where chlorophyll-containing organisms (producers such as algae and aquatic plants) convert carbon dioxide to organic matter with a consequent production of oxygen

Streeter and Phelps (1925) proposed the basic concept of the DO balance in streams. The Streeter-Phelps equation predicts the DO "sag" that occurs after biodegradable constituents are discharged into streams. A biodegradable constituent is anything that can be broken down by microorganisms. BOD is the measure of the quantity of oxygen consumed by microorganisms during the decomposition of organic matter. When nutrients such as nitrate and phosphate are released into the water, growth of algae and aquatic plants is stimulated. The result is an increase in microbial populations, higher levels of BOD, and increased oxygen demand from the photosynthetic organisms during the dark hours. This results in a reduction in DO concentrations, especially during the early morning hours just before dawn.

In addition to natural sources of BOD, such as leaf fall from vegetation near the water's edge, aquatic plants, and drainage from organically rich areas like swamps and bogs, there are also anthropogenic (human) sources of organic matter. Point sources, which may contribute high levels of BOD, include wastewater treatment facilities. Organic matter also comes from nonpoint sources such as agricultural runoff, urban runoff, and livestock operations. Both point and nonpoint sources can contribute significantly to the oxygen demand in a water body. The DO sag is shown in the following figure (Chapra 1997):



Water quality models have built upon the Streeter-Phelps equation to evaluate the DO balance in streams. The analysis for segment N12 is based on BOD_5 and reaeration only. There is not enough coincident nutrient and algal historical data from this site to assess impacts of nutrient loads on algal growth that also impact DO levels. Free floating and attached algae as well as aquatic plants are of concern. The extent to which algae impact the DO resources of a river is dependent on many factors, such as turbidity, which can decrease light transmittance through the water column. Additionally, the photosynthetic rate constantly changes in response to variations in sunlight intensity and is not constant. This results in diurnal fluctuations in DO levels (Mills et al. 1985). In addition, there is not enough data available to estimate the impacts of SOD at these sites.

The Streeter-Phelps analysis was based on the following equation (Mills et al. 1985):

where: DO_o = Calculated DO concentration (mg/L)
D_S = DO at saturation (mg/L)
D_o = Initial DO deficit (mg/L)
k_a = Reaeration rate (1/day)
k_d = BOD_5 decay rate (1/day)
x = Distance downstream of discharge (ft)
v = Stream velocity (ft/day)
L_0 = Initial BOD_5 (mg/L) at x = 0

The initial BOD_5 concentration (L_o) was calculated from observed TOC data. Literature states that the ratio of BOD_5 to TOC is typically between 1.0 and 1.6

(Metcalf and Eddy, Inc. 1991). For analysis, a ratio of 1.3 was used to calculate BOD_5 for each sample date.

Literature provides equations to calculate both the BOD_5 decay rate coefficient (k_d) and reaeration rate coefficient (k_a). The decay rate coefficient is dependent on stream depth, and the reaeration coefficient is dependent on depth and velocity. Due to the limits of the data set shown in Table 5-10, the decay rate coefficient was calculated from either known depths or rating curves allowing the reaeration coefficient to be calculated from the Streeter-Phelps equation presented above as the only unknown variable. The rating curves used to determine depths are available in Appendix K.

The BOD_5 decay rate coefficient (k_d) at 20°C was calculated based on the following equation (USEPA 1997b):

$$k_{d20} = 0.3\left[\frac{H}{8}\right]^{-0.434} \quad \text{for } 0 < H < 8$$

$$= 0.3 \text{ for } H > 8$$

The BOD_5 decay rate coefficient was corrected for temperature with the following equation (Novotny and Olem 1994):

$$k_{dT} = k_{d20}\theta^{(T-20)}$$

where k_{dT} = BOD_5 decay rate coefficient at temperature T; T in °C
θ = Thermal factor

The thermal factor (θ) in the above equation has an accepted value of 1.047 for the BOD_5 decay rate coefficient (Novotny and Olem 1994). The decay rate coefficient typically falls between 0.02 and 3.4 day^{-1}. The reaeration rate coefficient typically ranges between 0 and 100 day^{-1} (USEPA 1997b).

For comparison purposes, the reaeration coefficient (k_a) was calculated based on the following equation (USEPA 1997b):

$$k_a = \frac{12.9\, v^{0.5}}{H^{1.5}} \text{ at } 20^\circ C$$

where: v = Stream velocity (feet/s)
H = Stream depth (feet)

Like the BOD_5 decay rate coefficient, the reaeration coefficient is corrected for temperature with the following equation (Novotny and Olem 1994):

$$k_{aT} = k_{a20}\theta^{(T-20)}$$

where: k_{dT} = Reaeration rate coefficient at temperature T; T in °C
θ = Thermal factor

The thermal factor (θ) for the reaeration coefficient has an accepted value of 1.025 (Novotny and Olem 1994).

Table 10-3 shows the observed TOC data and the BOD_5 concentrations (L_0) calculated from observed TOC data. It also shows the k_a and k_d coefficients calculated with the above equations. In addition, the estimated BOD_5 load was calculated based on the calculated BOD_5 concentration and average daily flow on the day the sample was taken. Revised k_a and k_d values are also shown in Table 10-3. These values were utilized in the Streeter-Phelps equation described above and the resulting calculated DO was compared to observed DO readings. If there was not a match between the calculated DO and observed DO, k_a and k_d were revised within their accepted ranges so that calculated DO more closely matched observed DO. If possible, only k_a was revised as it was calculated based on estimated depth and flow while k_d was based on estimated depth. As shown in Table 10-3, the reaeration coefficient was much lower for the impaired sample date than for the non-impaired date. Additionally, the flow for the impaired date was below average as discussed in Section 5.1.5.2.2. Analysis details are contained in Appendix L. In addition to lower flow condtions, there are many factors that may contribute to depressed DO in the Big Muddy River including nutrients stimulating algal activity and other organic loads which could exert an oxygen demand within the system.

Table 10-3 Streeter-Phelps Calculated BOD_5 Concentrations (L_0) and Loads Associated with DO Concentrations

Sample Location and Date	N12 7/24/2000	N12 9/6/2000
Measured DO (mg/L)	7.9	4.7
Measured TOC (mg/L)	5.6	5.5
Calculated BOD_5 Concentration (mg/L)	7.3	7.2
Calculated BOD_5 Load (lb/day)	81,071	15,526
Calculated k_a (1/day)	0.6	1.2
Revised k_a (1/day)	45.4	3.2
Calculated k_d (1/day)	0.36	0.46
Revised k_d (1/day)	0.36	0.46
Flow (cfs)	2,060	400

In addition to the analysis described above, analyses were conducted examining the Big Muddy River during 7Q10 flows or critical low flows with the Carbondale WWTP at its average design flow and BOD limit of 30 mg/L BOD. During these critical conditions, the discharge of the WWTP should not cause DO levels to fall below the 6.0 mg/L standard within segment N12. This was determined by assessing what BOD concentration would need to discharged from the facility to depress DO concentrations below 6 mg/L. It was estimated that a BOD concentration of over 450 mg/L would

have to be discharged in order for DO concentrations to fall below 6.0 mg/L. Therefore, no wasteload allocation will be recommended for this facility in Section 11. Analyses details are also contained in Appendix L.

An error analysis was run on the literature ranges of values for k_a and k_d for each sample date to validate their use for the Streeter-Phelps analysis. This analysis is contained in Appendix M.

10.3.3 pH Analysis Development and Results

An analytical method was used to analyze pH in segment N12 of the Big Muddy River. The method incorporates TDS concentrations, ionic strength, an activity coefficient, and flows to calculate a maximum hydrogen ion loading that will maintain a pH value between 6.5 and 9.0 within segment N12.

The ionic strength is calculated with the following equation:

$$\mu = (2.5 \times 10^{-5}) \times TDS$$

where: μ = ionic strength
TDS = 95th percentile concentration, mg/L or ppm

The 95th percentile concentration of TDS is used to provide a conservative estimate (Snoeyink and Jenkins 1980).

Activity coefficients are used to convert measured H^+ ion activity to molar H^+ ion concentration. The coefficient is dependent on ionic strength and is determined from literature (Snoeyink and Jenkins 1980). The maximum hydrogen ion loading for a particular flow and pH can then be calculated with the following equation:

$$[H^+] = \frac{10^{-pH} \times 1\,\text{gram/mole} \times 28.37\,\text{L/ft}^3 \times Q \times 86400\,\text{s/day}}{\gamma}$$

where: $[H^+]$ = ion load, lb/d
Q = flow, cfs
γ = activity coefficient

This equation can be used to develop the maximum allowable hydrogen ion concentration for a specific pH and varying flow regimes. Figure 10-2 shows the maximum allowable H^+ ion loading at a pH of 6.5 for various flows. Using a pH of 6.5 and the three-year peak flow in the above equation will result in the maximum hydrogen ion concentration allowed to maintain a pH of at least 6.5. The three-year peak flow is utilized because pH is considered a potential cause of use impairment if the water quality standard is at least once in the most recent three-year period (Illinois EPA 2000) allowable excursion.

The 95th percentile of the TDS concentrations in segment N12 is 1,194 mg/L resulting in an ionic strength of 0.02. An activity coefficient of 0.9 was determined from literature for segment N12. The chart used to determine the activity coefficient is provided in Appendix N. As mentioned in Section 5.1.3, flows for segment N12 were obtained from USGS gage 05599500. A lognormal distribution was used to develop the three-year peak flow through segment N12 of 16,426 cfs. Using this flow in the above equation, a maximum allowable hydrogen ion concentration of 14,200 g/day or 31 lb/day was calculated. Analysis details are contained in Appendix O.

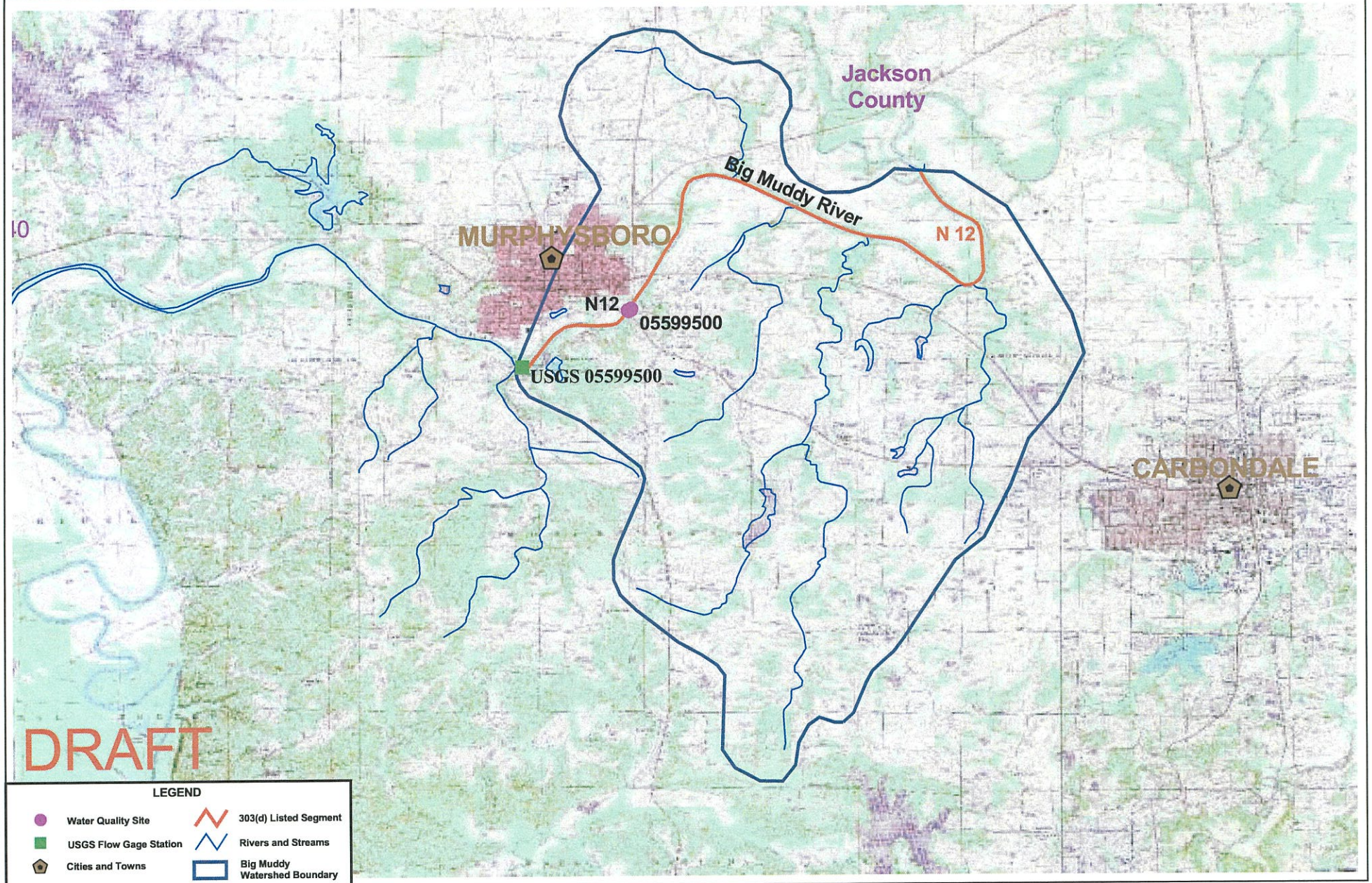


Figure 10-1
Big Muddy River #1 Watershed &
Historic Sampling Locations

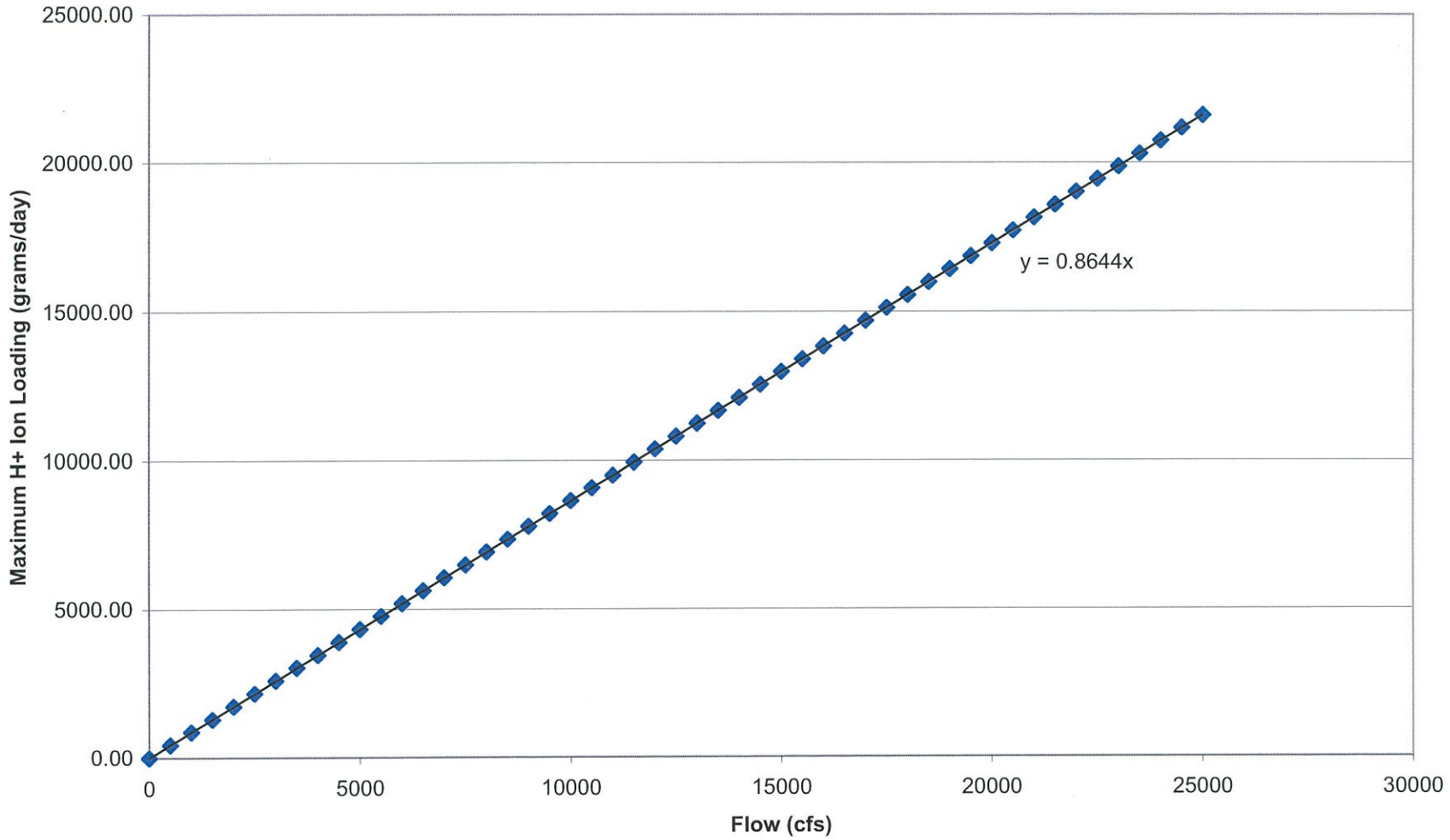
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Figure 10-2: Flow versus Maximum H^+ Ion Loading at a Constant pH of 6.5



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Section 11
Total Maximum Daily Load for Big Muddy River Watershed

11.1 TMDL Endpoints for the Big Muddy River

The TMDL endpoints for manganese, sulfates, pH, and DO in a stream segment are summarized in Table 11-1. For manganese and sulfates, the concentrations must be below the TMDL endpoint. For DO, concentrations must be greater than 6.0 mg/L for 16 hours of any 24-hour period. For pH, the desired measurement is between the endpoint limits. These endpoints are based on protection of aquatic life in the Big Muddy River and its tributaries. Some of the average concentrations, which are based on a limited data set, meet the desired endpoints. However, the data set has maximum or minimum values, presented in Section 5.1.5.2.4, that do not meet the desired endpoints and this was the basis for TMDL analysis. Further monitoring as outlined in the monitoring plan presented in Section 12, will help further define when impairments are occurring in the watershed and support the TMDL allocations outlined in the remainder of this section.

Table 11-1 TMDL Endpoints and Average Observed Concentrations for Impaired Constituents in the Big Muddy River Watershed

Constituent	TMDL Endpoint	Average Observed Value for N12
Manganese	1.0 mg/L	0.6 mg/L
Sulfates	500 mg/L	250 mg/L
DO	6.0 mg/L (16 hours of any 24-hour period)	8.5 mg/L
pH	6.5 - 9 s.u.	7.3 s.u.

11.2 Pollutant Source and Linkages

Pollutant sources for the Big Muddy River were identified through the existing data review described in Section 5. Based on the data review, the source of manganese and sulfates in the Big Muddy River segment N12 is groundwater potentially contaminated by abandoned coal mines. The likely source of oxygen demanding constituents is primarily factors occurring during low flow conditions, such as slow-moving waters and increased water temperatures promoting algal growth. Nonpoint source loads in the watershed may also contribute to low DO in the stream. Sources of low pH include acid mine drainage and fluctuations due to algal growth in aquatic systems.

11.3 Allocation

As explained in Section 1, the TMDL for Big Muddy River segment N12 will address the following equation:

$$TMDL = LC = \Sigma WLA + \Sigma LA + MOS$$

where: LC = Maximum amount of pollutant loading a water body can receive without violating water quality standards
WLA = The portion of the TMDL allocated to existing or future point sources
LA = Portion of the TMDL allocated to existing or future nonpoint sources and natural background
MOS = An accounting of uncertainty about the relationship between pollutant loads and receiving water quality

Each of these elements will be discussed in this section as well as consideration of seasonal variation in the TMDL calculation.

11.3.1 Manganese and Sulfates TMDL

11.3.1.1 Loading Capacity

The loading capacity for manganese and sulfates for impaired segment N12 was based on the Monte Carlo analysis described in Section 10. The LTA, determined by analysis to meet water quality standards generated from the Monte Carlo analysis, is the basis for loading capacity for segment N12. This LTA was multiplied by average flow in each segment to determine an average load. These average loads are shown in Table 11-2.

Table 11-2 Average Loads Based on LTA for Manganese and Sulfates

Constituent	LTA (mg/L)	Allowable Load (lb/day)
Manganese	0.2	2,244
Sulfates	103.7	1,163,422

11.3.1.2 Seasonal Variation

A season is represented by changes in weather; for example, a season can be classified as warm or cold as well as wet or dry. Seasonal variation is represented in the Big Muddy River segment N12 TMDL as conditions were investigated during all seasons of the year. Section 5.1.3 discusses the flow data available for Segment NC12 and Section 5.1.5 and Appendix A contain the water quality data available for manganese and sulfate. A review of the flow data and water quality data (Figures 5-4 and 5-5) show that the water quality data were gathered at various times during the year, thus capturing seasonal variations in loadings into the river. Since the various pollutant sources are expected to contribute loadings in different quantities during different time periods (e.g., spring run-off loads), the loadings for this TMDL will focus on a LTA loading rather than specifying different loadings by season. As more data are gathered, further refinement of the seasonal variation may be possible.

11.3.1.3 Margin of Safety

The MOS can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a

combination of both. An explicit MOS of 10 percent is recommended for manganese and sulfates in the Big Muddy River segment N12 Watershed because of the limited data set available for analysis and because Monte Carlo analysis incorporates uncertainty to some degree into the LTA.

Uncertainty in water quality is accounted for in the Monte Carlo analysis based upon how the analysis is done. The distribution of the water quality data is estimated and numerous iterations are run to determine the reduction needed to meet the target of one exceedence in three years. A data set with significant variation will result in a final target (LTA) that is significantly lower than the water quality standard as compared to a data set with little variation that would likely result in a LTA being slightly lower than the water quality standard. By this process, uncertainty in the data is addressed. For these reasons, an explicit 10 percent MOS is considered appropriate based upon the data available. As more data become available such as a regression analysis between flow and in-stream concentrations, the MOS could be revisited and revised if appropriate.

11.3.1.4 Waste Load Allocation

TMDLs completed in upstream watersheds that relate to mining activity will help reduce pollutant loads to segment N12. This also applies to the next section discussing Load Allocation.

11.3.1.5 Load Allocation and Summary TMDLs

Table 11-3 shows a summary of the TMDL for manganese and sulfates in the Big Muddy River segment N12 watershed. The calculated allowable loads (LC) necessary to maintain the water quality standard are reduced by the MOS, representing the uncertainty in the data analysis, to determine the allowable loading from the watershed, the LA. The LC was calculated from the LTA presented in Section 10.3.1. Reductions of 70 percent for manganese and 62 percent for sulfates were estimated as the required decreases in loadings so that water quality standards will be met in the stream segments.

Table 11-3 TMDL Summary for Manganese and Sulfates

Constituent	LC (lb/day)	WLA (lb/day)	LA (lb/day)	MOS (lb/day)	Reduction Needed (lb/day)	Reduction Needed (percent)
Manganese	2,244	0	2,020	224	4,662	70%
Sulfates	1,163,422	0	1,047,080	116,342	1,722,615	62%

Table 11-4 LTAs Required Based on TMDL MOS

Constituent	Monte Carlo LTA (mg/L)	Recalculated LTA (mg/L)
Manganese	0.20	0.18
Sulfates	103.7	93

The required LTAs presented in Section 10 and in Table 11-2 were reduced because of the applied MOS and are presented in Table 11-4. The recalculated LTA represents the LA in Table 11-3. Methods to meet these LTAs will be outlined in Section 12.

11.3.2 DO TMDL

11.3.2.1 Loading Capacity

As discussed in Section 10.3.2, the analysis suggests that the principle cause of DO impairments in segment N12 is a lack of aeration caused by low flows. Table 11-5 shows the aeration coefficient calculated from the observed DO in Section 10.3 for sample dates that did not meet the TMDL endpoint and the coefficient that would be required to meet the TMDL endpoint of 6.0 mg/L DO (16 hours of any 24-hour period) for sampling events that had DO measurements less than 6.0 mg/L. Increasing aeration in the stream is not a parameter for which a TMDL can be developed. Therefore, no loading capacity will be developed at this time. Methods to achieve elevated reaeration coefficients will be outlined in Section 10.

Table 11-5 Calculated Reaeration Coefficients and Required Reaeration Coefficients in the Big Muddy River Segment N12 Watershed Based on TMDL Endpoint for DO

Segment	Date	Measured DO Concentration (mg/L)	Modeled k_a (1/day)	Required k_a (1/day)
N12	9/6/00	4.7	3.2	11.5

Based on the data analysis, increases of aeration would be required in summer months but not during winter conditions. Monitoring data to make the analysis more robust will be discussed in Section 12 as well as management measures to increase aeration and reduce nonpoint source loads contributing to non-attainment of the DO water quality standard.

To confirm that reductions in BOD_5 loads to meet the water quality standard are not an appropriate measure for controlling DO in this watershed, the Streeter-Phelps equations presented in Section 10.3.2 were used to estimate the BOD_5 loading required to meet the water quality standard on each sample date impaired for DO.

Table 11-6 shows the BOD_5 loads estimated from TOC as discussed in Section 10.3.2 and the BOD_5 loading that would be necessary to meet water quality standards.

Table 11-6 Calculated BOD_5 Loads and Required Loads in the Big Muddy River Segment N12 Watershed Based on TMDL Endpoint for DO

Segment	Date	Measured DO Concentration (mg/L)	Calculated BOD_5 (lb/d)	Required BOD_5 (lb/d)
N12	9/6/00	4.7	7.2	0

Table 11-6 shows that the reductions in BOD_5 loads necessary for compliance with the DO loads are not a feasible option for increasing DO in the Big Muddy River Watershed.

11.3.3 pH TMDL

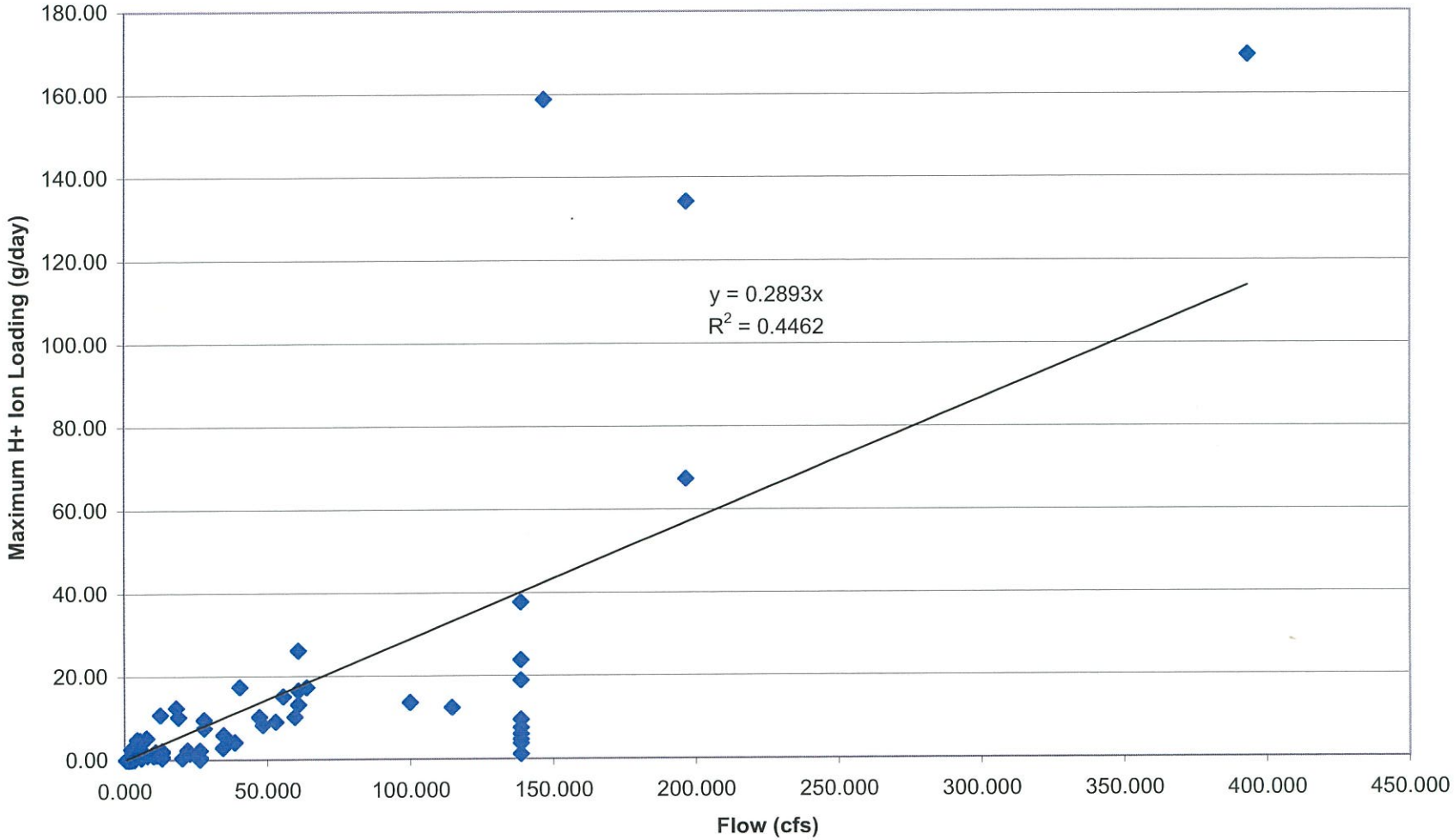
Figure 11-1 shows the existing maximum hydrogen ion concentration versus flow using hydrogen concentrations calculated from the pH sample data for segment N12 and the equation presented in Section 10.3.3. From this figure, the maximum hydrogen

ion concentration for the three-year peak flow of 16,426 cfs was determined as 10.5 lb/day. The allowable maximum hydrogen ion concentration calculated in Section 10 is 31 lb/day. The existing concentration is below the allowable concentration indicating that no allocations are necessary at this time to meet the TMDL endpoint for pH in Big Muddy River segment N12. Because the relationship between hydrogen ion concentration and pH is an inverse log-arithmetic function, since the maximum load is greater than the allowable load no allocations are needed to increase the pH within the watershed.

Since current pH loadings are less than the allowable loading predicted from analysis, no TMDL for pH is recommended at this time. Although no TMDL is recommended, the implementation strategies outlined in Section 12 will also help control pH in the Big Muddy River segment N12 Watershed.

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Figure 11-1: Flow versus Maximum H^+ Ion Loading for Segment N12 of the Big Muddy River



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Section 12
Implementation Plan for Big Muddy River Watershed

12.1 Implementation Actions and Management Measures for Manganese and Sulfates

An adaptive management or phased approach is recommended for the manganese and sulfates TMDL for this watershed, because of the limited amount of longitudinal data available for the TMDL analysis of segment N12 in the Big Muddy River Watershed. Longitudinal data would be represented by multiple sampling locations in segment N12. Adaptive management is a systematic process for continually improving management policies and practices through learning from the outcomes of operational programs. Some of the differentiating characteristics of adaptive management are:

- acknowledgement of uncertainty about what policy or practice is "best" for the particular management issue,
- thoughtful selection of the policies or practices to be applied (the assessment and design stages of the cycle),
- careful implementation of a plan of action designed to reveal the critical knowledge that is currently lacking.
- monitoring of key response indicators,
- analysis of the management outcomes in consideration of the original objectives, and incorporation of the results into future decisions (British Columbia Ministry of Forests 2000).

Based on existing data review, presented in Section 10, the likely sources of manganese and sulfates in the Big Muddy River segment N12 watershed are from abandoned mines. Further source identification is required as outlined in the next section. Acid mine drainage and excessive algal growth could cause pH impairments, but as explained in Section 11, no TMDL for pH is recommended at this time. BMPs recommended for DO, manganese, and sulfates should also help mitigate pH impairments.

12.1.1 Source Identification for Manganese and Sulfates

It is recommended that further source identification activities take place within the watershed because the current data regarding sources of manganese and sulfates in the segment N12 watershed is limited. The GIS data and mapping provided in Section 5 (Figure 5-1) should be the basis for the start of the source investigation. Collection of data during various flow conditions may also be beneficial in determining the source of these constituents. For the segment N12 watershed, the location of the potential

discharge from the abandoned coal mines should be identified in addition to other mining activity, which could contribute manganese and sulfate concentrations in the receiving waters. Once potential sources are identified and located, sampling stations should be placed in appropriate locations to assess water quality downstream of these sources. The potential source identification and station sampling placement should be the result of field investigations.

Although the watershed delineation through mined areas may not be exact, the implementation actions and management measures remain applicable to the entire Big Muddy River Watershed.

12.1.2 Manganese and Sulfates Management Measures

It is likely that the main contributors to impairments within the watershed are abandoned mine sites. If the major source of manganese and sulfates in the segment N12 watershed is attributed to abandoned mining, active chemical treatment methods, passive treatment methods, and mine reclamation are available. Active chemical treatment typically involves the addition of alkaline chemicals, such as calcium carbonate, sodium hydroxide, sodium bicarbonate, and anhydrous ammonia to acid mine drainage. These chemicals raise the pH to acceptable levels and decrease the solubility of dissolved metals. Metal precipitates form and settle out of the solution. Active chemical treatment is not a viable option for the segment N12 watershed because the chemicals are expensive, and the treatment system requires additional costs associated with operation and maintenance as well as the disposal of metal-laden sludge.

Reclamation of abandoned mines is another method of controlling pollutants. Reclamation of abandoned mine land involves clearing site vegetation, removing contaminated topsoil and coal, and restoring functionality of the site for recreational, agricultural, or wildlife habitat purposes. The environmental benefits realized from abandoned mine reclamation projects are numerous and significant, including restoring land for future use and improving water quality. Restoration of the land can result in increased and enhanced pasture land, recreational areas, or wildlife habitat (Pennsylvania Department of Environmental Protection [PDEP] 2002). However, reclamation projects tend to be costly and resource intensive and may not be appropriate for abandoned mine sites in segment N12 watershed.

Passive methods could be utilized until full reclamation of a mine occurs. Chemical addition and energy consuming treatment processes are virtually eliminated with passive treatment systems. The operation and maintenance requirements of passive systems are considerably less than active treatment systems (PDEP 2002). Therefore, passive treatment systems would be the best solution for controlling manganese and sulfates from abandoned coal mines in segment N12 of the Big Muddy River Watershed.

Following are examples of the passive treatment technologies:

- Aerobic wetland
- Compost or anaerobic wetland
- Open limestone channels
- Diversion wells
- Anoxic limestone drains
- Vertical flow reactors
- Pyroclastic process

The remainder of this section discusses these technologies.

12.1.2.1 Aerobic Wetland

An aerobic wetland consists of a large surface area pond with horizontal surface flow. The pond may be planted with cattails and other wetland species. Aerobic wetlands can only effectively treat water that is net alkaline (pH greater than 7). In aerobic wetland systems, metals are precipitated through oxidation reactions to form oxides and hydroxides. A typical aerobic wetland will have a water depth of 6 to 18 inches (PDEP 2002).

12.1.2.2 Compost or Anaerobic Wetland

Compost wetlands, or anaerobic wetlands as they are sometimes called, consist of a large pond with a lower layer of organic substrate. The flow is horizontal within the substrate layer of the basin. Piling the compost a little higher than the free water surface can encourage the flow within the substrate. Typically, the compost layer consists of spent mushroom compost that contains about 10 percent calcium carbonate. Other compost materials include peat moss, wood chips, sawdust, or hay. A typical compost wetland will have 12 to 24 inches of organic substrate and be planted with cattails or other emergent vegetation (PDEP 2002).

12.1.2.3 Open Limestone Channels

Open limestone channels may be the simplest passive treatment method. Open limestone channels are constructed in two ways. In the fist method, a drainage ditch constructed of limestone collects contaminated acid mine drainage water. The other method consists of placing limestone fragments directly in a contaminated stream. Dissolution of the limestone adds alkalinity to the water and raises the pH. This treatment requires large quantities of limestone for long-term success (PDEP 2002).

12.1.2.4 Diversion Wells

Diversion wells are another simple way to increase the alkalinity of contaminated waters. Acidic water is conveyed by a pipe to a downstream "well," which contains crushed limestone aggregate. The hydraulic force of the pipe flow causes the limestone to turbulently mix and abrade into fine particles preventing armoring (PDEP 2002).

12.1.2.5 Anoxic Limestone Drains

An anoxic limestone drain is a buried bed of limestone constructed to intercept subsurface mine water flow and prevent contact with atmospheric oxygen. Keeping

oxygen out of the water prevents oxidation of metals and armoring of the limestone. An anoxic limestone drain can be considered a pretreatment step to increase alkalinity and raise pH before the water enters a constructed aerobic wetland (PDEP 2002).

12.1.2.6 Vertical Flow Reactors

Vertical flow reactors were conceived as a way to overcome the alkalinity producing limitations of anoxic limestone drains and the large area requirements of compost wetlands. The vertical flow reactor consists of a treatment cell with an underdrained limestone base topped with a layer of organic substrate and standing water. The water flows vertically through the compost and limestone and is collected and discharged through a system of pipes. The vertical flow reactor increases alkalinity by limestone dissolution and bacterial sulfate reduction (PDEP 2002).

12.1.2.7 Pyrolusite Process

This is a patented process, which utilizes site-specific cultured microbes to remove iron, manganese, and aluminum from acid mine drainage. The treatment process consists of a shallow bed of limestone aggregate inundated with acid mine drainage. After laboratory testing determines the proper combination, microorganisms are introduced to the limestone bed by inoculation ports located throughout the bed. The microorganisms grow on the surface of the limestone chips and oxidize the metal contaminants while etching away limestone, which in turn increases the alkalinity and raises the pH of water. This process has been used on several sites in western Pennsylvania with promising results (PDEP 2002).

12.2 Implementation Actions and Management Measures for Dissolved Oxygen

DO impairments are addressed by focusing on organic loads that consume oxygen through decomposition and nutrient loads that can cause algal growth, which can also deplete DO. Analysis provided in Section 10 established a relationship between reaeration, BOD_5, and DO concentrations in Big Muddy River segment N12, so management measures for segment N12 will focus on increasing reaeration decreasing BOD_5 loads to increase DO concentrations.

DO impairments in Big Muddy River segment N12 are mostly attributed to low flow or stagnant conditions within the creek. Runoff from nonpoint sources may also contribute a BOD_5 load in Big Muddy River segment N12. An additional contributor to low DO is increased water temperatures. Therefore, management measures for the segment N12 watershed will focus on reducing nonpoint source loading through sediment and surface runoff controls, reducing stream temperatures, and reducing stagnant conditions through reaeration.

Implementation actions, management measures, or BMPs are used to control the generation or distribution of pollutants. BMPs are either structural, such as wetlands, sediment basins, fencing, reaeration structures, or filter strips; or managerial, such as conservation tillage, nutrient management plans, or crop rotation. Both types require

good management to be effective in reducing pollutant loading to water resources (Osmond et al. 1995).

It is generally more effective to install a combination of BMPs or a BMP system. A BMP system is a combination of two or more individual BMPs that are used to control a pollutant from the same critical source. In other words, if the watershed has more than one identified pollutant, but the transport mechanism is the same, then a BMP system that establishes controls for the transport mechanism can be employed. (Osmond et al. 1995).

Implementation actions and management measures are described for each nonpoint source in the watershed. Nonpoint sources include cropland, rural grassland, and animal management facilities.

12.2.1 DO Concentration Management

The sources of nonpoint source pollution in the Big Muddy River TMDL are divided between agricultural cropland and rural grasslands. There are three animal management facilities in the watershed. Although, two have been classified as no impact facilities, the third has not been assessed. BMPs evaluated for treatment of these nonpoint sources are:

- Filter strips
- Wetlands
- Reaeration

Organic and nutrient loads originating from cropland is most efficiently treated with a combination of riparian buffer or grass filter strips. Wetlands can be used to treat pollutant loads originating from animal management operations. Instream management measures for DO focus on reaeration techniques. The Streeter-Phelps equations presented in Section 10 utilizes a reaeration coefficient. Increasing the reaeration coefficient by physical means will increase DO in Big Muddy River segment N12.

12.2.1.1 Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment, to the Big Muddy River segment N12. Filter strips implemented along stream segments slow and filter nutrients and sediment out of runoff, help reduce stream water temperatures thereby increasing the water body DO saturation level, and provide bank stabilization decreasing erosion and deposition. The following paragraphs focus on the implementation of filter strips in Big Muddy River segment N12 watershed. Finally, design criteria and size selection of filter strips are detailed.

Organic debris in topsoil contributes to the BOD_5 load to water bodies (USEPA 1997). Increasing the length of stream bordered by grass and riparian buffer strips will decrease the amount of BOD_5 and nutrient load associated with sediment loads to Big Muddy River segment N12. Nutrient criteria, currently being developed and expected

to be adopted around 2007 by the Illinois EPA, will assess the instream nutrient concentrations required for the watershed. As stated previously, excess nutrients in streams can cause excessive algal growth, which can deplete DO in streams. Adoption of nutrient criteria will potentially affect this DO TMDL and help control exceedences of DO water quality criteria in Big Muddy River segment N12.

Filter strips will help control BOD_5 levels by removing organic loads associated with sediment from runoff; however, no studies were identified as providing an estimate of removal efficiency. Grass filter strips can remove as much as 75 percent of sediment and 45 percent of total phosphorus from runoff, so it is assumed that the removal of BOD_5 falls within this range (NCSU 2000). Riparian buffer strips also help reduce water temperatures increasing the water body DO saturation level as explained in Section 10.

Riparian vegetation, specifically shade, plays a significant role in controlling stream temperature change. The shade provided will reduce solar radiation loading to the stream. Furthermore, riparian vegetation provides bank stability that reduces sediment loading to the stream and the stream width-to-depth ratio. Research in California (Ledwith 1996), Washington (Dong et al. 1998), and Maine (Hagan and Whitman 2000) show that riparian buffers effect microclimate factors such as air temperature and relative humidity proximal to the stream. Ledwith (1996) found that a 500-foot buffer had an air temperature decrease of 12°F at the stream over a zero-foot buffer. The greatest change occurred in the first 100 feet of the 500-foot buffer where the temperature decreased 2°F per 30 feet from the stream bank. A decrease in the air temperature proximal to the stream would result in a smaller convective flux to the stream during the day.

Filter strip widths for the Big Muddy River TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 12-1 outlines the guidance for filter strip flow length by slope (NRCS 1999). Based on slope estimates near tributaries within the watershed, filter strips widths of 72 to 144 feet could be incorporated in locations throughout the watershed. The total acreage examined was 112 acres.

Table 12-1 Filter Strip Flow Lengths Based on Land Slope

Percent Slope	0.5%	1.0%	2.0%	3.0%	4.0%	5.0% or greater
Minimum	36	54	72	90	108	117
Maximum	72	108	144	180	216	234

The acreages provided above are used to calculate an approximation of BMP cost in Section 12.3 and should only be used as a guideline for watershed planning. It is recommended that landowners evaluate their land near streams and lakes and create or extend filter strips, where applicable, according to the NRCS guidance presented in

Table 12-1. Programs available to fund the construction of these buffer strips are discussed in Section 9.3.

12.2.1.2 Wetlands

Wetlands can be used as a structural control to treat loads from animal management operations located in the segment N12 watershed. Two of the three animal management facilities in the watershed have been designated as having no impact on receiving waters and the third has not been assessed. In the event that the third facility is found to have a negative impact on water quality, a constructed wetland could be used to treat organic, nutrient, and sediment loads from the animal management operations between the operation and the creek. Wetlands are an effective BMP for sediment, nutrient, and organic load control because they:

- prevent floods by temporarily storing water, allowing the water to evaporate, or percolate into the ground,
- improve water quality through natural pollution control such as plant nutrient uptake,
- filter sediment,
- slow overland flow of water thereby reducing soil erosion (USDA 1996).

While constructed wetlands have been demonstrated to effectively reduce nitrogen and sediment, literature shows mixed results for phosphorus removal. Studies have shown that artificial wetlands designed and constructed specifically to remove pollutants from surface water runoff have removal rates for suspended solids of greater than 90 percent, for total phosphorus of 0 to 90 percent, and for nitrogen species from 10 to 75 percent (Johnson, Evans, and Bass 1996; Moore 1993; USEPA 1993; Kovosic et al. 2000). In some cases, wetlands can be sources of phosphorus. Over the long term, it generally thought that wetlands are neither sources nor sinks of phosphorus (Kovosic et al. 2000).

Efficiency of pollutant removal in wetlands can be addressed in the design and maintenance of the constructed wetland. Location, hydraulic retention time and space requirements should be considered in design. To maintain removal efficiency, sheet flow should be maintained and substrate should be monitored to assess whether the wetland is operating optimally. Sediment or vegetation removal may be necessary if the wetland removal efficiency is lessened over a period of time (USEPA 1993; NCSU 1994).

It is recommended that further investigation take place within the watershed to confirm the impact of animal management facilities on Big Muddy River segment N12. Due to data illustrating the lack of impacts of nonpoint source runoff from these facilities, wetlands were not analyzed as a treatment for this TMDL. However, it is recommended that animal control facility managers consider wetlands to treat nonpoint source runoff from control facilities.

12.2.1.3 Reaeration

The purpose of reaeration is to increase DO concentrations in streams. Physical measures that will assist in increasing reaeration of a stream include bank stabilization, channel modifications, and the addition of riprap or pool and riffle sequences. Bank stabilization reduces erosion by planting vegetation along the bank or modification of the channel to decrease the slope of the bank. Riprap or pool and riffle sequences would increase reaeration by increasing turbulence. Turbulence creates an increase in the interaction between air and water, which draws air into the river increasing aeration. Expanding monitoring to several locations along the impaired segments could help identify reaches that would benefit the most from an increase of turbulence.

12.3 Reasonable Assurance

Reasonable assurance means that a demonstration is given that the pollutant reductions in this watershed will be implemented. It should be noted that all programs discussed in this section are voluntary. The discussion in Sections 12.1 and 12.2 provided a means for obtaining the reductions necessary. The remainder of this section discusses the programs available to assist with funding and an estimate of costs to the watershed for implementing these practices.

12.3.1 Available Programs for Manganese and Sulfates TMDL

The state agency primarily responsible for reclamation of pre-law coal mine areas is the IDNR, Office of Mines and Minerals, Abandoned Mined Lands Reclamation Division (AMLRD). The AMLRD contracts or oversees reclamation of pre-law mine sites utilizing funds from a "reclamation fee" (tax) on every ton of coal mined in Illinois since the implementation of the Surface Mining Control and Reclamation Act of 1977. The fee monies are sent to the U.S. Department of Interior and are then partially reallocated back to the states for several purposes, which include the reclamation of pre-law abandoned mined lands. This reclamation fee funds almost all of the reclamation of pre-law mine sites in Illinois. The AMLRD also has the responsibility to reclaim permitted mine sites where the operator has deserted the site and all of the bond money has been forfeited. This adds to the overall number of projects that the AMLRD has to complete (Muir et al. 1997).

Abandoned mine sites are reclaimed through the ALMRD according to a priority list as monies become available. Because the federally designated first priority for ALMRD projects is safety, most of the early reclamation projects were not environmentally oriented. Even so, the AMLRD has completed a large number of environmentally oriented reclamation projects (Muir et al. 1997). Due to the uncertainty of sources of manganese and sulfates in the Big Muddy River segment N12 Watershed, no cost estimates were developed for mitigation of the potential sources provided in this report. If the abandoned mines in the segment N12 watershed are shown to contribute to impairment of segments within the watershed, funds from the ALMRD focused on environmental projects should be directed towards water bodies with TMDLs.

12.3.2 Available Programs for DO TMDL

Approximately 42 percent of the Big Muddy River segment N12 watershed is classified as rural grassland (pasture land, CRP, waterways, buffer strips, etc.), row crop, and small grains land. There are several voluntary conservation programs established through the 2002 U.S. Farm Bill that encourage landowners to implement resource-conserving practices for water quality and erosion control purposes. These programs would apply to crop fields and rural grasslands that are presently used as pasture land. Each program is discussed separately in the following sections.

12.3.2.1 Clean Water Act Section 319 Grants

Section 319 was added to the CWA to establish a national program to address nonpoint sources of water pollution. Through this program, each state is allocated section 319 funds on an annual basis according to a national allocation formula based on the total annual appropriation for the section 319 grant program. The total award consists of two categories of funding; incremental funds and base funds. A state is eligible to receive EPA 319(h) grants upon USEPA's approval of the state's Nonpoint Source Assessment Report and Nonpoint Source Management Program. States may reallocate funds through subawards (e.g., contracts, subgrants) to both public and private entities, including local governments, tribal authorities, cities, counties, regional development centers, local school systems, colleges and universities, local nonprofit organizations, state agencies, federal agencies, watershed groups, for-profit groups, and individuals. Subawards to individuals are limited to demonstration projects (USEPA 2003, 2002).

USEPA designates incremental funds, a $100-million award, for the restoration of impaired water through the development and implementation of watershed-based plans and TMDLs for impaired waters. Base funds, funds other than incremental funds, are used to provide staffing and support to manage and implement the state Nonpoint Source Management Program. Section 319 funding can be used to implement activities which improve water quality, such as filter strips, streambank stabilization, etc (USEPA 2003, 2002).

12.3.2.2 Streambank Stabilization and Restoration Practice

The Streambank Stabilization and Restoration Practice (SSRP) was established to address problems associated with streambank erosion; such as loss or damage to valuable farmland, wildlife habitat, roads; stream capacity reduction through sediment deposition; and degraded water quality, fish, and wildlife habitat. The primary goals of the SSRP are to develop and demonstrate vegetative, stone structure and other low cost bio-engineering techniques for stabilizing streambanks and to encourage the adoption of low-cost streambank stabilization practices by making available financial incentives, technical assistance, and educational information to landowners with critically eroding streambanks. A cost share of 75 percent is available for approved project components; such as willow post installation, bendway weirs, rock riffles, stream barbs/rock, vanes, lunker structures, gabion baskets, and stone toe protection techniques. There is no limit on the total program payment for cost-share projects that a landowner can receive in a fiscal year. However, maximum cost per foot of bank

treated is used to cap the payment assistance on a per foot basis and maintain the program's objectives of funding low-cost techniques (IDA 2000).

12.3.2.3 Conservation Reserve Program

This voluntary program encourages landowners to plant long-term resource-conserving cover to improve soils, water, and wildlife resources. CRP is the USDA's single largest environmental improvement program and one of its most productive and cost-efficient. It is administered through the FSA by USDA's CCC. The program was initially established in the Food Security Act of 1985. The duration of the contracts under CRP range from 10 to 15 years.

Eligible land must be one of the following:

1. Cropland that is planted or considered planted to an agricultural commodity two of the five most recent crop years (including field margins), and must be physically and legally capable of being planted in a normal manner to an agricultural commodity.

2. Certain marginal pasture land enrolled in the Water Bank Program.

The CCC bases rental rates on the relative productivity of soils within each county and the average of the past three years of local dryland cash-rent or cash-rent equivalent. The maximum rental rate is calculated in advance of enrollment. Producers may offer land at the maximum rate or at a lower rental rate to increase likelihood of offer acceptance. In addition, the CCC provides cost-share assistance for up to 50 percent of the participant's costs in establishing approved conservation practices. CCC also encourages restoration of wetlands by offering a one-time incentive payment equal to 25 percent of the costs incurred. This incentive is in addition to the 50 percent cost share provided to establish cover (USDA 1999).

Finally, CCC offers additional financial incentives of up to 20 percent of the annual payment for certain continuous sign-up practices. Continuous sign-up provides management flexibility to farmers and ranchers to implement certain high-priority conservation practices on eligible land. The land must be determined by NRCS to be eligible and suitable for any of the following practices:

- Riparian buffers
- Filter strips
- Grass waterways
- Shelter belts
- Field windbreaks
- Living snow fences
- Contour grass strips
- Salt tolerant vegetation
- Shallow water areas for wildlife
- Eligible acreage within an USEPA-designated wellhead protection area (FSA 1997)

12.3.2.4 Wetlands Reserve Program

The WRP is a voluntary program that provides technical and financial assistance to eligible landowners to restore, enhance, and protect wetlands. The goal of WRP is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. At least 70 percent of each project area will be restored to the original natural condition to the extent practicable. The remaining 30 percent of each area may be restored to other than natural conditions. Landowners have the option of enrolling eligible lands through permanent easements, 30-year easements, or restoration cost-share agreements. The program is offered on a continuous sign-up basis and is available nationwide. WRP offers landowners an opportunity to establish, at minimal cost, long-term conservation and wildlife habitat enhancement practices and protection. It is administered through the NRCS (2002b).

The 2002 Farm Bill reauthorized the program through 2007. Increasing the acreage enrollment cap to 2,275,000 acres with an annual enrollment of 250,000 acres per calendar year. The program is limited by the acreage cap and not by program funding. The program offers three enrollment options: permanent easements, 30-year conservation easements, and 10-year restoration cost-share agreements. Since the program began in 1985, the average cost per acre is $1,100 in restorative costs and the average project size is 177 acres. The costs for each enrollment options follow in Table 12-2 (USDA 1996).

Table 12-2 Costs for Enrollment Options of WRP Program

Option	Permanent Easement	30-year Easement	Restoration Agreement
Payment for Easement	100% Agricultural Value	75% Agricultural Value	NA
Payment Options	Lump Sum	Lump Sum	NA
Restoration Payments	100% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements

12.3.2.5 Environmental Quality Incentive Program

The EQIP is a voluntary USDA conservation program for farmers and private landowners engaged in livestock or agricultural production who are faced with serious threats to soil, water, and related natural resources. It provides technical, financial, and educational assistance primarily in designated "priority areas." Priority areas are defined as watershed, regions, or areas of special environmental sensitivity that have significant soil, water, or natural resource related concerns. The program goal is to maximize environmental benefits per dollar expended and provides "(1) flexible technical and financial assistance to farmers and ranchers that face the most serious natural resource problems; (2) assistance to farmers and ranchers in complying with federal, state, and tribal environmental laws, and encourage environmental enhancement; (3) assistance to farmers and ranchers in making beneficial, cost-effective changes to measures needed to conserve and improve natural resources; and (4) for the consolidation and simplification of the conservation planning process." As of 2001, 379,000 acres have been protected in Illinois using EQIP (NRCS 2002d,e).

Landowners, with the assistance of a local NRCS or other service provider, are responsible for development of a site-specific conservation plan that addresses the primary natural resource concerns of the priority area. Conservation practices include but are not limited to erosion control, filter strips, buffers, and grassed waterways. If the plan is approved by NRCS, a five- to 10-year contract that provides cost-share and incentive payments is developed.

Cost-share assistance may pay landowners up to 75 percent of the costs of conservation practices, such as grassed waterways, filter strips, manure management, capping abandoned wells, and other practices important to improving and maintaining the health of natural resources in the area. Total incentive and cost-share payments are limited to $10,000 per person per year and $50,000 over the life of the contract.

12.3.2.6 Wildlife Habitat Incentives Program

The WHIP is a voluntary program that encourages the creation of high quality wildlife habitat of national, state, tribal, or local significance. WHIP is administered through NRCS, which provides technical and financial assistance to landowners for development of upland, riparian, and aquatic habitat areas on their property. NRCS works with the participant to develop a wildlife habitat development plan that becomes the basis of the cost-share agreement between NRCS and the participant. Most contracts are five to 10 years in duration, depending upon the practices to be installed. However, longer term contracts of 15 years or greater may also be funded. Under the agreement:

- The landowner agrees to maintain the cost-shared practices and allow NRCS or its agent access to monitor its effectiveness.
- NRCS agrees to provide technical assistance and pay up to 75 percent of the cost of installing the wildlife habitat practices. Additional financial or technical assistance may be available through cooperating partners (NRCS 2002c).

12.3.2.7 Illinois Department of Agriculture and Illinois EPA Nutrient Management Plan Project

As discussed in Section 9.2.1.1, the IDA and Illinois EPA are co-sponsoring a Cropland Nutrient Management Plan project in watersheds that have or are developing a TMDL. Under this project, 2,480 acres of cropland have been targeted in the Big Muddy River segment N12 watershed.

The FSA administers the CRP. NRCS administers the EQIP, WRP, and WHIP. Local NRCS and FSA contact information in Jackson County are listed in Table 12-3 below.

Table 12-3 Local NRCS and FSA Contact Information

Contact	Address	Phone
Local NRCS Office		
W. Scott Martin	1213 N. 14th Street Murphysboro, Illinois 62966	618-684-3064 x 3
Local FSA Office		
Murphysboro Service Center	1213 N. 14th Street Murphysboro, Illinois 62966	618-684-3471 x 3

12.3.3 Cost Estimates for BMPs

Cost estimates for different BMPs and individual practice prices such as filter strip installation are detailed in the following sections. Table 12-4 outlines the cost of implementation measures per acre. Finally, an estimate of the total order of magnitude costs for implementation measures in the Big Muddy River segment N12 Watershed are presented in Section 12.3.3.3 and Table 12-5.

12.3.3.1 Streambank Stabilization

Cost information of streambank stabilization was taken from Johnson County NRCS. Johnson County NRCS estimates an average cost per foot to implement streambank stabilization measures at $40.00/foot. This price includes grading and shaping of the bank and critical area and dormant stub planting.

12.3.3.2 Filter Strips and Riparian Buffers

The Jackson County NRCS estimates an average cost per acre to install a grass filter strip with a 10-year life span at $90/acre. A riparian buffer strip established with bare root stock has a life span of 10 years and an installation cost of $384/acre. Based on this preliminary estimate, it appears that grass filter strips would be a more cost-effective way to control BOD and nutrient loads in the watershed.

12.3.3.3 Planning Level Cost Estimates for Implementation Measures

Cost estimates for different implementation actions are presented in Table 12-4. The column labeled *Program* lists the financial assistance program available for various BMPs. The programs represented in the table are the WRP and the CRP.

Table 12-4 Cost Estimate of Various BMP Measures in the Big Muddy River Watershed

Source	Program or Sponsor	BMP	Life Span	Installation Mean $/acre	Maintenance $/ac/yr
Nonpoint	CRP	Grass Filter Strips	10	$90.00	$9.00
	CRP	Riparian Buffer	10	$384.00	$40.00
	319 or SSRP	Streambank Stabilization *	10	$40.00	$4.00

* Streambank stabilization cost calculated on linear foot basis.

The total order of magnitude capital costs for implementation measures in the watershed were estimated to be $1,700,000. The total cost is calculated as the number of acres over which a BMP or structural measure is applied by the cost per acre. Table 12-5 summarizes the number of acres each measure is applied to in the basin and the

corresponding cost. The acreages reported in Table 12-5 are a preliminary estimate in order to provide an overall understanding of cost of implementation in the watershed. The total only represents capital costs and annual maintenance costs. These do not represent the total costs of operating the measure over its life cycle.

Table 12-5 Cost Estimate of Implementation Measures for the Big Muddy Watershed

BMP	Treated Acres	Capital Costs		Maintenance Costs	
		Mean $/acre	Watershed $	$/ac/yr	Watershed $/yr
Grass Filter Strips	112	$90.00	$10,080.00	$9.00	$1,000.00
Streambank Stabilization *	42,240	$40.00	$1,689,600.00	$4.00	$168,960.00
Total			**$1,699,680.00**		**$169,960.00**

* Streambank stabilization cost calculated on linear foot basis.

12.4 Monitoring Plan

The purpose of the monitoring plan for the Big Muddy River segment N12 Watershed is to assess the overall implementation of management actions outlined in this section. This can be accomplished by conducting the following monitoring programs:

- track implementation of management measures in the watershed and in upstream contributing watersheds,
- estimate effectiveness of management measures,
- continued ambient monitoring.

Tracking the implementation of management measures can be used to address the following goals (NCSU 2000):

- determine the extent to which management measures and practices have been implemented compared to action needed to meet TMDL endpoints.
- establish a baseline from which decisions can be made regarding the need for additional incentives for implementation efforts,
- measure the extent of voluntary implementation efforts,
- support workload and cost analysis for assistance or regulatory programs,
- determine the extent to which management measures are properly maintained and operated,

Estimating the effectiveness of the BMPs implemented in the watershed could be completed by monitoring before and after the BMP is incorporated into the watershed. Additional monitoring could be conducted on specific structural systems such as a constructed wetland. Inflow and outflow measurements could be conducted to determine site-specific removal efficiency.

Illinois EPA monitors segment N12 yearly through the Ambient Water Quality Monitoring Network program and conducts Intensive Basin Surveys every 5 years. Continuation of this monitoring will assess instream water quality as improvements in the watershed are completed. This data will also be used to assess whether water quality standards in the watershed are being attained. To further support DO modeling and to plan for future nutrient criteria in the watershed, the following parameters should be added to the monitoring list:

- BOD_5
- BOD_{20}
- Chlorophyll "a" or algae monitoring

Monitoring to assess groundwater concentrations of manganese should be conducted to determine source locations of subsurface abandoned mine activity. Location of groundwater contamination would help prioritize areas that will require remediation so that water quality standards can be achieved in the future.

12.5 Implementation Time Line

Implementing the actions outlined in this section for the Big Muddy River segment N12 Watershed should occur in phases and the effectiveness of the management actions should be assessed as improvements are made. It is assumed that it may take up to one to two years for further source identification in the watershed. It is also assumed that it may take up to five years to secure funding for actions needed in the watershed and five to seven years after funding to implement the measures. The length of time required to meet water quality standards will be based on the types of BMPs implemented in the watershed. In summary, meeting water quality standards in the segment N12 watershed may take 15 to 20 years to complete.

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Section 13
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Appendix A
Historic Water Quality Data

Primary Station ID	Start Date	Parameter Long Name	Result Value
5599500	1/9/1990	MANGANESE, TOTAL (UG/L AS MN)	470
5599500	2/8/1990	MANGANESE, TOTAL (UG/L AS MN)	373
5599500	4/16/1990	MANGANESE, TOTAL (UG/L AS MN)	337
5599500	5/22/1990	MANGANESE, TOTAL (UG/L AS MN)	112
5599500	5/22/1990	MANGANESE, TOTAL (UG/L AS MN)	109
5599500	7/9/1990	MANGANESE, TOTAL (UG/L AS MN)	783
5599500	8/21/1990	MANGANESE, TOTAL (UG/L AS MN)	617
5599500	9/24/1990	MANGANESE, TOTAL (UG/L AS MN)	560
5599500	11/13/1990	MANGANESE, TOTAL (UG/L AS MN)	765
5599500	1/8/1991	MANGANESE, TOTAL (UG/L AS MN)	138
5599500	2/12/1991	MANGANESE, TOTAL (UG/L AS MN)	222
5599500	4/9/1991	MANGANESE, TOTAL (UG/L AS MN)	472
5599500	6/4/1991	MANGANESE, TOTAL (UG/L AS MN)	590
5599500	6/4/1991	MANGANESE, TOTAL (UG/L AS MN)	600
5599500	7/16/1991	MANGANESE, TOTAL (UG/L AS MN)	682
5599500	8/20/1991	MANGANESE, TOTAL (UG/L AS MN)	2473
5599500	10/15/1991	MANGANESE, TOTAL (UG/L AS MN)	782
5599500	11/12/1991	MANGANESE, TOTAL (UG/L AS MN)	460
5599500	1/7/1992	MANGANESE, TOTAL (UG/L AS MN)	300
5599500	2/20/1992	MANGANESE, TOTAL (UG/L AS MN)	646
5599500	4/14/1992	MANGANESE, TOTAL (UG/L AS MN)	860
5599500	5/18/1992	MANGANESE, TOTAL (UG/L AS MN)	680
5599500	7/13/1992	MANGANESE, TOTAL (UG/L AS MN)	1000
5599500	8/17/1992	MANGANESE, TOTAL (UG/L AS MN)	1900
5599500	1/12/1993	MANGANESE, TOTAL (UG/L AS MN)	160
5599500	2/16/1993	MANGANESE, TOTAL (UG/L AS MN)	340
5599500	1/6/1994	MANGANESE, TOTAL (UG/L AS MN)	470
5599500	3/2/1994	MANGANESE, TOTAL (UG/L AS MN)	280
5599500	4/6/1994	MANGANESE, TOTAL (UG/L AS MN)	820
5599500	5/23/1994	MANGANESE, TOTAL (UG/L AS MN)	860
5599500	7/6/1994	MANGANESE, TOTAL (UG/L AS MN)	350
5599500	8/4/1994	MANGANESE, TOTAL (UG/L AS MN)	400
5599500	9/19/1994	MANGANESE, TOTAL (UG/L AS MN)	890
5599500	11/1/1994	MANGANESE, TOTAL (UG/L AS MN)	1200
5599500	12/7/1994	MANGANESE, TOTAL (UG/L AS MN)	590
5599500	1/30/1995	MANGANESE, TOTAL (UG/L AS MN)	360
5599500	2/21/1995	MANGANESE, TOTAL (UG/L AS MN)	310
5599500	4/12/1995	MANGANESE, TOTAL (UG/L AS MN)	710
5599500	5/10/1995	MANGANESE, TOTAL (UG/L AS MN)	282
5599500	6/15/1995	MANGANESE, TOTAL (UG/L AS MN)	540
5599500	7/20/1995	MANGANESE, TOTAL (UG/L AS MN)	820
5599500	8/22/1995	MANGANESE, TOTAL (UG/L AS MN)	380
5599500	10/31/1995	MANGANESE, TOTAL (UG/L AS MN)	1200
5599500	12/18/1995	MANGANESE, TOTAL (UG/L AS MN)	550
5599500	1/31/1996	MANGANESE, TOTAL (UG/L AS MN)	290
5599500	2/29/1996	MANGANESE, TOTAL (UG/L AS MN)	1200
5599500	3/25/1996	MANGANESE, TOTAL (UG/L AS MN)	480
5599500	5/1/1996	MANGANESE, TOTAL (UG/L AS MN)	230
5599500	6/25/1996	MANGANESE, TOTAL (UG/L AS MN)	1200
5599500	7/31/1996	MANGANESE, TOTAL (UG/L AS MN)	530

5599500	4/24/1997	MANGANESE, TOTAL (UG/L AS MN)	470
N12	10/27/1997	MANGANESE, TOTAL (UG/L AS MN)	640
N12	11/20/1997	MANGANESE, TOTAL (UG/L AS MN)	370
N12	2/3/1998	MANGANESE, TOTAL (UG/L AS MN)	500
N12	3/5/1998	MANGANESE, TOTAL (UG/L AS MN)	260
N12	4/16/1998	MANGANESE, TOTAL (UG/L AS MN)	460
N12	5/14/1998	MANGANESE, TOTAL (UG/L AS MN)	380
N12	6/17/1998	MANGANESE, TOTAL (UG/L AS MN)	240
N12	7/21/1998	MANGANESE, TOTAL (UG/L AS MN)	670
N12	8/27/1998	MANGANESE, TOTAL (UG/L AS MN)	470
N12	10/8/1998	MANGANESE, TOTAL (UG/L AS MN)	1100
N12	12/1/1998	MANGANESE, TOTAL (UG/L AS MN)	970
N12	1/4/1999	MANGANESE, TOTAL (UG/L AS MN)	430
N12	2/8/1999	MANGANESE, TOTAL (UG/L AS MN)	190
N12	3/22/1999	MANGANESE, TOTAL (UG/L AS MN)	180
N12	4/27/1999	MANGANESE, TOTAL (UG/L AS MN)	600
N12	6/10/1999	MANGANESE, TOTAL (UG/L AS MN)	400
N12	9/16/1999	MANGANESE, TOTAL (UG/L AS MN)	1900
N12	11/1/1999	MANGANESE, TOTAL (UG/L AS MN)	870
N12	12/6/1999	MANGANESE, TOTAL (UG/L AS MN)	510
N12	1/3/2000	MANGANESE, TOTAL (UG/L AS MN)	360
N12	3/8/2000	MANGANESE, TOTAL (UG/L AS MN)	570
N12	4/12/2000	MANGANESE, TOTAL (UG/L AS MN)	640
N12	5/1/2000	MANGANESE, TOTAL (UG/L AS MN)	550
N12	7/24/2000	MANGANESE, TOTAL (UG/L AS MN)	450
N12	9/6/2000	MANGANESE, TOTAL (UG/L AS MN)	260

Primary Station ID	Start Date	Parameter Long Name	Result Value
5599500	1/9/1990	SULFATE, TOTAL (MG/L AS SO4)	450
5599500	1/9/1990	SULFATE, TOTAL (MG/L AS SO4)	460
5599500	2/8/1990	SULFATE, TOTAL (MG/L AS SO4)	164
5599500	2/8/1990	SULFATE, TOTAL (MG/L AS SO4)	170
5599500	4/16/1990	SULFATE, TOTAL (MG/L AS SO4)	120
5599500	4/16/1990	SULFATE, TOTAL (MG/L AS SO4)	117
5599500	5/22/1990	SULFATE, TOTAL (MG/L AS SO4)	64
5599500	5/22/1990	SULFATE, TOTAL (MG/L AS SO4)	63
5599500	7/9/1990	SULFATE, TOTAL (MG/L AS SO4)	350
5599500	7/9/1990	SULFATE, TOTAL (MG/L AS SO4)	364
5599500	8/21/1990	SULFATE, TOTAL (MG/L AS SO4)	181
5599500	8/21/1990	SULFATE, TOTAL (MG/L AS SO4)	179
5599500	8/21/1990	SULFATE, TOTAL (MG/L AS SO4)	180
5599500	9/24/1990	SULFATE, TOTAL (MG/L AS SO4)	231
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	500
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	557
5599500	1/8/1991	SULFATE, TOTAL (MG/L AS SO4)	83
5599500	1/8/1991	SULFATE, TOTAL (MG/L AS SO4)	85
5599500	2/12/1991	SULFATE, TOTAL (MG/L AS SO4)	110
5599500	2/12/1991	SULFATE, TOTAL (MG/L AS SO4)	114
5599500	4/9/1991	SULFATE, TOTAL (MG/L AS SO4)	230
5599500	4/9/1991	SULFATE, TOTAL (MG/L AS SO4)	195
5599500	6/4/1991	SULFATE, TOTAL (MG/L AS SO4)	265
5599500	6/4/1991	SULFATE, TOTAL (MG/L AS SO4)	240
5599500	7/16/1991	SULFATE, TOTAL (MG/L AS SO4)	360
5599500	7/16/1991	SULFATE, TOTAL (MG/L AS SO4)	360
5599500	8/20/1991	SULFATE, TOTAL (MG/L AS SO4)	380
5599500	8/20/1991	SULFATE, TOTAL (MG/L AS SO4)	380
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	360
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	290
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	350
5599500	1/7/1992	SULFATE, TOTAL (MG/L AS SO4)	170
5599500	1/7/1992	SULFATE, TOTAL (MG/L AS SO4)	165
5599500	2/20/1992	SULFATE, TOTAL (MG/L AS SO4)	230
5599500	4/14/1992	SULFATE, TOTAL (MG/L AS SO4)	206
5599500	5/18/1992	SULFATE, TOTAL (MG/L AS SO4)	203
5599500	7/13/1992	SULFATE, TOTAL (MG/L AS SO4)	300
5599500	7/13/1992	SULFATE, TOTAL (MG/L AS SO4)	303
5599500	8/17/1992	SULFATE, TOTAL (MG/L AS SO4)	330
5599500	1/12/1993	SULFATE, TOTAL (MG/L AS SO4)	78
5599500	2/16/1993	SULFATE, TOTAL (MG/L AS SO4)	191
5599500	1/6/1994	SULFATE, TOTAL (MG/L AS SO4)	270
5599500	3/2/1994	SULFATE, TOTAL (MG/L AS SO4)	168
5599500	4/6/1994	SULFATE, TOTAL (MG/L AS SO4)	240
5599500	5/23/1994	SULFATE, TOTAL (MG/L AS SO4)	170
5599500	7/6/1994	SULFATE, TOTAL (MG/L AS SO4)	163
5599500	8/4/1994	SULFATE, TOTAL (MG/L AS SO4)	260
5599500	9/19/1994	SULFATE, TOTAL (MG/L AS SO4)	440
5599500	11/1/1994	SULFATE, TOTAL (MG/L AS SO4)	660
5599500	12/7/1994	SULFATE, TOTAL (MG/L AS SO4)	172

5599500	1/30/1995	SULFATE, TOTAL (MG/L AS SO4)	162
5599500	2/21/1995	SULFATE, TOTAL (MG/L AS SO4)	164
5599500	4/12/1995	SULFATE, TOTAL (MG/L AS SO4)	210
5599500	5/10/1995	SULFATE, TOTAL (MG/L AS SO4)	186
5599500	6/15/1995	SULFATE, TOTAL (MG/L AS SO4)	91
5599500	7/20/1995	SULFATE, TOTAL (MG/L AS SO4)	162
5599500	8/22/1995	SULFATE, TOTAL (MG/L AS SO4)	146
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	197
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	376
5599500	1/31/1996	SULFATE, TOTAL (MG/L AS SO4)	173
5599500	2/29/1996	SULFATE, TOTAL (MG/L AS SO4)	513
5599500	3/25/1996	SULFATE, TOTAL (MG/L AS SO4)	171
5599500	5/1/1996	SULFATE, TOTAL (MG/L AS SO4)	58.7
5599500	6/25/1996	SULFATE, TOTAL (MG/L AS SO4)	147
5599500	7/31/1996	SULFATE, TOTAL (MG/L AS SO4)	226
5599500	4/24/1997	SULFATE, TOTAL (MG/L AS SO4)	227
N12	########	SULFATE, TOTAL (MG/L AS SO4)	566
N12	########	SULFATE, TOTAL (MG/L AS SO4)	653
N12	2/3/1998	SULFATE, TOTAL (MG/L AS SO4)	303
N12	4/16/1998	SULFATE, TOTAL (MG/L AS SO4)	201
N12	5/14/1998	SULFATE, TOTAL (MG/L AS SO4)	82
N12	6/17/1998	SULFATE, TOTAL (MG/L AS SO4)	109
N12	7/21/1998	SULFATE, TOTAL (MG/L AS SO4)	162
N12	8/27/1998	SULFATE, TOTAL (MG/L AS SO4)	196
N12	10/8/1998	SULFATE, TOTAL (MG/L AS SO4)	340
N12	12/1/1998	SULFATE, TOTAL (MG/L AS SO4)	566
N12	1/4/1999	SULFATE, TOTAL (MG/L AS SO4)	104
N12	2/8/1999	SULFATE, TOTAL (MG/L AS SO4)	81.8
N12	3/22/1999	SULFATE, TOTAL (MG/L AS SO4)	91.9
N12	4/27/1999	SULFATE, TOTAL (MG/L AS SO4)	154
N12	6/10/1999	SULFATE, TOTAL (MG/L AS SO4)	160
N12	9/16/1999	SULFATE, TOTAL (MG/L AS SO4)	435
N12	11/1/1999	SULFATE, TOTAL (MG/L AS SO4)	601
N12	12/6/1999	SULFATE, TOTAL (MG/L AS SO4)	639
N12	1/3/2000	SULFATE, TOTAL (MG/L AS SO4)	401
N12	3/8/2000	SULFATE, TOTAL (MG/L AS SO4)	184
N12	4/12/2000	SULFATE, TOTAL (MG/L AS SO4)	363
N12	5/1/2000	SULFATE, TOTAL (MG/L AS SO4)	229
N12	7/24/2000	SULFATE, TOTAL (MG/L AS SO4)	68
N12	9/6/2000	SULFATE, TOTAL (MG/L AS SO4)	140

Primary Station ID	Start Date	Parameter Long Name	Result Value
5599500	1/9/1990	PH (STANDARD UNITS)	7.8
5599500	1/9/1990	PH (STANDARD UNITS)	7.8
5599500	2/8/1990	PH (STANDARD UNITS)	8.3
5599500	2/8/1990	PH (STANDARD UNITS)	8.3
5599500	2/8/1990	PH (STANDARD UNITS)	7.5
5599500	2/8/1990	PH (STANDARD UNITS)	8.3
5599500	2/8/1990	PH (STANDARD UNITS)	8.8
5599500	2/8/1990	PH (STANDARD UNITS)	8.8
5599500	2/8/1990	PH (STANDARD UNITS)	8
5599500	4/16/1990	PH (STANDARD UNITS)	7
5599500	4/16/1990	PH (STANDARD UNITS)	7
5599500	5/22/1990	PH (STANDARD UNITS)	6.9
5599500	5/22/1990	PH (STANDARD UNITS)	6.6
5599500	7/9/1990	PH (STANDARD UNITS)	7.9
5599500	7/9/1990	PH (STANDARD UNITS)	7.3
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.3
5599500	7/9/1990	PH (STANDARD UNITS)	7.3
5599500	8/21/1990	PH (STANDARD UNITS)	7.5
5599500	8/21/1990	PH (STANDARD UNITS)	7.2
5599500	8/21/1990	PH (STANDARD UNITS)	7.2
5599500	9/24/1990	PH (STANDARD UNITS)	7.8
5599500	11/13/1990	PH (STANDARD UNITS)	8.2
5599500	11/13/1990	PH (STANDARD UNITS)	8.2
5599500	1/8/1991	PH (STANDARD UNITS)	6.4
5599500	1/8/1991	PH (STANDARD UNITS)	6.4
5599500	2/12/1991	PH (STANDARD UNITS)	7.1
5599500	2/12/1991	PH (STANDARD UNITS)	7.1
5599500	2/12/1991	PH (STANDARD UNITS)	7
5599500	2/12/1991	PH (STANDARD UNITS)	7.1
5599500	2/12/1991	PH (STANDARD UNITS)	7.1
5599500	2/12/1991	PH (STANDARD UNITS)	6.8
5599500	2/12/1991	PH (STANDARD UNITS)	6.8
5599500	2/12/1991	PH (STANDARD UNITS)	7
5599500	2/12/1991	PH (STANDARD UNITS)	7
5599500	4/9/1991	PH (STANDARD UNITS)	7.4
5599500	4/9/1991	PH (STANDARD UNITS)	7.4
5599500	6/4/1991	PH (STANDARD UNITS)	7.3
5599500	6/4/1991	PH (STANDARD UNITS)	7.2
5599500	7/16/1991	PH (STANDARD UNITS)	7.9
5599500	7/16/1991	PH (STANDARD UNITS)	7.7
5599500	7/16/1991	PH (STANDARD UNITS)	7.9
5599500	7/16/1991	PH (STANDARD UNITS)	7.8
5599500	7/16/1991	PH (STANDARD UNITS)	7.8
5599500	7/16/1991	PH (STANDARD UNITS)	7.8
5599500	7/16/1991	PH (STANDARD UNITS)	7.8

5599500	8/20/1991	PH (STANDARD UNITS)	6.9
5599500	8/20/1991	PH (STANDARD UNITS)	6.9
5599500	10/15/1991	PH (STANDARD UNITS)	7.05
5599500	11/12/1991	PH (STANDARD UNITS)	7
5599500	11/12/1991	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	6.9
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	2/20/1992	PH (STANDARD UNITS)	7.2
5599500	2/20/1992	PH (STANDARD UNITS)	7.2
5599500	4/14/1992	PH (STANDARD UNITS)	7.3
5599500	4/14/1992	PH (STANDARD UNITS)	7.3
5599500	4/14/1992	PH (STANDARD UNITS)	7.44
5599500	4/14/1992	PH (STANDARD UNITS)	7.33
5599500	4/14/1992	PH (STANDARD UNITS)	7.29
5599500	4/14/1992	PH (STANDARD UNITS)	7.29
5599500	5/18/1992	PH (STANDARD UNITS)	7.1
5599500	7/13/1992	PH (STANDARD UNITS)	7.1
5599500	7/13/1992	PH (STANDARD UNITS)	7.1
5599500	8/17/1992	PH (STANDARD UNITS)	7.7
5599500	1/12/1993	PH (STANDARD UNITS)	7.4
5599500	2/16/1993	PH (STANDARD UNITS)	7.6
5599500	1/6/1994	PH (STANDARD UNITS)	7.7
5599500	3/2/1994	PH (STANDARD UNITS)	8
5599500	4/6/1994	PH (STANDARD UNITS)	7.8
5599500	5/23/1994	PH (STANDARD UNITS)	7.7
5599500	7/6/1994	PH (STANDARD UNITS)	7.6
5599500	8/4/1994	PH (STANDARD UNITS)	7.7
5599500	9/19/1994	PH (STANDARD UNITS)	8.5
5599500	11/1/1994	PH (STANDARD UNITS)	8
5599500	12/7/1994	PH (STANDARD UNITS)	7.9
5599500	1/30/1995	PH (STANDARD UNITS)	7.6
5599500	2/21/1995	PH (STANDARD UNITS)	7.9
5599500	4/12/1995	PH (STANDARD UNITS)	7.2
5599500	5/10/1995	PH (STANDARD UNITS)	7
5599500	6/15/1995	PH (STANDARD UNITS)	7.3
5599500	7/20/1995	PH (STANDARD UNITS)	7.9
5599500	8/22/1995	PH (STANDARD UNITS)	7.3
5599500	10/31/1995	PH (STANDARD UNITS)	7.1
5599500	12/18/1995	PH (STANDARD UNITS)	7.2
5599500	1/31/1996	PH (STANDARD UNITS)	7.4
5599500	2/29/1996	PH (STANDARD UNITS)	7.4
5599500	3/25/1996	PH (STANDARD UNITS)	6.6
5599500	5/1/1996	PH (STANDARD UNITS)	6.8
5599500	6/25/1996	PH (STANDARD UNITS)	6.8
5599500	7/31/1996	PH (STANDARD UNITS)	7.3

5599500	4/24/1997	PH (STANDARD UNITS)	7.2
N12	10/27/1997	PH (STANDARD UNITS)	7.2
N12	11/20/1997	PH (STANDARD UNITS)	6.4
N12	2/3/1998	PH (STANDARD UNITS)	7.5
N12	3/5/1998	PH (STANDARD UNITS)	7.5
N12	4/16/1998	PH (STANDARD UNITS)	7.2
N12	5/14/1998	PH (STANDARD UNITS)	7
N12	6/17/1998	PH (STANDARD UNITS)	7.1
N12	7/21/1998	PH (STANDARD UNITS)	6.7
N12	8/27/1998	PH (STANDARD UNITS)	6.4
N12	10/8/1998	PH (STANDARD UNITS)	7.3
N12	12/1/1998	PH (STANDARD UNITS)	7.3
N12	1/4/1999	PH (STANDARD UNITS)	8.1
N12	2/8/1999	PH (STANDARD UNITS)	7.3
N12	3/22/1999	PH (STANDARD UNITS)	7.2
N12	4/27/1999	PH (STANDARD UNITS)	7.4
N12	6/10/1999	PH (STANDARD UNITS)	6.5
N12	9/16/1999	PH (STANDARD UNITS)	7.3
N12	11/1/1999	PH (STANDARD UNITS)	7.4
N12	12/6/1999	PH (STANDARD UNITS)	7
N12	1/3/2000	PH (STANDARD UNITS)	6.6
N12	3/8/2000	PH (STANDARD UNITS)	6.6
N12	4/12/2000	PH (STANDARD UNITS)	7.1
N12	5/1/2000	PH (STANDARD UNITS)	7.6
N12	7/24/2000	PH (STANDARD UNITS)	6.9
N12	9/6/2000	PH (STANDARD UNITS)	6.5

Primary Station ID	Start Date	Parameter Long Name	Result Value
5599500	1/9/1990	OXYGEN, DISSOLVED MG/L	20.8
5599500	1/9/1990	OXYGEN, DISSOLVED MG/L	20.8
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12.5
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12.3
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	11.6
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	11.4
5599500	4/16/1990	OXYGEN, DISSOLVED MG/L	8.5
5599500	4/16/1990	OXYGEN, DISSOLVED MG/L	8.5
5599500	5/22/1990	OXYGEN, DISSOLVED MG/L	4.3
5599500	5/22/1990	OXYGEN, DISSOLVED MG/L	4.5
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	3.7
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.4
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.5
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.5
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.5
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.3
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.3
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.3
5599500	8/21/1990	OXYGEN, DISSOLVED MG/L	5.6
5599500	8/21/1990	OXYGEN, DISSOLVED MG/L	4.4
5599500	8/21/1990	OXYGEN, DISSOLVED MG/L	4.4
5599500	9/24/1990	OXYGEN, DISSOLVED MG/L	7.1
5599500	11/13/1990	OXYGEN, DISSOLVED MG/L	9.1
5599500	11/13/1990	OXYGEN, DISSOLVED MG/L	9.1
5599500	1/8/1991	OXYGEN, DISSOLVED MG/L	12.9
5599500	1/8/1991	OXYGEN, DISSOLVED MG/L	12.9
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.1
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	13
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.2
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.4
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	13.3
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	12
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.8
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.8
5599500	4/9/1991	OXYGEN, DISSOLVED MG/L	7.6
5599500	4/9/1991	OXYGEN, DISSOLVED MG/L	7.6
5599500	6/4/1991	OXYGEN, DISSOLVED MG/L	4.8
5599500	6/4/1991	OXYGEN, DISSOLVED MG/L	4.7
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.67
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.6
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.7
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	7
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	7.2
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.8
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.8

5599500	8/20/1991	OXYGEN, DISSOLVED MG/L	9.2
5599500	8/20/1991	OXYGEN, DISSOLVED MG/L	9.2
5599500	10/15/1991	OXYGEN, DISSOLVED MG/L	9.45
5599500	11/12/1991	OXYGEN, DISSOLVED MG/L	10.8
5599500	11/12/1991	OXYGEN, DISSOLVED MG/L	10.8
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.6
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.6
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	2/20/1992	OXYGEN, DISSOLVED MG/L	10.1
5599500	2/20/1992	OXYGEN, DISSOLVED MG/L	10.1
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.8
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.8
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	9
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.7
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.73
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.69
5599500	5/18/1992	OXYGEN, DISSOLVED MG/L	6.9
5599500	7/13/1992	OXYGEN, DISSOLVED MG/L	4.3
5599500	7/13/1992	OXYGEN, DISSOLVED MG/L	4.3
5599500	8/17/1992	OXYGEN, DISSOLVED MG/L	9.6
5599500	1/12/1993	OXYGEN, DISSOLVED MG/L	10.4
5599500	2/16/1993	OXYGEN, DISSOLVED MG/L	11.3
5599500	1/6/1994	OXYGEN, DISSOLVED MG/L	11.6
5599500	3/2/1994	OXYGEN, DISSOLVED MG/L	11.6
5599500	4/6/1994	OXYGEN, DISSOLVED MG/L	9.3
5599500	5/23/1994	OXYGEN, DISSOLVED MG/L	5.4
5599500	7/6/1994	OXYGEN, DISSOLVED MG/L	5.5
5599500	8/4/1994	OXYGEN, DISSOLVED MG/L	5.8
5599500	9/19/1994	OXYGEN, DISSOLVED MG/L	5.6
5599500	11/1/1994	OXYGEN, DISSOLVED MG/L	10.5
5599500	12/7/1994	OXYGEN, DISSOLVED MG/L	7.9
5599500	1/30/1995	OXYGEN, DISSOLVED MG/L	12
5599500	2/21/1995	OXYGEN, DISSOLVED MG/L	11.7
5599500	4/12/1995	OXYGEN, DISSOLVED MG/L	8.6
5599500	5/10/1995	OXYGEN, DISSOLVED MG/L	5.9
5599500	6/15/1995	OXYGEN, DISSOLVED MG/L	3.9
5599500	7/20/1995	OXYGEN, DISSOLVED MG/L	4.7
5599500	8/22/1995	OXYGEN, DISSOLVED MG/L	4.1
5599500	10/31/1995	OXYGEN, DISSOLVED MG/L	7.3
5599500	12/18/1995	OXYGEN, DISSOLVED MG/L	10.8
5599500	1/31/1996	OXYGEN, DISSOLVED MG/L	12.2
5599500	2/29/1996	OXYGEN, DISSOLVED MG/L	10.7
5599500	3/25/1996	OXYGEN, DISSOLVED MG/L	11
5599500	5/1/1996	OXYGEN, DISSOLVED MG/L	6.9
5599500	6/25/1996	OXYGEN, DISSOLVED MG/L	6.2
5599500	7/31/1996	OXYGEN, DISSOLVED MG/L	6.8

5599500	4/24/1997	OXYGEN, DISSOLVED MG/L	8.3
N12	10/27/1997	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.2
N12	11/20/1997	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.8
N12	2/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.3
N12	3/5/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.6
N12	4/16/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.8
N12	5/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.7
N12	6/17/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.8
N12	7/21/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.2
N12	8/27/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.3
N12	10/8/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.1
N12	12/1/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.2
N12	1/4/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12.4
N12	2/8/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.3
N12	3/22/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.5
N12	4/27/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.2
N12	6/10/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.8
N12	9/16/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.6
N12	11/1/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.7
N12	12/6/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.2
N12	1/3/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.5
N12	3/8/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.8
N12	4/12/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.5
N12	5/1/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.2
N12	7/24/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.9
N12	9/6/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.7

Secondary ID .1	Start Date	Parameter Long Name	Result Value
RNC-1	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	5/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	6/6/1990	DEPTH OF POND OR RESERVOIR IN FEET	54
RNC-1	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	6/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	52
RNC-1	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	65
RNC-1	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	65
RNC-1	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	65
RNC-1	7/23/1990	DEPTH OF POND OR RESERVOIR IN FEET	37
RNC-1	8/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	76
RNC-1	5/21/1991	DEPTH OF POND OR RESERVOIR IN FEET	59
RNC-1	6/4/1991	DEPTH OF POND OR RESERVOIR IN FEET	64
RNC-1	6/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	88
RNC-1	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	64
RNC-1	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	64
RNC-1	6/19/1991	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	70
RNC-1	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	70
RNC-1	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	70
RNC-1	7/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	9/16/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	5/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	80
RNC-1	5/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	78
RNC-1	6/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	78
RNC-1	7/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	84
RNC-1	7/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	81
RNC-1	8/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	81
RNC-1	5/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	72

RNC-1	5/31/1993	DEPTH OF POND OR RESERVOIR IN FEET	73
RNC-1	6/14/1993	DEPTH OF POND OR RESERVOIR IN FEET	74
RNC-1	6/29/1993	DEPTH OF POND OR RESERVOIR IN FEET	71
RNC-1	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	75
RNC-1	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	5/11/1994	DEPTH OF POND OR RESERVOIR IN FEET	85
RNC-1	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	56.5
RNC-1	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	56.5
RNC-1	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	56.5
RNC-1	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	8/3/1994	DEPTH OF POND OR RESERVOIR IN FEET	70
RNC-1	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/27/1994	DEPTH OF POND OR RESERVOIR IN FEET	72
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	6/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	6/16/1996	DEPTH OF POND OR RESERVOIR IN FEET	63
RNC-1	7/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	62
RNC-1	7/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	66
RNC-1	8/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	65
RNC-1	8/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	9/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	62
RNC-1	9/18/1996	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	10/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	59.5
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	50
RNC-1	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	59.5
RNC-1	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	59.5
RNC-1	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	59.5
RNC-1	5/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	59
RNC-1	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	6/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	71
RNC-1	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	56.5
RNC-1	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	8/5/1997	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	8/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	9/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	55

RNC-1	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	55.2
RNC-1	6/3/1998	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	6/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	7/7/1998	DEPTH OF POND OR RESERVOIR IN FEET	54
RNC-1	7/31/1998	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	8/14/1998	DEPTH OF POND OR RESERVOIR IN FEET	56.6
RNC-1	9/4/1998	DEPTH OF POND OR RESERVOIR IN FEET	62
RNC-1	9/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	4/28/2000	DEPTH OF POND OR RESERVOIR IN FEET	24
RNC-1	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-1	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-2	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	5/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	47
RNC-2	6/6/1990	DEPTH OF POND OR RESERVOIR IN FEET	49
RNC-2	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	51
RNC-2	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	7/23/1990	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	8/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	4/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	46
RNC-2	5/21/1991	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	6/4/1991	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	6/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	6/19/1991	DEPTH OF POND OR RESERVOIR IN FEET	43
RNC-2	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	38.5
RNC-2	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	38.5
RNC-2	7/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	39

RNC-2	8/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	38.5
RNC-2	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	38.5
RNC-2	9/16/1991	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	5/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-2	5/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-2	6/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-2	7/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	18
RNC-2	7/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-2	8/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-2	5/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	21
RNC-2	5/31/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
RNC-2	6/14/1993	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-2	6/29/1993	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-2	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	24
RNC-2	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	40.5
RNC-2	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	40.5
RNC-2	5/11/1994	DEPTH OF POND OR RESERVOIR IN FEET	21
RNC-2	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	8/3/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
RNC-2	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	39.5
RNC-2	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	39.5
RNC-2	8/27/1994	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	6/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/16/1996	DEPTH OF POND OR RESERVOIR IN FEET	43
RNC-2	7/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	7/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	8/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	44
RNC-2	8/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	41.5
RNC-2	9/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	9/18/1996	DEPTH OF POND OR RESERVOIR IN FEET	37.5
RNC-2	10/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	5/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	41.5
RNC-2	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	43
RNC-2	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	46
RNC-2	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	46
RNC-2	8/5/1997	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	8/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	39

RNC-2	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	9/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	37
RNC-2	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	36
RNC-2	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	36
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	35.5
RNC-2	6/3/1998	DEPTH OF POND OR RESERVOIR IN FEET	41.2
RNC-2	6/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	7/7/1998	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	7/31/1998	DEPTH OF POND OR RESERVOIR IN FEET	33
RNC-2	8/14/1998	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	9/4/1998	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	9/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-3	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RNC-3	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RNC-3	5/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	20
RNC-3	6/6/1990	DEPTH OF POND OR RESERVOIR IN FEET	21
RNC-3	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	25.5
RNC-3	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	25.5
RNC-3	6/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-3	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	7/23/1990	DEPTH OF POND OR RESERVOIR IN FEET	18
RNC-3	8/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	4/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-3	5/21/1991	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-3	6/4/1991	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	6/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	6/19/1991	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	7/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	8/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-3	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	9/16/1991	DEPTH OF POND OR RESERVOIR IN FEET	15

RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	5/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
RNC-3	5/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	13
RNC-3	6/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	13
RNC-3	7/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
RNC-3	7/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	8/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
RNC-3	5/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-3	5/31/1993	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	6/14/1993	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-3	6/29/1993	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-3	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
RNC-3	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
RNC-3	5/11/1994	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	8/3/1994	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RNC-3	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RNC-3	8/27/1994	DEPTH OF POND OR RESERVOIR IN FEET	14
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	6/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-3	6/16/1996	DEPTH OF POND OR RESERVOIR IN FEET	36
RNC-3	7/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-3	7/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	44
RNC-3	8/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-3	8/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	39.5
RNC-3	9/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	37
RNC-3	9/18/1996	DEPTH OF POND OR RESERVOIR IN FEET	32.5
RNC-3	10/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	31.5
RNC-3	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	31
RNC-3	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	31
RNC-3	5/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RNC-3	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	6/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	31
RNC-3	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	31
RNC-3	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RNC-3	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RNC-3	8/5/1997	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	8/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RNC-3	9/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	26

RNC-3	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-3	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	24.5
RNC-3	6/3/1998	DEPTH OF POND OR RESERVOIR IN FEET	33.3
RNC-3	6/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	7/7/1998	DEPTH OF POND OR RESERVOIR IN FEET	33
RNC-3	7/31/1998	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	8/14/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	9/4/1998	DEPTH OF POND OR RESERVOIR IN FEET	19
RNC-3	9/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	29
RNC-3	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-4	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	5/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	12
RNC-4	6/6/1990	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RNC-4	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	6/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	7/23/1990	DEPTH OF POND OR RESERVOIR IN FEET	4.5
RNC-4	8/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	5
RNC-4	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	4/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	5/21/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	6/4/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	6/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	6/19/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	8/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	2.5
RNC-4	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	2
RNC-4	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	2
RNC-4	9/16/1991	DEPTH OF POND OR RESERVOIR IN FEET	2
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	5/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	5/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	4

RNC-4	6/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	7/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	8/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	5/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	5/31/1993	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	6/14/1993	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	6/29/1993	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	2.5
RNC-4	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	2
RNC-4	5/11/1994	DEPTH OF POND OR RESERVOIR IN FEET	5
RNC-4	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	8/3/1994	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	8/27/1994	DEPTH OF POND OR RESERVOIR IN FEET	5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RNC-4	6/16/1996	DEPTH OF POND OR RESERVOIR IN FEET	17
RNC-4	7/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-4	7/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	8/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	10
RNC-4	8/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RNC-4	9/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	9/18/1996	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	10/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	12.5
RNC-4	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	12.5
RNC-4	5/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RNC-4	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	11.5
RNC-4	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	11.5
RNC-4	6/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	20
RNC-4	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-4	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-4	8/5/1997	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	8/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RNC-4	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	9/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RNC-4	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	4.5
RNC-4	6/3/1998	DEPTH OF POND OR RESERVOIR IN FEET	11.2
RNC-4	6/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	10

RNC-4	7/7/1998	DEPTH OF POND OR RESERVOIR IN FEET	13
RNC-4	7/31/1998	DEPTH OF POND OR RESERVOIR IN FEET	11.5
RNC-4	8/14/1998	DEPTH OF POND OR RESERVOIR IN FEET	13
RNC-4	9/4/1998	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	9/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	10
RNC-4	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	10
RNC-4	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-4	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	11

Secondary ID .1	Start Date	Parameter Long Name	Result Value	Sample Depth (ft)
5599540	1/8/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	2/5/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	
5599540	4/16/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	5/16/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	6/28/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	7/31/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	
5599540	9/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.023	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.100	
5599540	12/4/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	1/29/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	2/28/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.032	
5599540	3/25/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	5/23/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	6/25/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	8/7/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	9/25/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	
5599540	2/3/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	3/10/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	4/15/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	5/7/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	7/1/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	
5599540	8/12/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	9/23/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	1/27/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	9/29/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	1/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	
5599540	3/3/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.060	
5599540	4/21/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	
5599540	5/19/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	7/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	9/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	11/7/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	12/8/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	
5599540	1/9/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	2/8/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	3/23/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	5/3/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	6/29/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	8/2/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	
5599540	9/7/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	1/11/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.021	
5599540	2/28/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	3/19/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	4/25/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	6/20/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	
5599540	8/13/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	

5599540	3/24/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	4/29/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
RNC-1	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.001	1
RNC-1	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.001	Lake Bottom
RNC-1	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.021	1
RNC-1	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	Lake Bottom
RNC-1	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	1
RNC-1	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.075	Lake Bottom
RNC-1	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-1	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.100	Lake Bottom
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.584	1
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.083	Lake Bottom
RNC-1	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.031	1
RNC-1	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	Lake Bottom
RNC-1	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-1	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	Lake Bottom
RNC-1	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-1	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.067	Lake Bottom
RNC-1	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1
RNC-1	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	Lake Bottom
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	1
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.031	Lake Bottom
RNC-1	5/18/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	
RNC-1	6/29/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	
RNC-1	7/28/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	
RNC-1	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.038	1
RNC-1	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.037	Lake Bottom
RNC-1	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	1
RNC-1	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.011	Lake Bottom
RNC-1	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	1
RNC-1	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	Lake Bottom
RNC-1	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.022	1
RNC-1	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.031	Lake Bottom
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.022	Lake Bottom
RNC-1	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-1	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	Lake Bottom
RNC-1	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.028	1
RNC-1	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.035	Lake Bottom
RNC-1	7/10/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.033	
RNC-1	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-1	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.117	Lake Bottom
RNC-1	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.021	1
RNC-1	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.059	Lake Bottom
RNC-1	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	1
RNC-1	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.174	Lake Bottom
RNC-1	11/3/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.021	
RNC-1	8/25/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.036	
RNC-1	9/21/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.034	
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	
RNC-1	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.011	1

RNC-1	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	12
RNC-1	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	Lake Bottom
RNC-1	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	1
RNC-1	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	13
RNC-1	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.008	Lake Bottom
RNC-1	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1
RNC-1	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.100	Lake Bottom
RNC-1	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.009	1
RNC-1	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.038	Lake Bottom
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	1
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.095	Lake Bottom
RNC-2	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.001	1
RNC-2	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.018	1
RNC-2	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-2	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.018	1
RNC-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	1
RNC-2	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.024	1
RNC-2	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1
RNC-2	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.018	1
RNC-2	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-2	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	1
RNC-2	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-2	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-2	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	1
RNC-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	1
RNC-2	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	1
RNC-2	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.039	1
RNC-2	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.024	1
RNC-2	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.026	1
RNC-2	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	1
RNC-2	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.011	1
RNC-2	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-2	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-2	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	1
RNC-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-3	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.001	1
RNC-3	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-3	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.025	1
RNC-3	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.024	1
RNC-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-3	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.036	1
RNC-3	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.024	1
RNC-3	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	1
RNC-3	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	1
RNC-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.029	1
RNC-3	5/18/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-3	6/29/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.069	1
RNC-3	7/28/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	1
RNC-3	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.084	1
RNC-3	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1

RNC-3	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	1
RNC-3	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.032	1
RNC-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.025	1
RNC-3	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.043	1
RNC-3	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.059	1
RNC-3	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.037	1
RNC-3	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	1
RNC-3	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.034	1
RNC-3	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-3	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.023	1
RNC-3	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-3	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.022	1
RNC-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.023	1
RNC-4	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.046	1
RNC-4	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.152	1
RNC-4	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.109	1
RNC-4	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.116	1
RNC-4	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.036	1
RNC-4	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.097	1
RNC-4	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.106	1
RNC-4	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.130	1
RNC-4	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.090	1
RNC-4	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.072	1
RNC-4	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.185	1
RNC-4	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.136	1
RNC-4	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.123	1
RNC-4	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.155	1
RNC-4	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.078	1
RNC-4	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.121	1
RNC-4	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.072	1
RNC-4	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.063	1
RNC-4	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.245	1
RNC-4	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.147	1
RNC-4	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.047	1
RNC-4	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.070	1
RNC-4	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.077	1
RNC-4	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.047	1
RNC-4	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.033	1

Secondary ID .1	Start Date	Parameter Long Name	Result Value
RNC-1	4/30/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	4.9
RNC-1	6/14/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.3
RNC-1	7/13/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.9
RNC-1	8/17/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.4
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	3.56
RNC-1	4/22/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.86
RNC-1	6/11/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	6.68
RNC-1	7/9/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.66
RNC-1	8/15/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.6
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.22
RNC-1	4/13/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	10.4
RNC-1	6/6/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.4
RNC-1	7/12/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	23.5
RNC-1	8/16/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.2
RNC-1	4/11/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.7
RNC-1	6/19/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	19
RNC-1	7/23/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.1
RNC-1	8/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	19.2
RNC-1	9/15/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.35
RNC-1	10/9/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.47
RNC-1	11/3/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.21
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	7.63
RNC-1	6/9/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	14.41
RNC-1	6/23/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	16.55
RNC-1	8/25/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	35.6
RNC-1	9/21/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	28.2
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	14.5
RNC-1	4/26/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	3.61
RNC-1	6/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	12.4
RNC-1	7/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.13
RNC-1	8/2/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	58.7
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.07
RNC-2	4/30/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.84
RNC-2	6/14/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	16
RNC-2	7/13/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	22.3
RNC-2	8/17/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.1
RNC-2	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	4.79
RNC-2	4/22/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.64
RNC-2	6/11/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	6.68
RNC-2	7/9/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.6
RNC-2	8/15/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	14.1
RNC-2	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	7.7
RNC-2	4/13/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	20.5
RNC-2	6/6/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	10
RNC-2	7/12/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.6
RNC-2	8/16/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.5
RNC-2	4/11/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.2
RNC-2	6/19/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	25.1
RNC-2	7/23/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	29
RNC-2	8/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	22.4
RNC-2	10/9/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.41
RNC-2	4/26/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.64
RNC-2	6/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.6

RNC-2	7/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.01
RNC-2	8/2/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.5
RNC-2	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	20.5
RNC-3	4/30/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.1
RNC-3	6/14/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11
RNC-3	7/13/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	23.5
RNC-3	8/17/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.1
RNC-3	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.61
RNC-3	4/22/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	17.1
RNC-3	6/11/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.4
RNC-3	7/9/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	30.7
RNC-3	8/15/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.4
RNC-3	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	12.8
RNC-3	4/13/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	32.9
RNC-3	6/6/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.61
RNC-3	7/12/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	28
RNC-3	8/16/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	27.7
RNC-3	4/11/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.2
RNC-3	6/19/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	29.8
RNC-3	7/23/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	33
RNC-3	8/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	40.8
RNC-3	10/9/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.5
RNC-3	4/26/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	20.7
RNC-3	6/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.6
RNC-3	7/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	12.4
RNC-3	8/2/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.75
RNC-3	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	25.5
RNC-4	4/30/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	27.62
RNC-4	6/14/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	38.84
RNC-4	7/13/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	30.92
RNC-4	8/17/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	35.04
RNC-4	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.15
RNC-4	4/22/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	26.7
RNC-4	6/11/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	74.17
RNC-4	7/9/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	50.73
RNC-4	8/15/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	47.12
RNC-4	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	16.69
RNC-4	4/13/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.31
RNC-4	6/6/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	51.62
RNC-4	7/12/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	69.83
RNC-4	8/16/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	75.65
RNC-4	4/11/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	3.98
RNC-4	6/19/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	46.44
RNC-4	7/23/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	79.63
RNC-4	8/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	58.99
RNC-4	10/9/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	55.63
RNC-4	4/26/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	29.1
RNC-4	6/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	49.9
RNC-4	7/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	41.5
RNC-4	8/2/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	53.1
RNC-4	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	16.4

Secondary ID .1	Start Date	Parameter Long Name		Result Value	Sample Depth (ft)
5599540	01/08/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	02/05/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	04/16/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
5599540	05/16/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
5599540	06/28/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	07/31/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	09/17/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4	
5599540	10/24/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	12/04/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	01/29/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
5599540	02/28/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	03/25/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2	
5599540	05/23/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	06/25/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	08/07/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2	
5599540	09/25/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.3	
5599540	11/14/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	12/16/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3	
5599540	02/03/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	03/10/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7	
5599540	04/15/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2	
5599540	05/07/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	07/01/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	08/12/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	09/23/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	11/16/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3	
5599540	12/21/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9	
5599540	01/27/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
5599540	03/01/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	04/12/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	
5599540	05/11/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
5599540	06/29/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	08/18/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	09/29/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	11/10/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	12/08/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	01/13/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	03/03/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	04/21/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	05/19/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
5599540	07/06/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
5599540	08/03/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	09/06/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	11/07/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4	
5599540	12/08/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	01/09/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	02/08/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.6	
5599540	03/23/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3	
5599540	05/03/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	06/29/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	08/02/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
5599540	09/07/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
5599540	10/18/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.5	
5599540	12/14/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.2	
5599540	01/11/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.3	
5599540	02/28/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
5599540	03/19/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	04/25/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	06/20/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
5599540	08/13/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
5599540	09/03/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.6	
5599540	11/12/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	12/11/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
5599540	01/14/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.5	
5599540	02/18/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
5599540	03/24/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	
5599540	04/29/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	06/09/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7	

5599540	07/16/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	08/28/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
RNC-1	4/30/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2	
RNC-1	4/30/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	6/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
RNC-1	6/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
RNC-1	7/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	
RNC-1	7/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
RNC-1	8/17/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
RNC-1	8/17/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9	
RNC-1	10/22/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3	
RNC-1	10/22/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
RNC-1	4/22/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
RNC-1	4/22/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	6/11/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
RNC-1	6/11/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9	
RNC-1	7/9/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
RNC-1	7/9/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
RNC-1	8/15/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4	
RNC-1	8/15/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.7	
RNC-1	10/16/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	10/16/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
RNC-1	4/13/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
RNC-1	4/13/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	6/6/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.5	
RNC-1	6/6/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
RNC-1	7/12/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9.1	
RNC-1	7/12/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
RNC-1	8/16/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9	
RNC-1	8/16/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
RNC-1	10/11/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	10/11/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9	
RNC-1	4/11/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
RNC-1	4/11/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.7	
RNC-1	6/19/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
RNC-1	6/19/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.7	
RNC-1	7/23/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
RNC-1	7/23/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
RNC-1	8/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
RNC-1	8/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.6	
RNC-1	10/9/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
RNC-1	10/9/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.6	
RNC-1	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	1
RNC-1	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	12
RNC-1	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	56
RNC-1	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9.2	1
RNC-1	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	13
RNC-1	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2	56
RNC-1	7/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	1
RNC-1	7/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	53
RNC-1	8/2/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9	1
RNC-1	8/2/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	55
RNC-1	10/11/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	1
RNC-1	10/11/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.99	53
RNC-2	4/30/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4	
RNC-2	6/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
RNC-2	7/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
RNC-2	8/17/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2	
RNC-2	10/22/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
RNC-2	4/22/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2	
RNC-2	6/11/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	
RNC-2	7/9/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.7	
RNC-2	8/15/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2	
RNC-2	10/16/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-2	4/13/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7	
RNC-2	6/6/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.5	
RNC-2	7/12/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.9	
RNC-2	8/16/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.8	
RNC-2	10/11/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	

RNC-2	4/11/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
RNC-2	6/19/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4
RNC-2	7/23/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6
RNC-2	8/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
RNC-2	10/9/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
RNC-2	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1
RNC-2	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.9
RNC-2	7/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3
RNC-2	8/2/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9
RNC-2	10/11/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
RNC-3	4/30/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2
RNC-3	6/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.7
RNC-3	7/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8
RNC-3	8/17/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4
RNC-3	10/22/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
RNC-3	4/22/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1
RNC-3	6/11/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3
RNC-3	7/9/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9.1
RNC-3	8/15/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3
RNC-3	10/16/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
RNC-3	4/13/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6
RNC-3	6/6/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3
RNC-3	7/12/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9
RNC-3	8/16/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.8
RNC-3	10/11/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
RNC-3	4/11/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
RNC-3	6/19/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.5
RNC-3	7/23/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.5
RNC-3	8/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6
RNC-3	10/9/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7
RNC-3	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2
RNC-3	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.9
RNC-3	7/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9
RNC-3	8/2/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9.2
RNC-3	10/11/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
RNC-4	4/30/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8
RNC-4	6/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9
RNC-4	7/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
RNC-4	8/17/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9
RNC-4	10/22/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7
RNC-4	4/22/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6
RNC-4	6/11/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8
RNC-4	7/9/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
RNC-4	8/15/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1
RNC-4	10/16/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9
RNC-4	4/13/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
RNC-4	6/6/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4
RNC-4	7/12/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1
RNC-4	8/16/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2
RNC-4	10/11/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3
RNC-4	4/11/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8
RNC-4	6/19/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6
RNC-4	7/23/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1
RNC-4	8/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
RNC-4	10/9/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
RNC-4	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1
RNC-4	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9
RNC-4	7/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2
RNC-4	8/2/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4
RNC-4	10/11/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2

Appendix B
Directory of Coal Mines for Jackson County, Illinois May 4, 2002

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR JACKSON COUNTY, ILLINOIS (IDNR 2000)
MAY 3, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC
13	BIG MUDDY COAL & IRON C	BIG MUDDY	9	SHAFT	MRP	1906-21	MURPHYSBORO	JACKSON	8S	2W	34
13	CONSOLIDATED C C OF ST LOUIS	C C C	9	SHAFT		1921-26	MURPHYSBORO	JACKSON	8S	2W	34
15	CARBONDALE C C EARLIER 78?	HARRISON		SHAFT		1878-91	MURPHYSBORO	JACKSON	8S	2W	33
15	ST LOUIS ORE & STEEL	HARRISON		SHAFT	RPP	1891-94	MURPHYSBORO	JACKSON	8S	2W	33
15	BIG MUDDY COAL & IRON C	HARRISON		SHAFT		1894-16	MURPHYSBORO	JACKSON	8S	2W	33
604	TEMPLETON C C	TEMPLETON	1	SLOPE	MRP	1927-44	MURPHYSBORO	JACKSON	9S	2W	16
2493	BIG MUDDY COAL & IRON C	BIG MUDDY	6	SHAFT		1898-09	MURPHYSBORO	JACKSON	9S	2W	10

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR JACKSON COUNTY, ILLINOIS (IDNR 2000)
MAY 3, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR JACKSON COUNTY, ILLINOIS (IDNR 2000)
MAY 3, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC

Appendix C
GWLF and BATHTUB Input and Output Files

GWLF Input Data Files

Subbasin 1

Transprt.dat

```
9,8
0.15,0.15,10,0,0,0.13,10
0
0
0
0
0
"APR",0.58,13,0,0.27
"MAY",0.9,14,1,0.27
"JUNE",0.94,14.5,1,0.27
"JULY",0.93,14.3,1,0.27
"AUG",0.92,13.4,1,0.27
"SEPT",0.92,12.2,1,0.27
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"MAR",0.61,11.8,0,0.14
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"Grassland",1640.2,68.7,0.00294
"Urban-Grass",6.8,74.2,0.00804
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Nutrient.dat

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Subbasin 2

Transprt.dat

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Nutrient.dat

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Subbasin 3

Transprt.dat

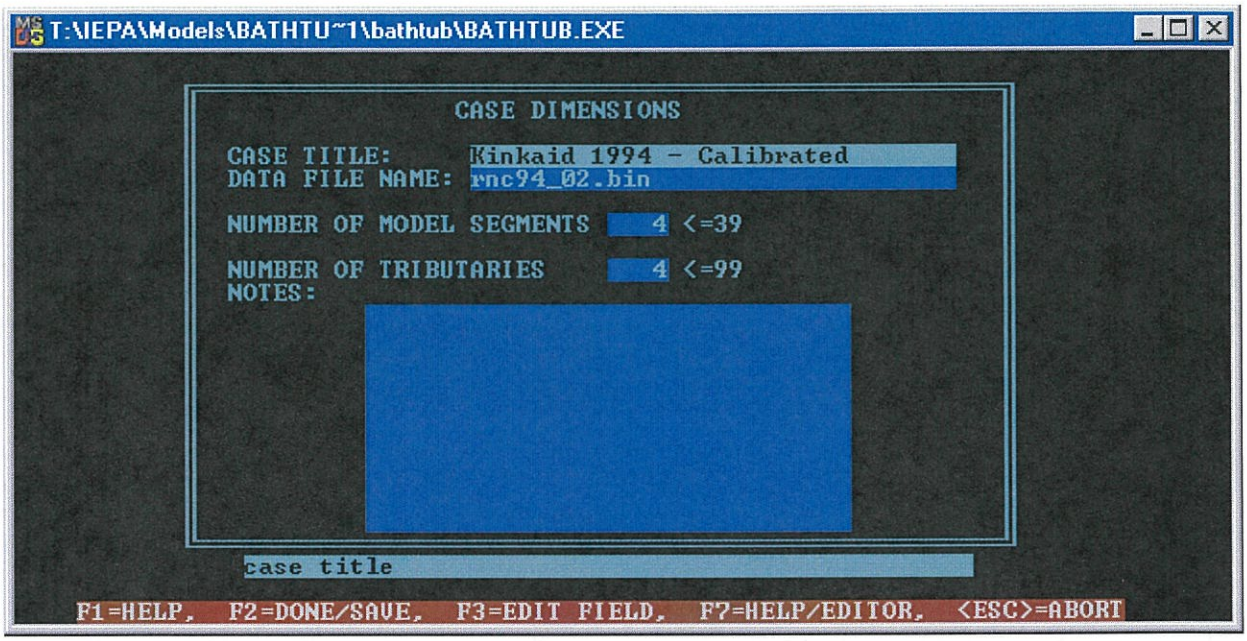
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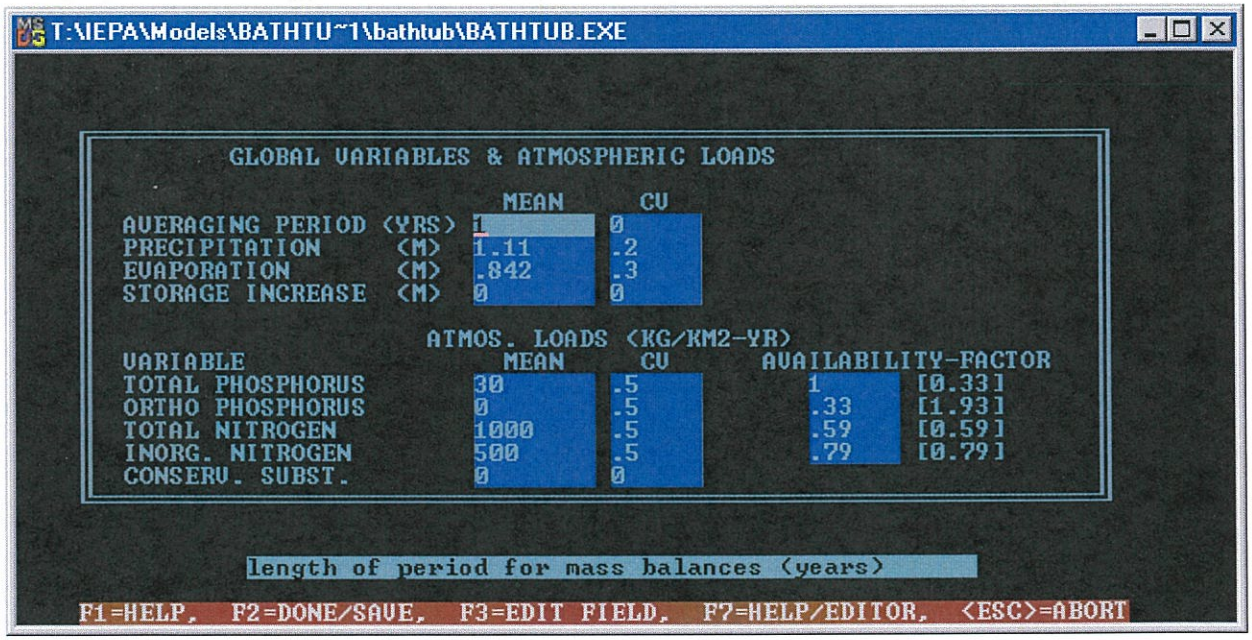
Nutrient.dat

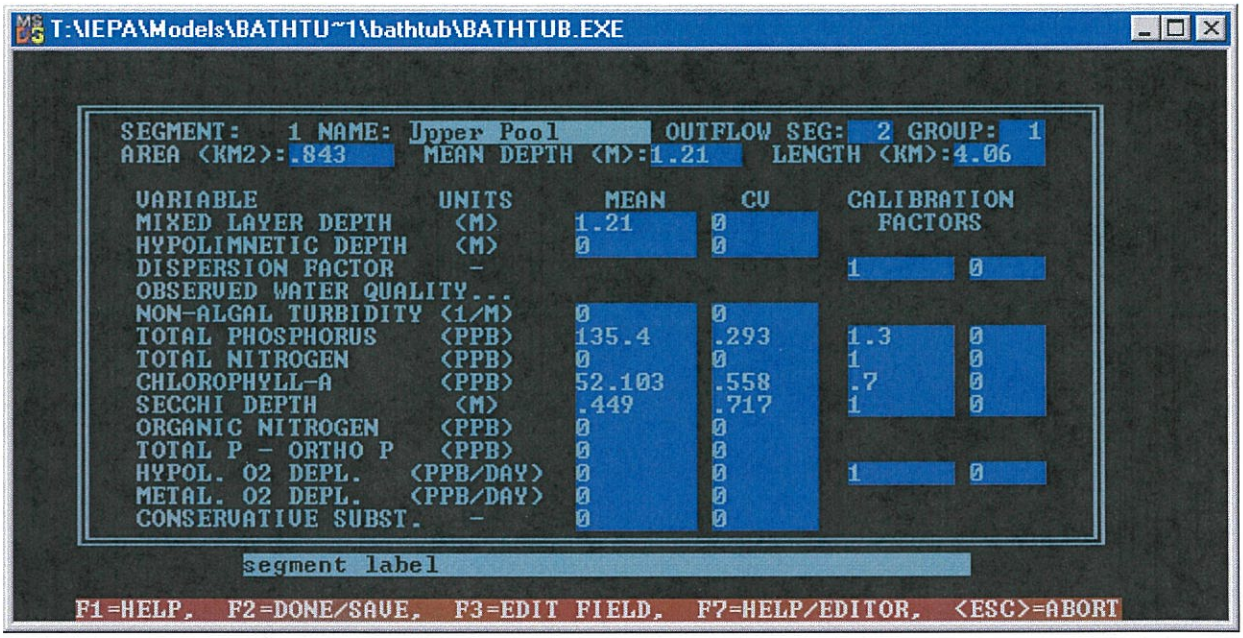
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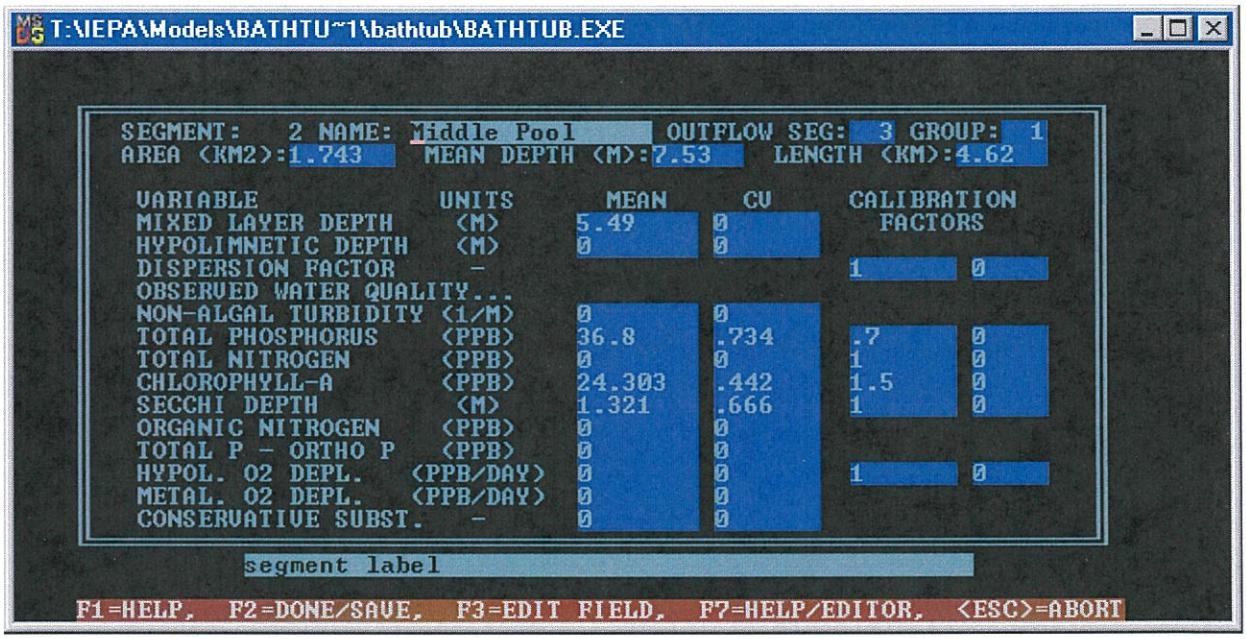
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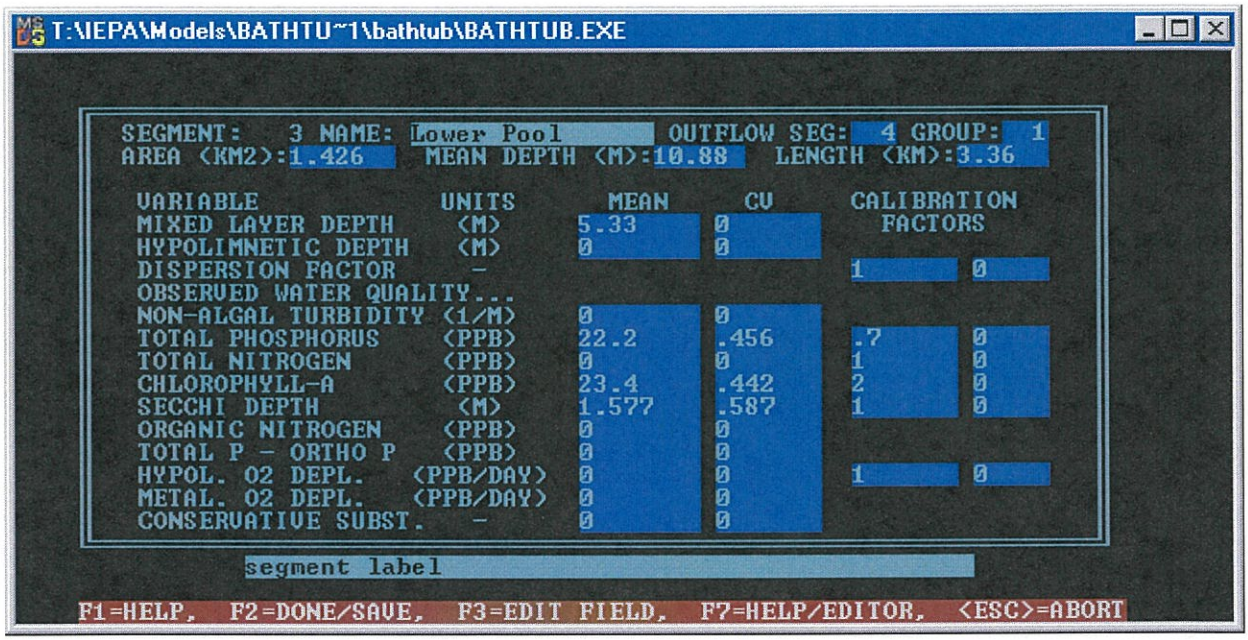
BATHTUB Model Input Screens for 1994 Simulation

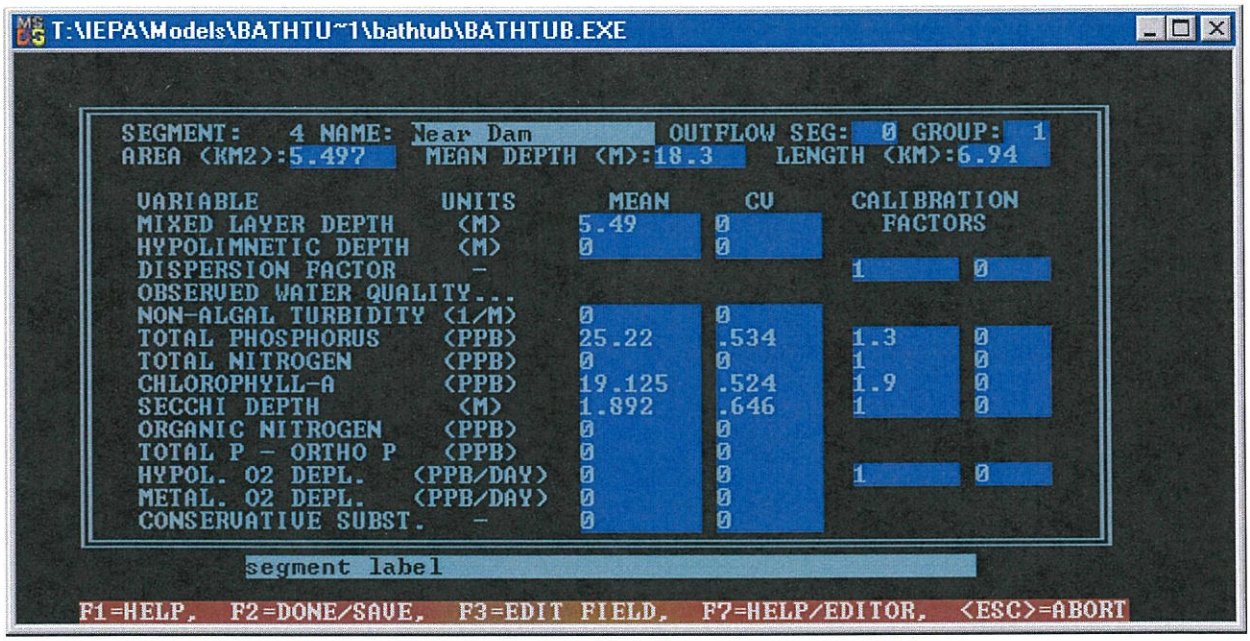


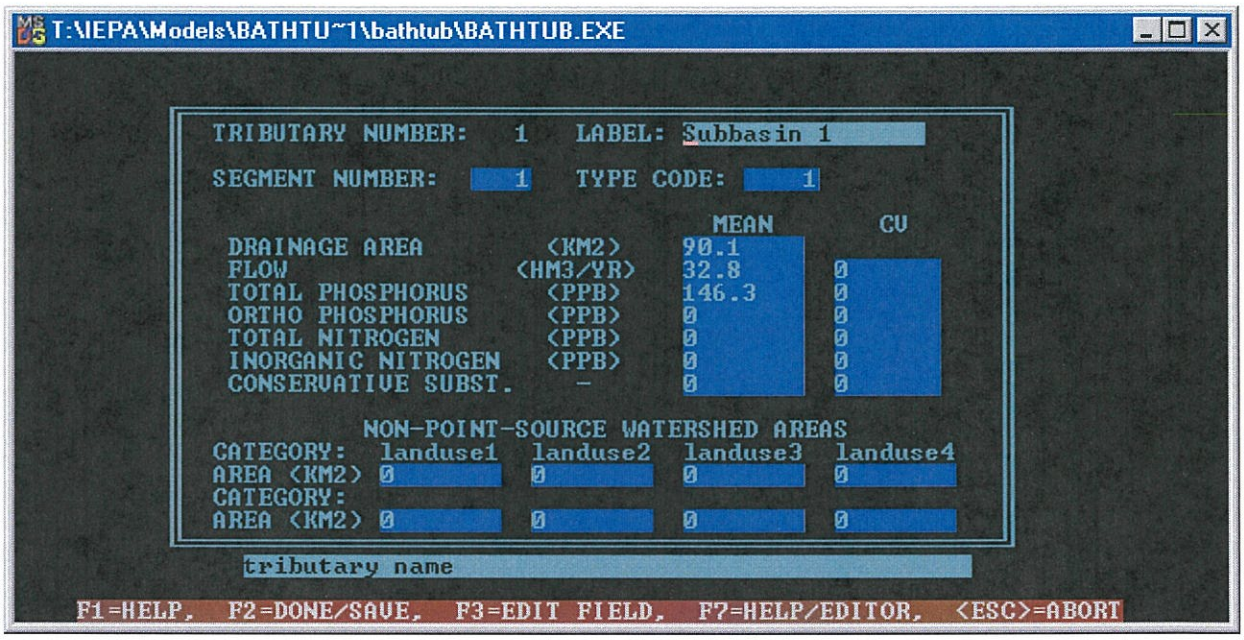


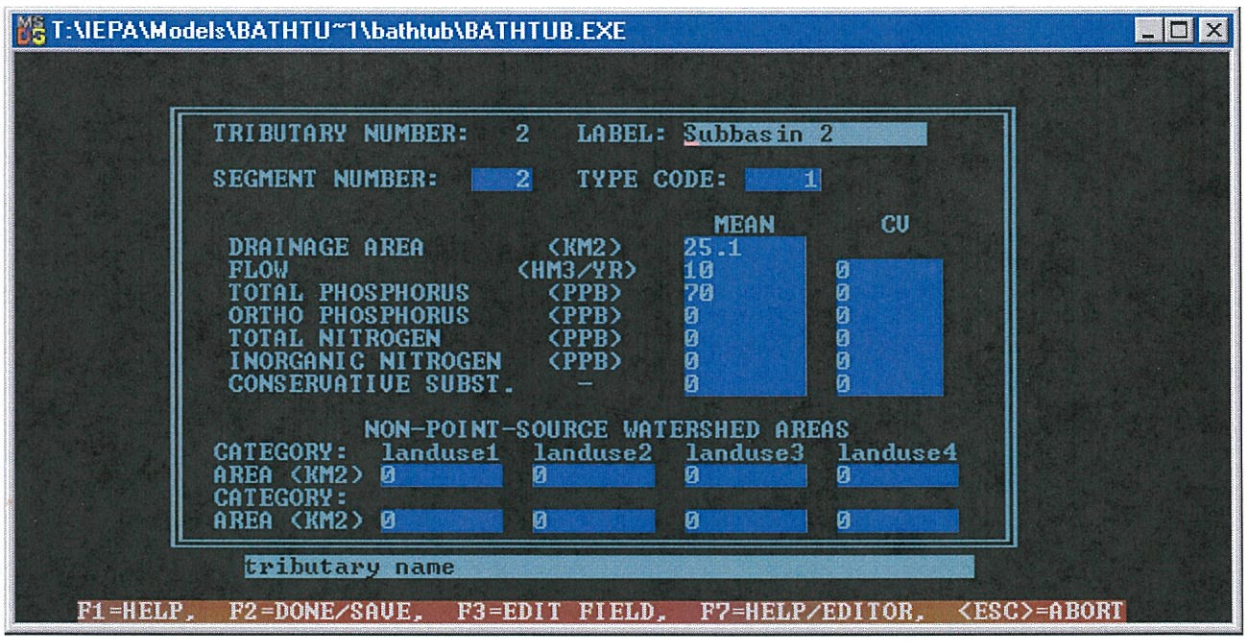

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2):.843 MEAN DEPTH (M):1.21 LENGTH (KM):4.06
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 1.21 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 135.4 .293 1.3 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 52.103 .558 .7 0
SECCHI DEPTH (M) .449 .717 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

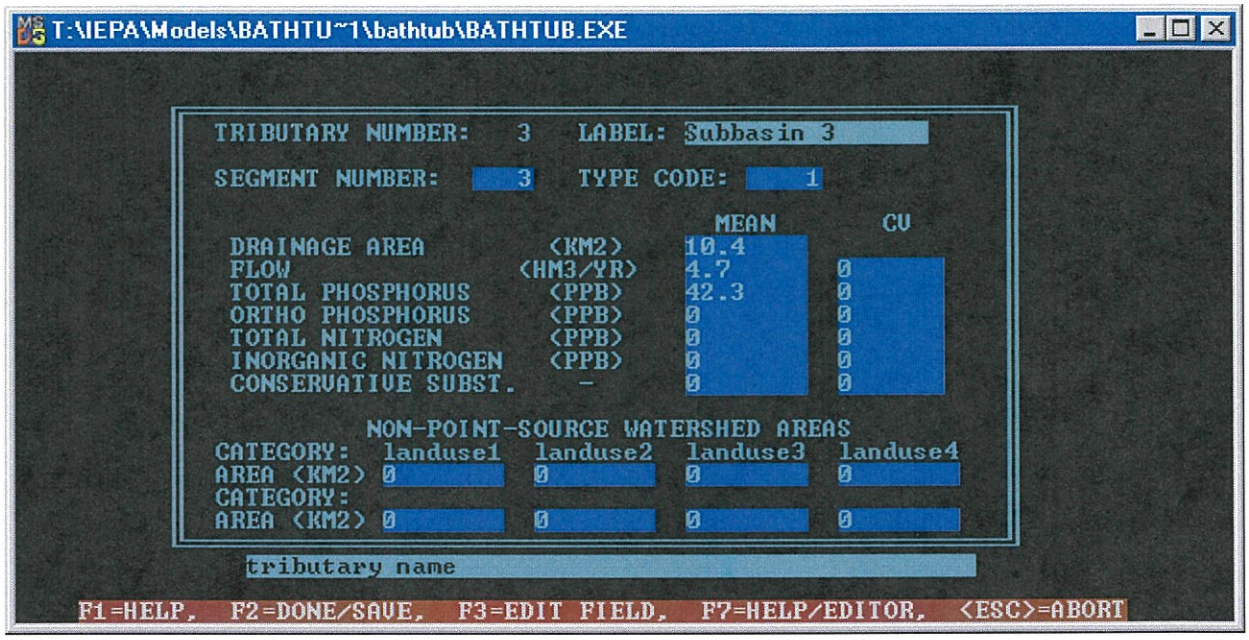

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 2 NAME: Middle Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2):1.743 MEAN DEPTH (M):7.53 LENGTH (KM):4.62
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.49 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 36.8 .734 .7 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 24.303 .442 1.5 0
SECCHI DEPTH (M) 1.321 .666 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

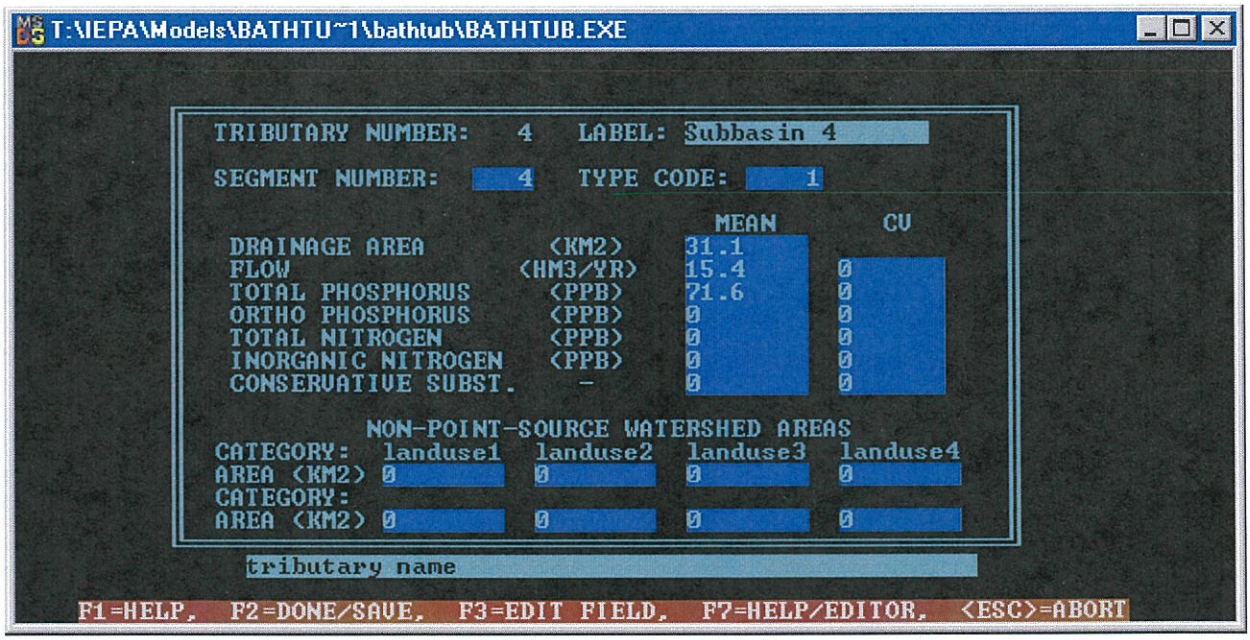

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 3 NAME: Lower Pool OUTFLOW SEG: 4 GROUP: 1
AREA (KM2):1.426 MEAN DEPTH (M):10.88 LENGTH (KM):3.36
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.33 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 22.2 .456 .7 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 23.4 .442 2 0
SECCHI DEPTH (M) 1.577 .587 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 4 NAME: Near Dam OUTFLOW SEG: 0 GROUP: 1
AREA (KM2):5.497 MEAN DEPTH (M):18.3 LENGTH (KM):6.94
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.49 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 25.22 .534 1.3 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 19.125 .524 1.9 0
SECCHI DEPTH (M) 1.892 .646 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 1 LABEL: Subbasin 1
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 90.1
FLOW (HM3/YR) 32.8 0
TOTAL PHOSPHORUS (PPB) 146.3 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 2 LABEL: Subbasin 2
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 25.1
FLOW (HM3/YR) 10 0
TOTAL PHOSPHORUS (PPB) 70 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 3 LABEL: Subbasin 3
SEGMENT NUMBER: 3 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 10.4
FLOW (HM3/YR) 4.7 0
TOTAL PHOSPHORUS (PPB) 42.3 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 4 LABEL: Subbasin 4
SEGMENT NUMBER: 4 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 31.1
FLOW (HM3/YR) 15.4 0
TOTAL PHOSPHORUS (PPB) 71.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

BATHTUB Model Output for 1994 Simulation

CASE: Kinkaid 1994 - Calibrated

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	135.4	.29	137.6	.48	.98	-.06	-.06	-.03
CHL-A	MG/M3	52.1	.56	49.9	.53	1.04	.08	.12	.06
SECCHI	M	.4	.72	.5	.66	.98	-.03	-.09	-.03
ORGANIC N	MG/M3	.0	.00	1364.6	.41	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	106.7	.39	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.8	.73	39.3	.45	.94	-.09	-.25	-.08
CHL-A	MG/M3	24.3	.44	22.2	.67	1.09	.20	.26	.11
SECCHI	M	1.3	.67	1.4	.53	.93	-.11	-.25	-.08
ORGANIC N	MG/M3	.0	.00	675.5	.47	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	39.0	.49	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	22.2	.46	23.1	.45	.96	-.09	-.15	-.06
CHL-A	MG/M3	23.4	.44	20.2	.67	1.16	.33	.43	.18
SECCHI	M	1.6	.59	1.7	.60	.92	-.14	-.29	-.10
ORGANIC N	MG/M3	.0	.00	623.3	.48	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	33.7	.58	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	25.2	.53	23.3	.46	1.08	.15	.30	.12
CHL-A	MG/M3	19.1	.52	19.1	.66	1.00	.01	.01	.00
SECCHI	M	1.9	.65	1.8	.60	1.05	.08	.19	.06
ORGANIC N	MG/M3	.0	.00	597.8	.46	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	31.7	.58	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.7	.48	36.3	.45	1.01	.02	.03	.01
CHL-A	MG/M3	23.6	.50	22.6	.53	1.05	.09	.14	.06
SECCHI	M	1.6	.64	1.6	.50	1.01	.02	.04	.01
ORGANIC N	MG/M3	.0	.00	683.9	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.0	.50	.00	.00	.00	.00

CASE: Kinkaid 1994 - Calibrated
GROSS WATER BALANCE:

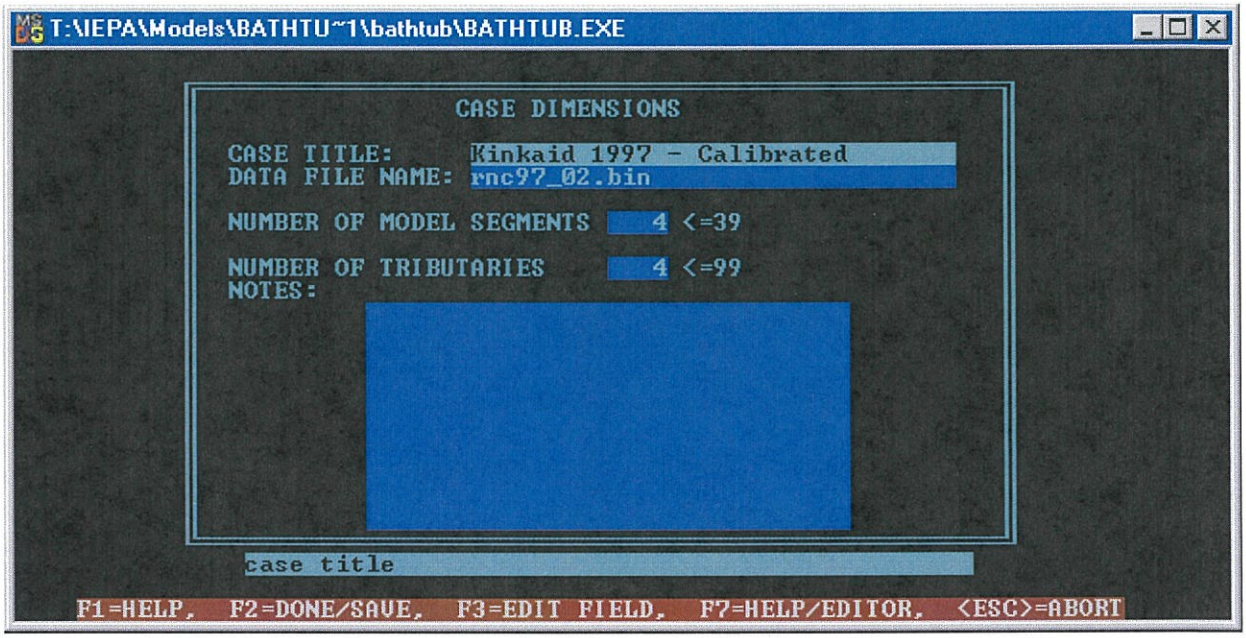
ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	32.800	.000E+00	.000	.364
2	1	Subbasin 2	25.100	10.000	.000E+00	.000	.398
3	1	Subbasin 3	10.400	4.700	.000E+00	.000	.452
4	1	Subbasin 4	31.100	15.400	.000E+00	.000	.495
PRECIPITATION			9.509	10.555	.446E+01	.200	1.110
TRIBUTARY INFLOW			156.700	62.900	.000E+00	.000	.401
***TOTAL INFLOW			166.209	73.455	.446E+01	.029	.442
ADVECTIVE OUTFLOW			166.209	65.448	.102E+02	.049	.394
***TOTAL OUTFLOW			166.209	65.448	.102E+02	.049	.394
***EVAPORATION			.000	8.007	.577E+01	.300	.000

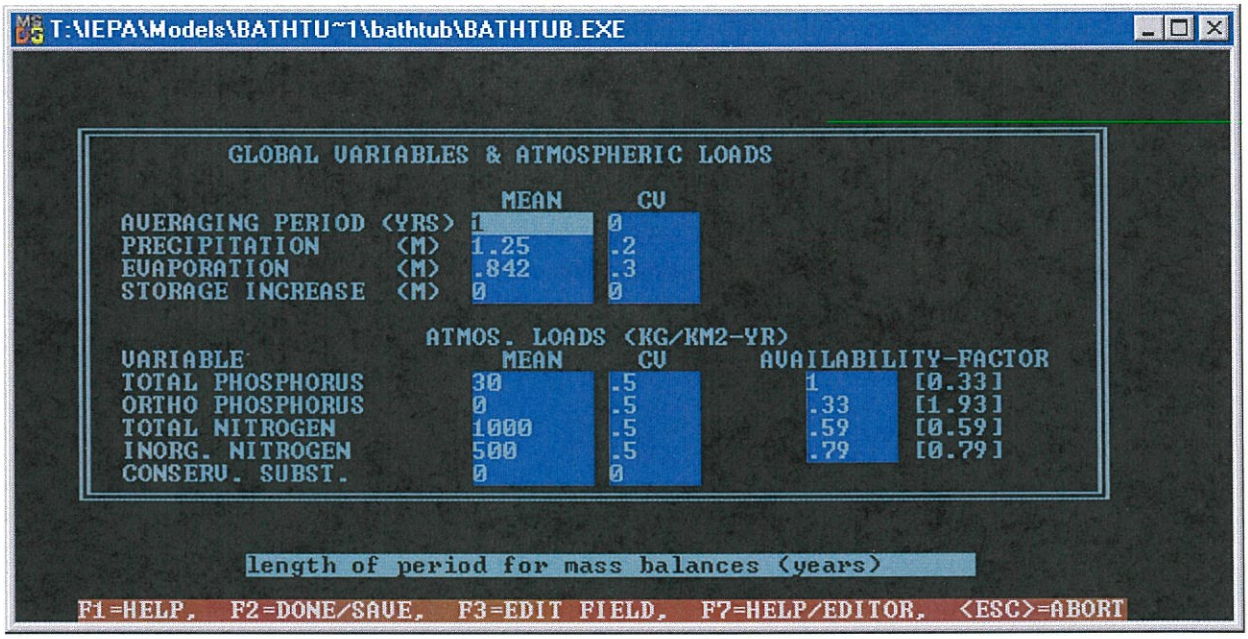
GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

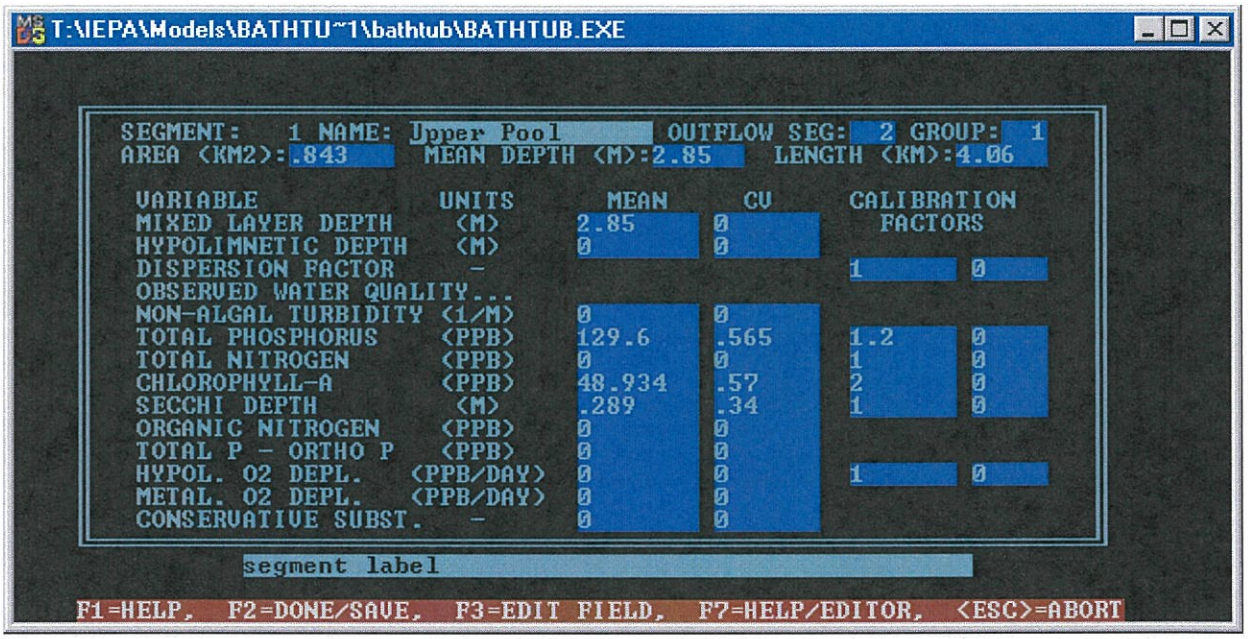
ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	4798.6	67.7	.000E+00	.0	.000	146.3	53.3
2	1	Subbasin 2	700.0	9.9	.000E+00	.0	.000	70.0	27.9
3	1	Subbasin 3	198.8	2.8	.000E+00	.0	.000	42.3	19.1
4	1	Subbasin 4	1102.6	15.6	.000E+00	.0	.000	71.6	35.5
PRECIPITATION			285.3	4.0	.203E+05	100.0	.500	27.0	30.0
TRIBUTARY INFLOW			6800.1	96.0	.000E+00	.0	.000	108.1	43.4
***TOTAL INFLOW			7085.4	100.0	.203E+05	100.0	.020	96.5	42.6
ADVECTIVE OUTFLOW			1521.9	21.5	.483E+06	2375.1	.457	23.3	9.2
***TOTAL OUTFLOW			1521.9	21.5	.483E+06	2375.1	.457	23.3	9.2
***RETENTION			5563.5	78.5	.495E+06	2432.9	.126	.0	.0

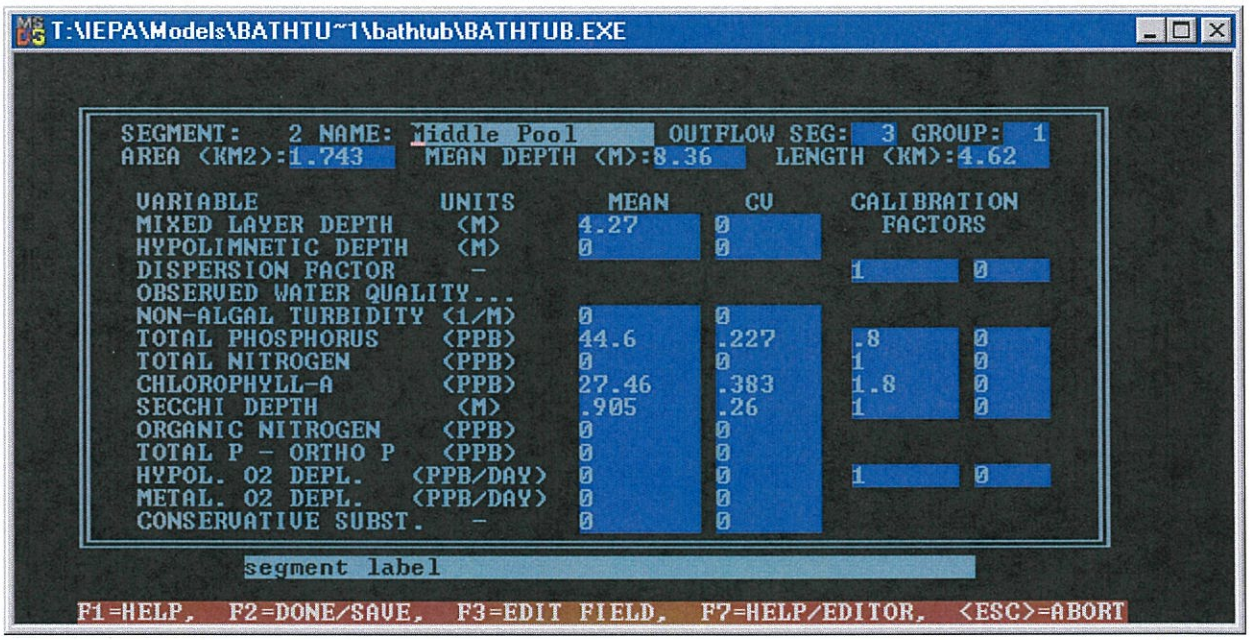
OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
6.88	1.9902	36.7	.6739	1.4839	.7852

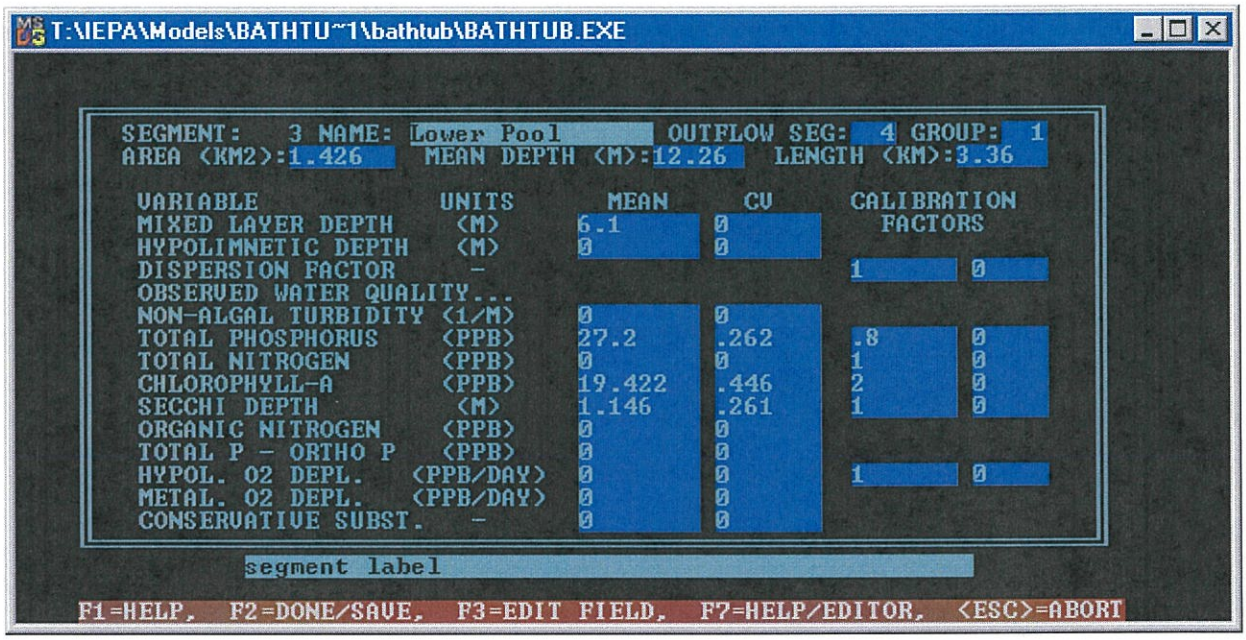
BATHTUB Model Input Screens for 1997 Simulation

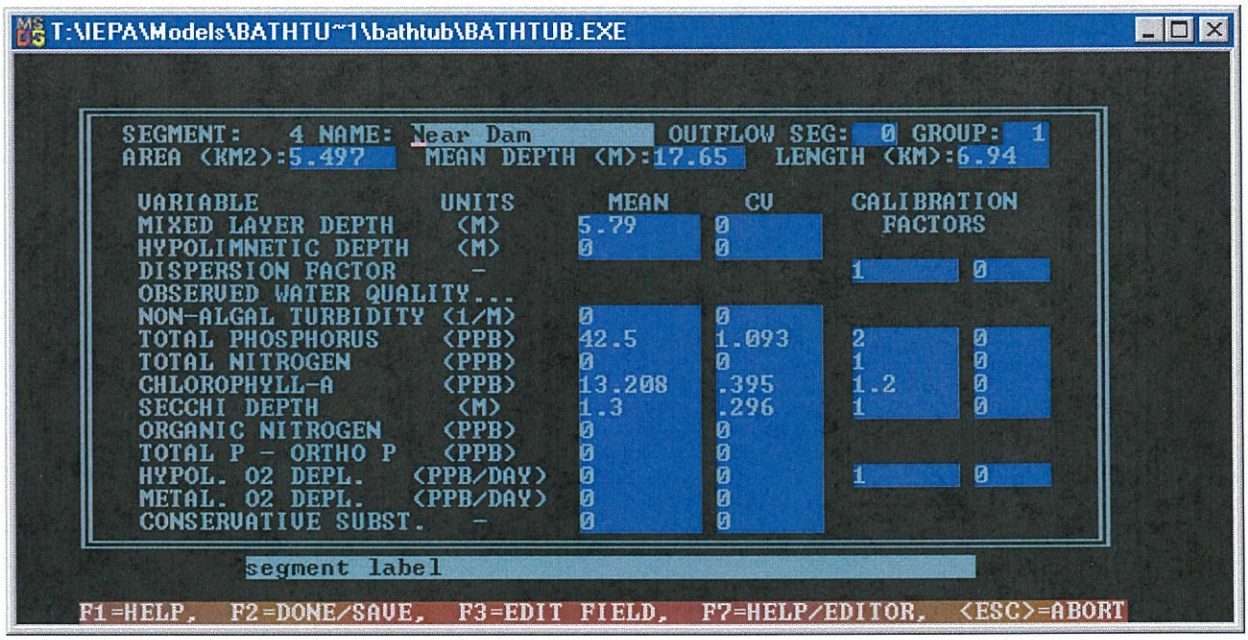


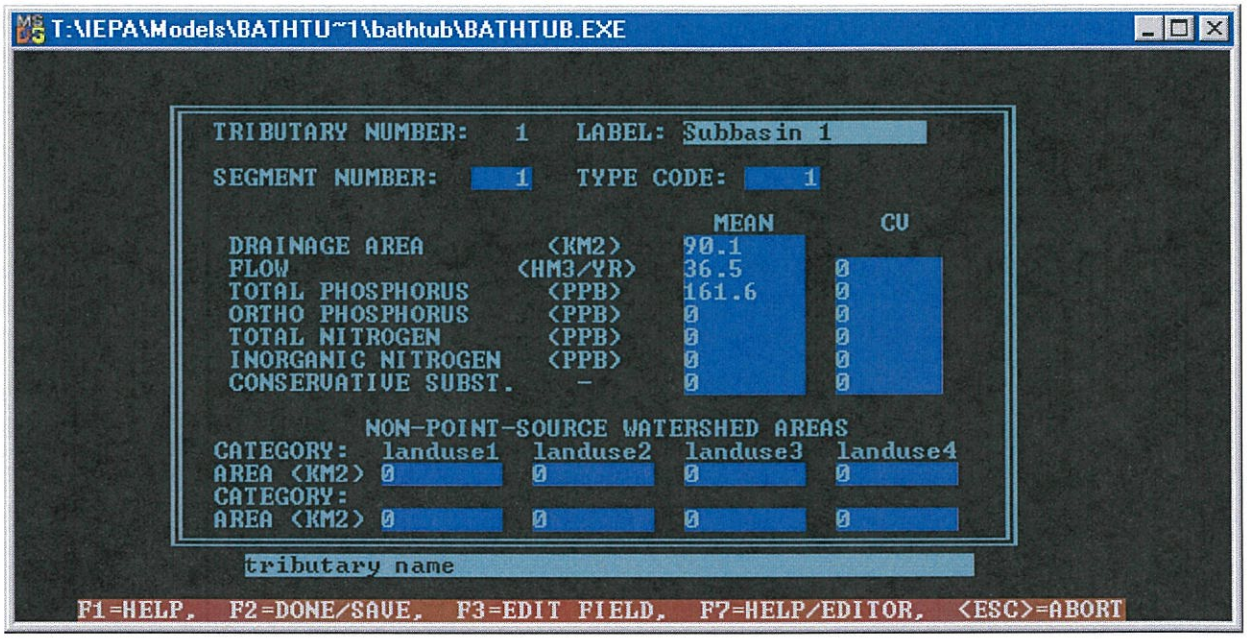


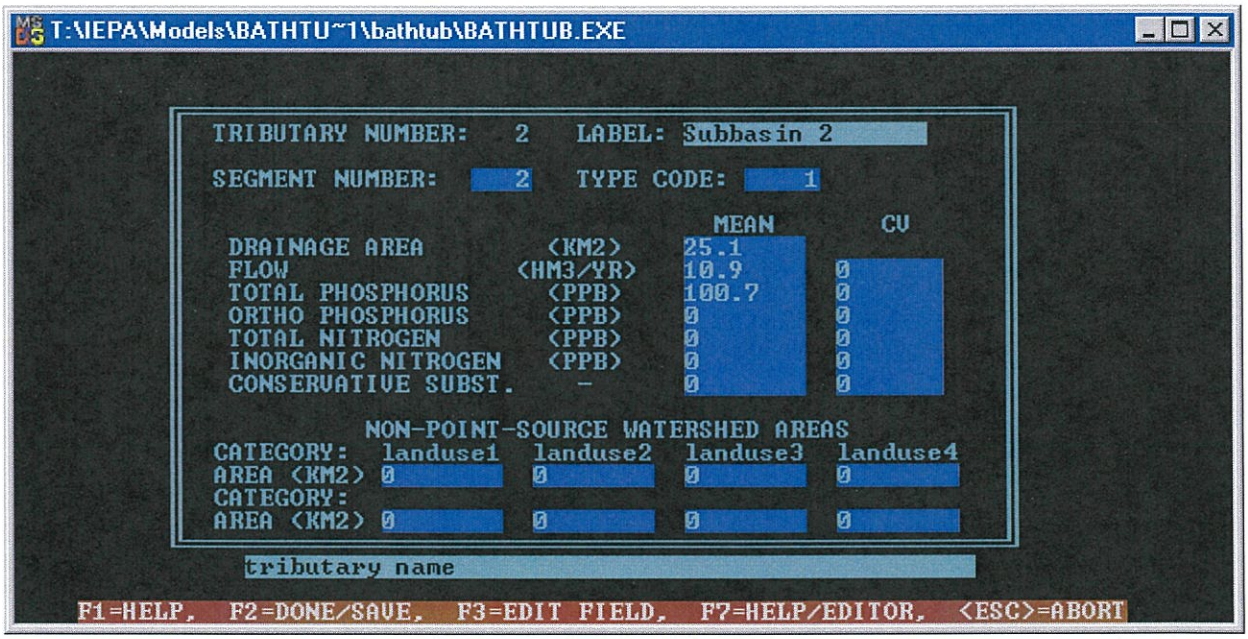

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2):.843 MEAN DEPTH (M):2.85 LENGTH (KM):4.06
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 2.85 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 129.6 .565 1.2 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 48.934 .57 2 0
SECCHI DEPTH (M) .289 .34 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

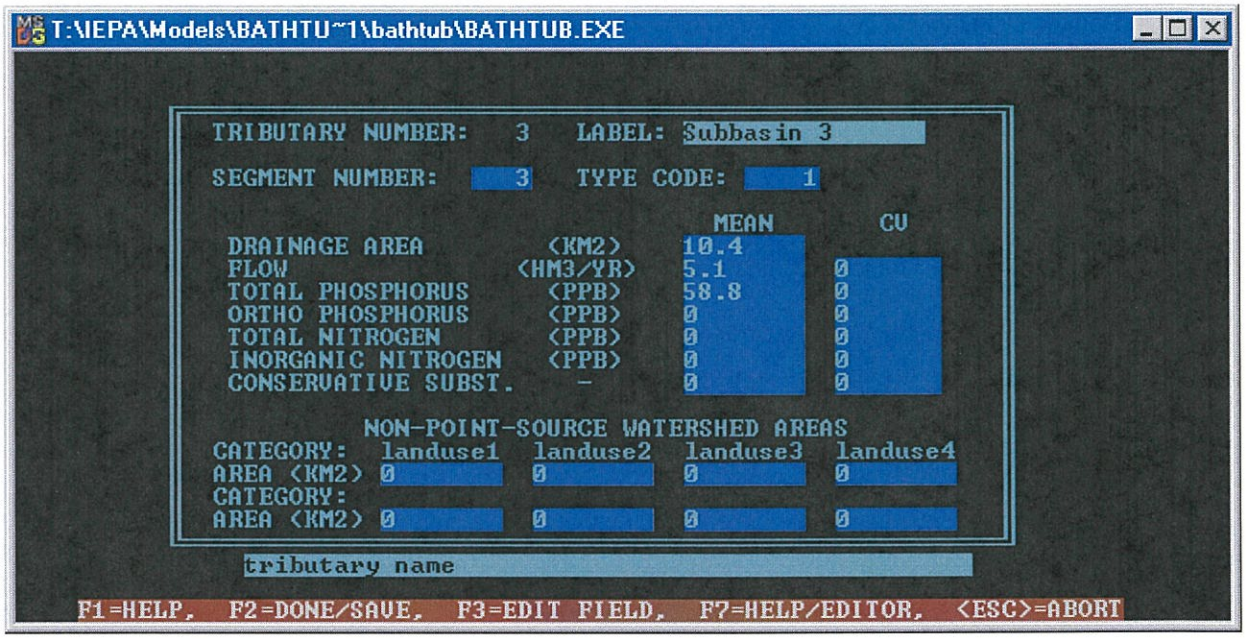

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 2 NAME: Middle Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2):1.743 MEAN DEPTH (M):8.36 LENGTH (KM):4.62
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 4.27 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 44.6 .227 .8 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 27.46 .383 1.8 0
SECCHI DEPTH (M) .905 .26 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

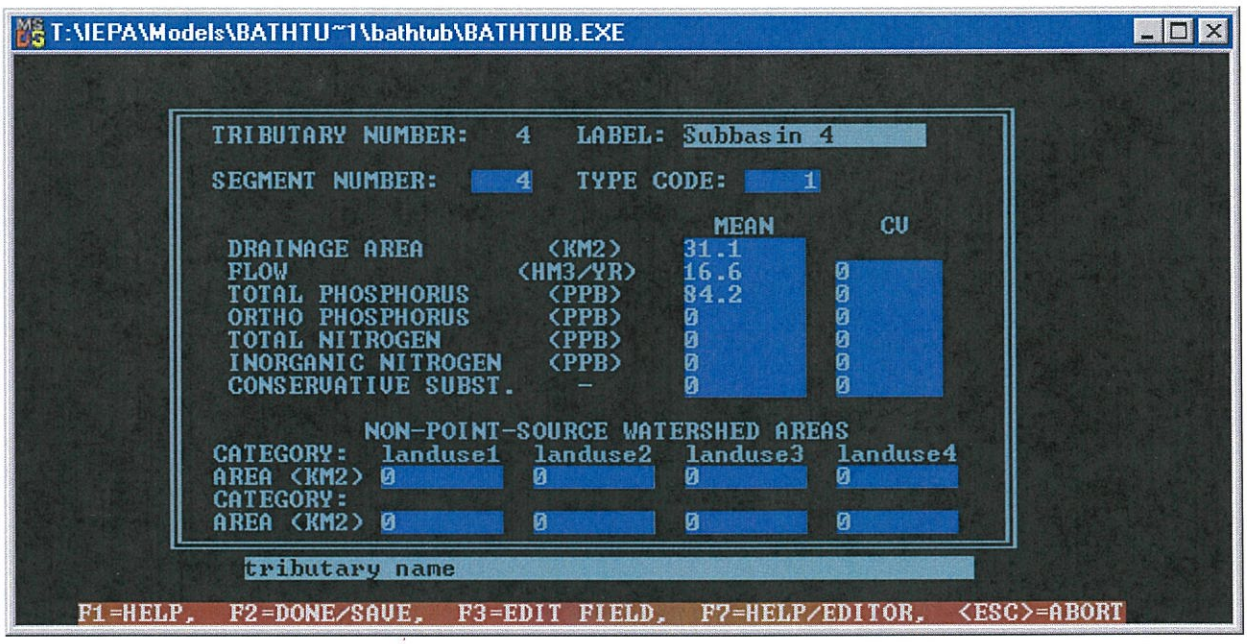

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 3 NAME: Lower Pool OUTFLOW SEG: 4 GROUP: 1
AREA (KM2):1.426 MEAN DEPTH (M):12.26 LENGTH (KM):3.36
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 6.1 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 27.2 .262 .8 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 19.422 .446 2 0
SECCHI DEPTH (M) 1.146 .261 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 4 NAME: Near Dam OUTFLOW SEG: 0 GROUP: 1
AREA (KM2):5.497 MEAN DEPTH (M):17.65 LENGTH (KM):6.94
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.79 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 42.5 1.093 2 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 13.208 .395 1.2 0
SECCHI DEPTH (M) 1.3 .296 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 1 LABEL: Subbasin 1
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 90.1
FLOW (HM3/YR) 36.5 0
TOTAL PHOSPHORUS (PPB) 161.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 2 LABEL: Subbasin 2
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 25.1
FLOW (HM3/YR) 10.9 0
TOTAL PHOSPHORUS (PPB) 100.7 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 3 LABEL: Subbasin 3
SEGMENT NUMBER: 3 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 10.4
FLOW (HM3/YR) 5.1 0
TOTAL PHOSPHORUS (PPB) 58.8 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 4 LABEL: Subbasin 4
SEGMENT NUMBER: 4 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 31.1
FLOW (HM3/YR) 16.6 0
TOTAL PHOSPHORUS (PPB) 84.2 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

BATHTUB Model Output for 1997 Simulation

CASE: Kinkaid 1997 - Calibrated

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	129.6	.56	133.1	.45	.97	-.05	-.10	-.04
CHL-A	MG/M3	48.9	.57	45.6	.46	1.07	.12	.20	.10
SECCHI	M	.3	.34	.3	.32	.98	-.07	-.09	-.05
ORGANIC N	MG/M3	.0	.00	1364.9	.32	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	130.1	.25	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	44.6	.23	43.0	.45	1.04	.16	.14	.07
CHL-A	MG/M3	27.5	.38	27.5	.50	1.00	.00	.00	.00
SECCHI	M	.9	.26	.9	.35	1.00	.00	.00	.00
ORGANIC N	MG/M3	.0	.00	814.6	.39	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	54.7	.42	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.2	.26	25.6	.45	1.06	.23	.22	.11
CHL-A	MG/M3	19.4	.45	15.9	.54	1.22	.45	.58	.29
SECCHI	M	1.1	.26	1.3	.38	.90	-.41	-.38	-.23
ORGANIC N	MG/M3	.0	.00	548.0	.36	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	33.3	.43	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	42.5	1.09	37.0	.45	1.15	.13	.52	.12
CHL-A	MG/M3	13.2	.40	12.9	.47	1.03	.06	.07	.04
SECCHI	M	1.3	.30	1.3	.33	.99	-.04	-.04	-.02
ORGANIC N	MG/M3	.0	.00	483.8	.30	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	29.2	.37	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	48.3	.75	44.9	.45	1.08	.10	.27	.08
CHL-A	MG/M3	19.9	.44	18.9	.43	1.05	.12	.15	.09
SECCHI	M	1.1	.29	1.1	.29	.98	-.09	-.09	-.06
ORGANIC N	MG/M3	.0	.00	632.2	.31	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	43.5	.35	.00	.00	.00	.00

CASE: Kinkaid 1997 - Calibrated

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	36.500	.000E+00	.000	.405
2	1	Subbasin 2	25.100	10.900	.000E+00	.000	.434
3	1	Subbasin 3	10.400	5.100	.000E+00	.000	.490
4	1	Subbasin 4	31.100	16.600	.000E+00	.000	.534
PRECIPITATION			9.509	11.886	.565E+01	.200	1.250
TRIBUTARY INFLOW			156.700	69.100	.000E+00	.000	.441
***TOTAL INFLOW			166.209	80.986	.565E+01	.029	.487
ADVECTIVE OUTFLOW			166.209	72.980	.114E+02	.046	.439
***TOTAL OUTFLOW			166.209	72.980	.114E+02	.046	.439
***EVAPORATION			.000	8.007	.577E+01	.300	.000

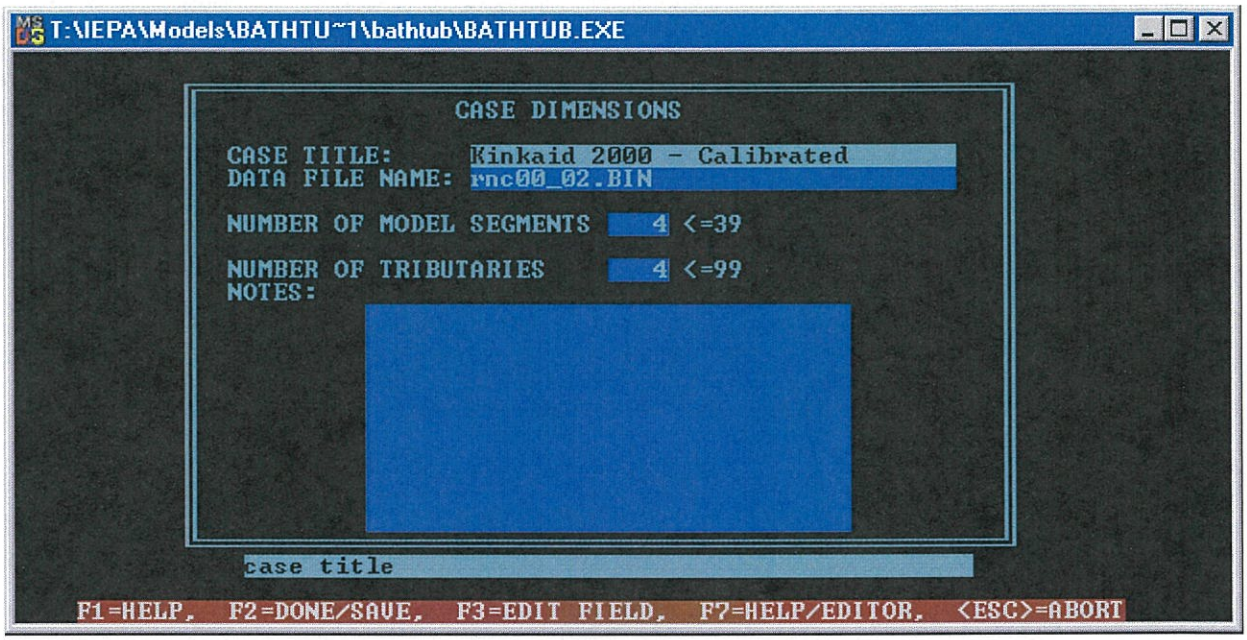
GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

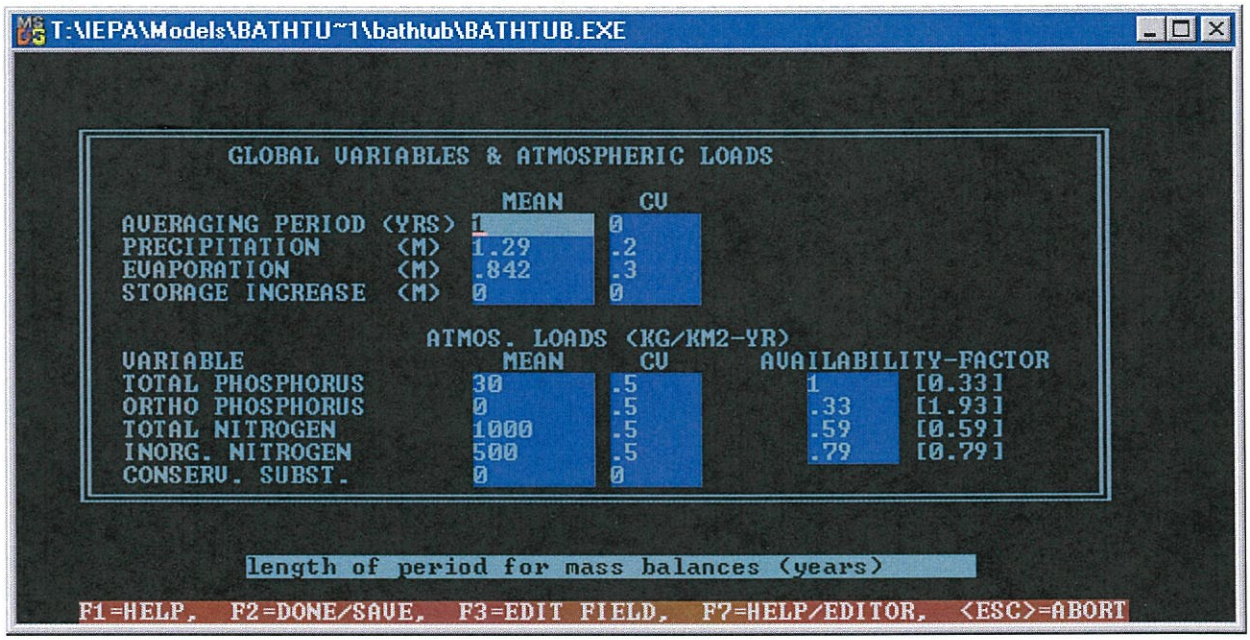
COMPONENT: TOTAL P

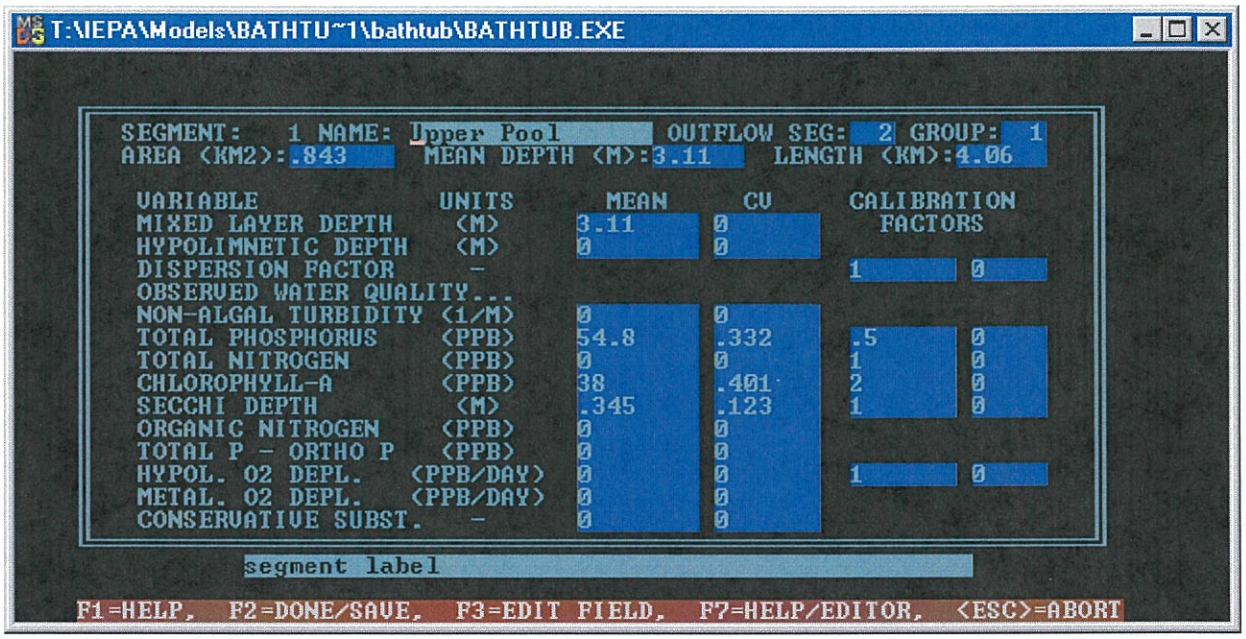
ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	5898.4	65.7	.000E+00	.0	.000	161.6	65.5
2	1	Subbasin 2	1097.6	12.2	.000E+00	.0	.000	100.7	43.7
3	1	Subbasin 3	299.9	3.3	.000E+00	.0	.000	58.8	28.8
4	1	Subbasin 4	1397.7	15.6	.000E+00	.0	.000	84.2	44.9
PRECIPITATION			285.3	3.2	.203E+05	100.0	.500	24.0	30.0
TRIBUTARY INFLOW			8693.6	96.8	.000E+00	.0	.000	125.8	55.5
***TOTAL INFLOW			8978.9	100.0	.203E+05	100.0	.016	110.9	54.0
ADVECTIVE OUTFLOW			2697.3	30.0	.150E+07	7379.0	.454	37.0	16.2
***TOTAL OUTFLOW			2697.3	30.0	.150E+07	7379.0	.454	37.0	16.2
***RETENTION			6281.6	70.0	.151E+07	7412.4	.195	.0	.0

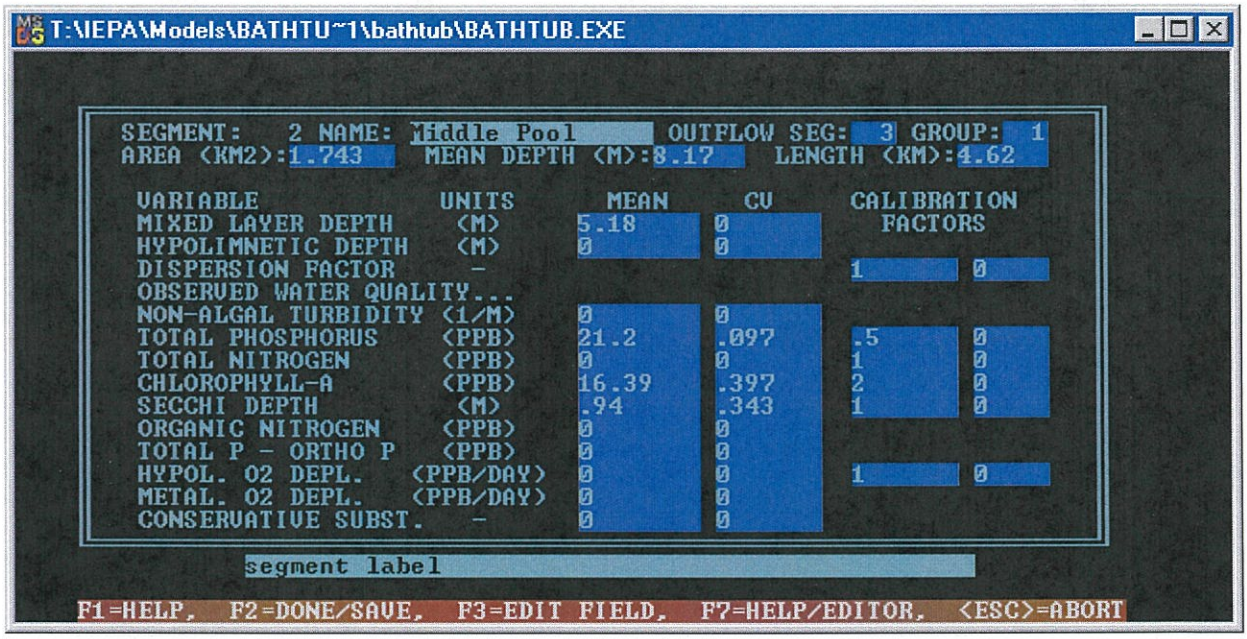
OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.67	1.8016	48.3	.7074	1.4135	.6996

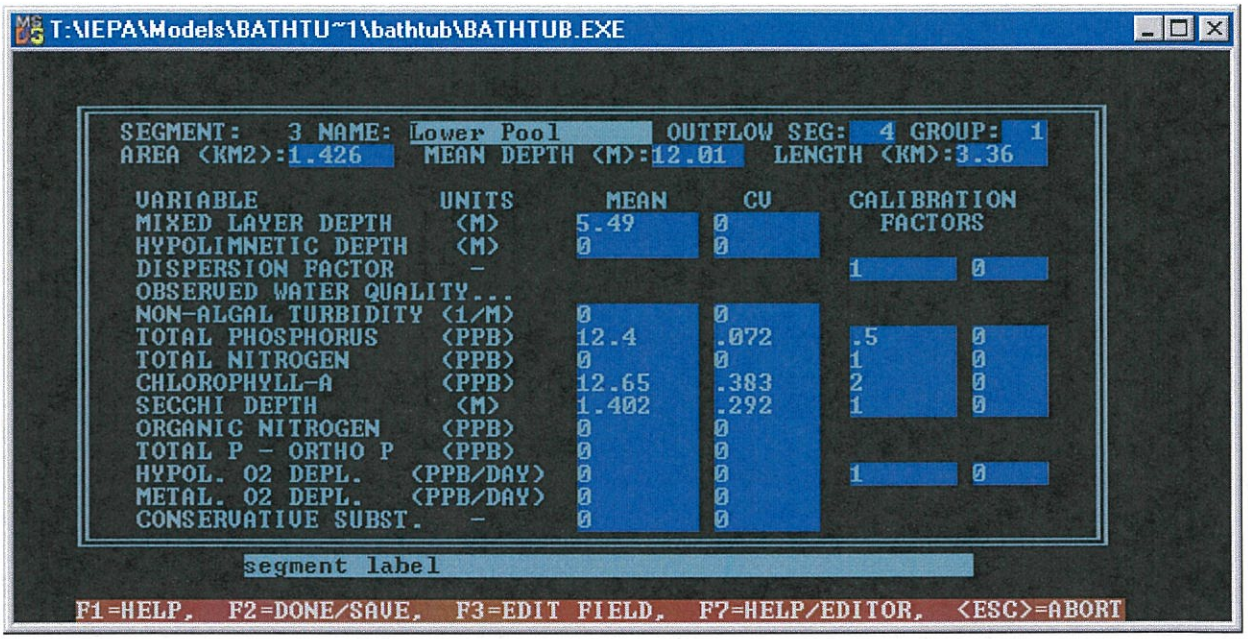
BATHTUB Model Input Screens for 2000 Simulation

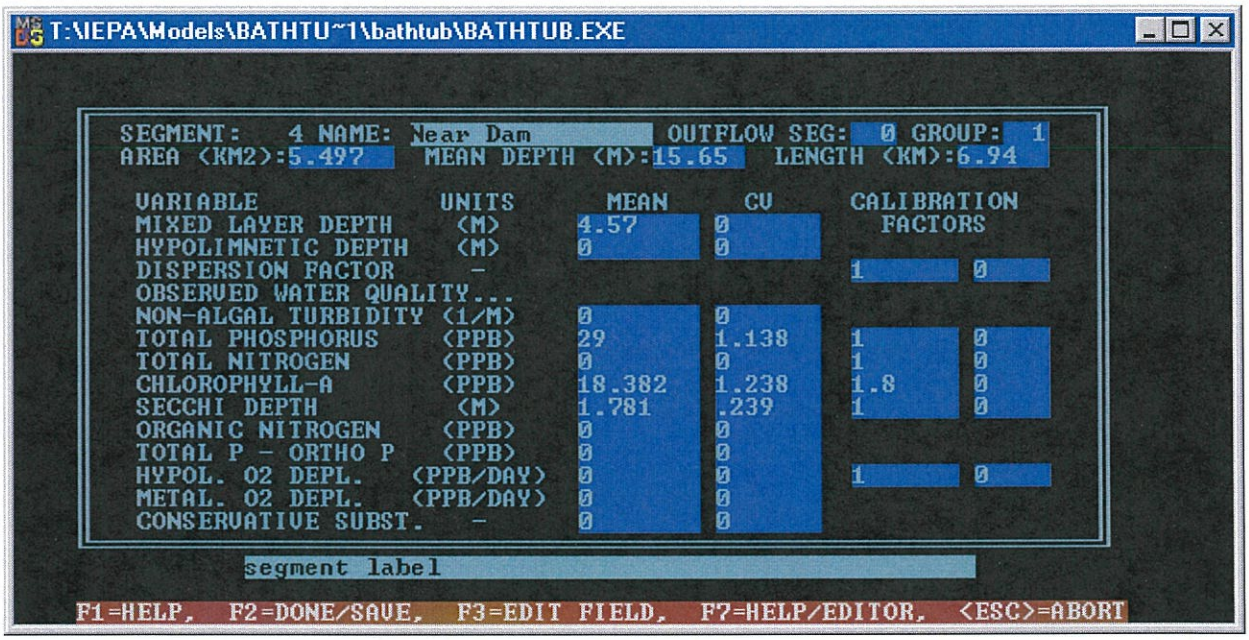


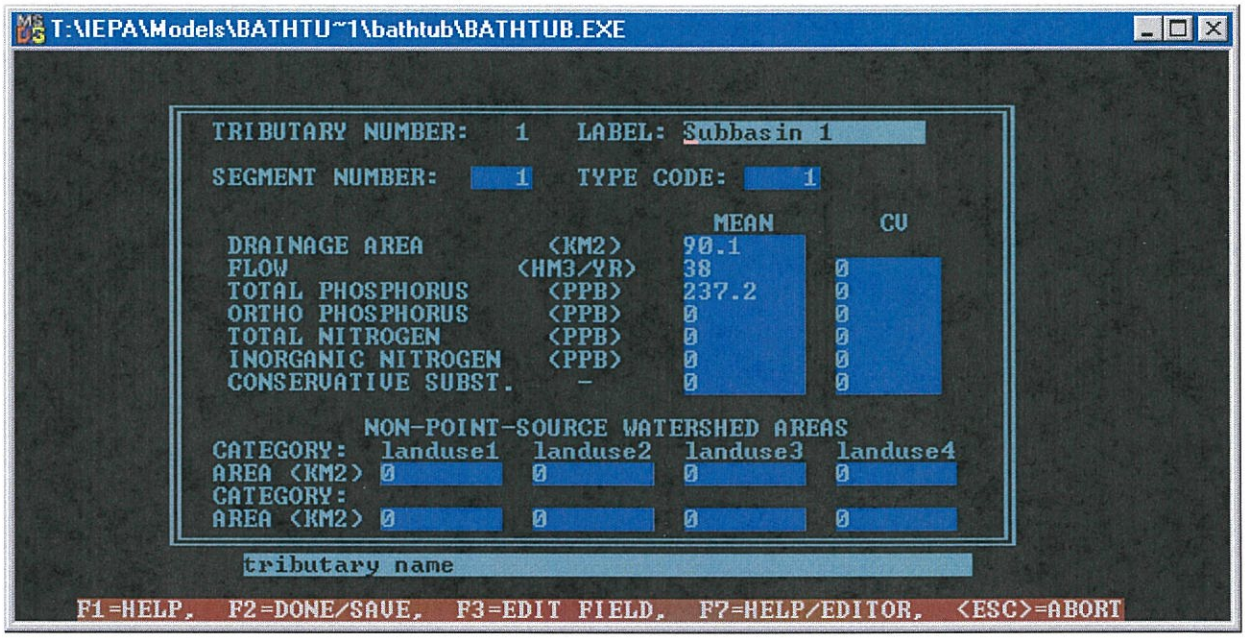


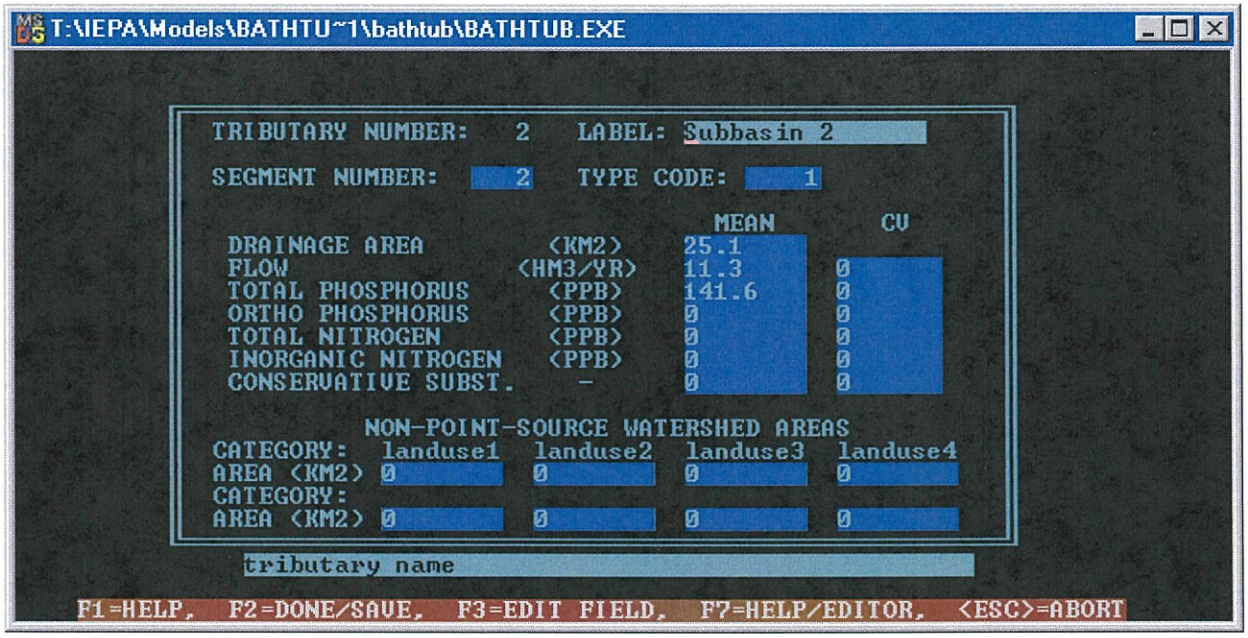

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2):.843 MEAN DEPTH (M):3.11 LENGTH (KM):4.06
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 3.11 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 54.8 .332 .5 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 38 .401 2 0
SECCHI DEPTH (M) .345 .123 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

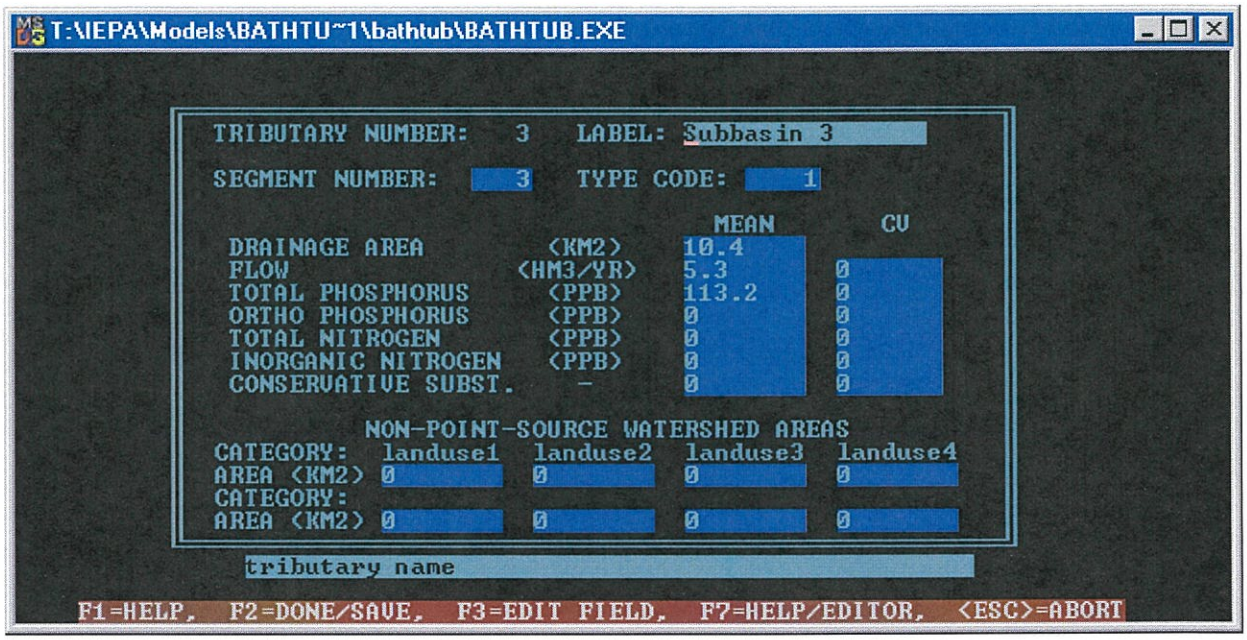

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 2 NAME: Middle Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2):1.743 MEAN DEPTH (M):8.17 LENGTH (KM):4.62
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.18 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 21.2 .097 .5 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 16.39 .397 2 0
SECCHI DEPTH (M) .94 .343 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

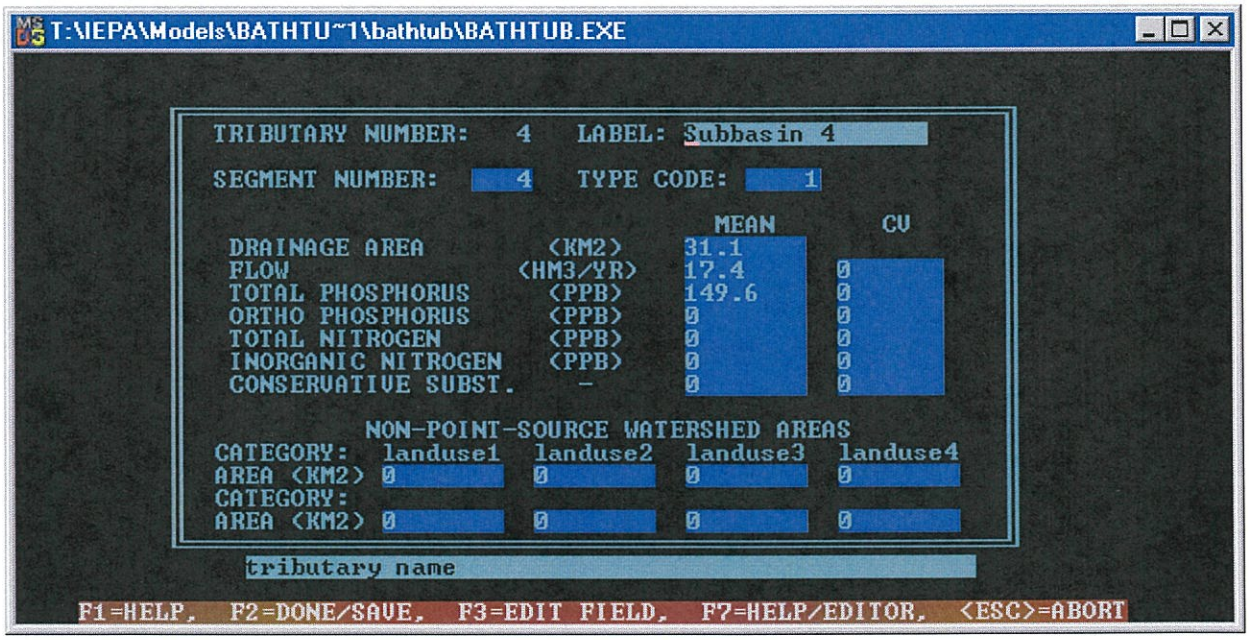

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 3 NAME: Lower Pool OUTFLOW SEG: 4 GROUP: 1
AREA (KM2):1.426 MEAN DEPTH (M):12.01 LENGTH (KM):3.36
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.49 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 12.4 .072 .5 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 12.65 .383 2 0
SECCHI DEPTH (M) 1.402 .292 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 4 NAME: Near Dam OUTFLOW SEG: 0 GROUP: 1
AREA (KM2):5.497 MEAN DEPTH (M):15.65 LENGTH (KM):6.94
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 4.57 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 29 1.138 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 18.382 1.238 1.8 0
SECCHI DEPTH (M) 1.781 .239 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 1 LABEL: Subbasin 1
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 90.1
FLOW (HM3/YR) 38 0
TOTAL PHOSPHORUS (PPB) 237.2 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 2 LABEL: Subbasin 2
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 25.1
FLOW (HM3/YR) 11.3 0
TOTAL PHOSPHORUS (PPB) 141.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 3 LABEL: Subbasin 3
SEGMENT NUMBER: 3 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 10.4
FLOW (HM3/YR) 5.3 0
TOTAL PHOSPHORUS (PPB) 113.2 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 4 LABEL: Subbasin 4
SEGMENT NUMBER: 4 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 31.1
FLOW (HM3/YR) 17.4 0
TOTAL PHOSPHORUS (PPB) 149.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

BATHTUB Model Output for 2000 Simulation

CASE: Kinkaid 2000 - Calibrated
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	54.8	.33	72.2	.45	.76	-.83	-1.03	-.49
CHL-A	MG/M3	38.0	.40	32.0	.42	1.19	.43	.50	.30
SECCHI	M	.3	.12	.4	.21	.95	-.43	-.19	-.22
ORGANIC N	MG/M3	.0	.00	1032.9	.31	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	99.0	.27	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	21.2	.10	32.6	.45	.65	-4.43	-1.60	-.93
CHL-A	MG/M3	16.4	.40	18.3	.52	.90	-.27	-.31	-.17
SECCHI	M	.9	.34	.9	.33	1.04	.13	.15	.09
ORGANIC N	MG/M3	.0	.00	623.0	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	43.9	.38	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	12.4	.07	19.4	.45	.64	-6.21	-1.66	-.98
CHL-A	MG/M3	12.6	.38	12.7	.56	.99	-.02	-.02	-.01
SECCHI	M	1.4	.29	1.4	.36	1.00	.01	.01	.01
ORGANIC N	MG/M3	.0	.00	477.6	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	28.0	.46	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	29.0	1.14	24.3	.45	1.20	.16	.66	.15
CHL-A	MG/M3	18.4	1.24	19.7	.70	.93	-.06	-.20	-.05
SECCHI	M	1.8	.24	1.7	.73	1.06	.24	.20	.07
ORGANIC N	MG/M3	.0	.00	614.0	.49	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	33.4	.58	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.4	.77	29.3	.45	.93	-.09	-.25	-.08
CHL-A	MG/M3	18.9	.87	19.5	.57	.97	-.04	-.09	-.03
SECCHI	M	1.4	.26	1.4	.56	1.05	.18	.16	.07
ORGANIC N	MG/M3	.0	.00	632.3	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.3	.45	.00	.00	.00	.00

CASE: Kinkaid 2000 - Calibrated

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	FLOW (HM3/YR) CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	38.000	.000E+00	.000	.422
2	1	Subbasin 2	25.100	11.300	.000E+00	.000	.450
3	1	Subbasin 3	10.400	5.300	.000E+00	.000	.510
4	1	Subbasin 4	31.100	17.400	.000E+00	.000	.559
PRECIPITATION			9.509	12.267	.602E+01	.200	1.290
TRIBUTARY INFLOW			156.700	72.000	.000E+00	.000	.459
***TOTAL INFLOW			166.209	84.267	.602E+01	.029	.507
ADVECTIVE OUTFLOW			166.209	76.260	.118E+02	.045	.459
***TOTAL OUTFLOW			166.209	76.260	.118E+02	.045	.459
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	9013.6	63.9	.000E+00	.0	.000	237.2	100.0
2	1	Subbasin 2	1600.1	11.3	.000E+00	.0	.000	141.6	63.7
3	1	Subbasin 3	600.0	4.3	.000E+00	.0	.000	113.2	57.7
4	1	Subbasin 4	2603.0	18.5	.000E+00	.0	.000	149.6	83.7
PRECIPITATION			285.3	2.0	.203E+05	100.0	.500	23.3	30.0
TRIBUTARY INFLOW			13816.7	98.0	.000E+00	.0	.000	191.9	88.2
***TOTAL INFLOW			14101.9	100.0	.203E+05	100.0	.010	167.3	84.8
ADVECTIVE OUTFLOW			1850.4	13.1	.702E+06	3452.5	.453	24.3	11.1
***TOTAL OUTFLOW			1850.4	13.1	.702E+06	3452.5	.453	24.3	11.1
***RETENTION			12251.5	86.9	.717E+06	3523.1	.069	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
8.02	1.5738	27.4	.2329	4.2933	.8688

Appendix D
GWLF Manual

G W L F

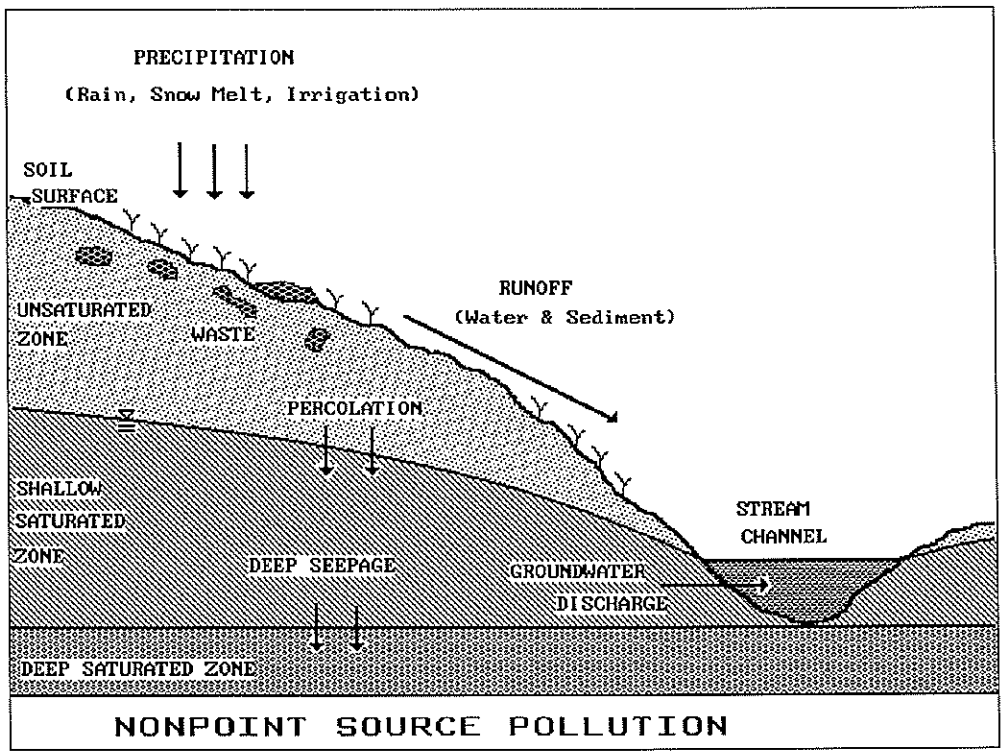
GENERALIZED WATERSHED LOADING FUNCTIONS

VERSION 2.0

USER'S MANUAL

December, 1992
(Corrected & reprinted: January, 1996)

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INTRODUCTION

Mathematical models for estimating nonpoint sources of nitrogen and phosphorus in streamflow include export coefficients, loading functions and chemical simulation models. Export coefficients are average annual unit area nutrient loads associated with watershed land uses. Coefficients provide gross estimates of nutrient loads, but are of limited value for determining seasonal loads or evaluating water pollution control measures. Chemical simulation models are mechanistic (mass balance) descriptions of nutrient availability, wash off, transport and losses. Chemical simulation models provide the most complete descriptions of nutrient loads, but they are too data intensive for use in many water quality studies.

Loading functions are engineering compromises between the empiricism of export coefficients and the complexity of chemical simulation models. Mechanistic modeling is limited to water and/or sediment movement. Chemical behavior of nutrients is either ignored or described by simple empirical relationships. Loading functions provide useful means of estimating nutrient loads when chemical simulation models are impractical.

The Generalized Watershed Loading Functions (GWLF) model described in this manual estimates dissolved and total monthly nitrogen and phosphorus loads in streamflow from complex watersheds. Both surface runoff and groundwater sources are included, as well as nutrient loads from point sources and on-site wastewater disposal (septic) systems. In addition, the model provides monthly streamflow, soil erosion and sediment yield values. The model does not require water quality data for calibration, and has been validated for an 85,000 ha watershed in upstate New York.

The model described in this manual is a based on the original GWLF model as described by Haith & Shoemaker (1987). However, the current version (Version 2.0) contains several enhancements. Nutrient loads from septic systems are now included and the urban runoff model has been modified to more closely approximate procedures used in the Soil Conservation Service's Technical Release 55 (Soil Conservation Service, 1986) and models such as SWMM (Huber & Dickinson, 1988) and STORM (Hydrologic Engineering Center, 1977). The groundwater model has been given a somewhat stronger conceptual basis by limiting the unsaturated zone moisture storage capacity. The graphics outputs have been converted to VGA and color has been used more extensively.

The most significant changes in the manual are an expanded mathematical description of the model (Appendix A) and much more detailed guidance on parameter estimation (Appendix B). Both changes are in response to suggestions by many users. The extra mathematical details are for the benefit of researchers who wish to modify (and improve) GWLF for their own purposes. The new sections on parameter estimation (and the many new tables) are for users who may not be familiar with curve numbers, erosivity coefficients, etc., or who do not have access to some of the primary sources. The general intent has been to make the manual self-contained.

This manual describes the computer software package which can be used to implement GWLF. The associated programs are written in QuickBASIC 4.5 for personal computers using the MS-DOS operating system and VGA graphics. The manual and associated programs (on floppy disk) are available without charge from the senior author. The programs are distributed in both executable (.EXE) and source code form (.BAS). Associated example data files and outputs for Example 1 and a 30-yr weather set for Walton NY used in Example 3 are also included on the disk.

The main body of this manual describes the program structures and input and output files and options. Three examples are also presented. Four appendices present the mathematical structure of GWLF, methods for estimation of model parameters, results of a validation study, and sample listings of input and output files.

In this manual, the program name, options in the menu page, and input by the user are written in **bold**, underline and *italic*, respectively.

MODEL DESCRIPTION

Model Structure

The GWLF model includes dissolved and solid-phase nitrogen and phosphorus in streamflow from the sources shown in Figure 1. Rural nutrient loads are transported in runoff water and eroded soil from numerous source areas, each of which is considered uniform with respect to soil and cover. Dissolved loads from each source area are obtained by multiplying runoff by dissolved concentrations. Runoff is computed by using the Soil Conservation Service Curve Number Equation. Solid-phase rural nutrient loads are given by the product of monthly sediment yield and average sediment nutrient concentrations. Erosion is computed using the Universal Soil Loss Equation and the sediment yield is the product of erosion and sediment delivery ratio. The yield in any month is proportional to the total transport capacity of daily runoff during the month. Urban nutrient loads, assumed to be entirely solid-phase, are modeled by exponential accumulation and washoff functions. Septic systems are classified according to four types: normal systems, ponding systems, short-circuiting systems, and direct discharge systems. Nutrient loads from septic systems are calculated by estimating the per capita daily load from each type of system and the number of people in the watershed served by each type. Daily evapotranspiration is given by the product of a cover factor and potential evapotranspiration. The latter is estimated as a function of daylight hours, saturated water vapor pressure and daily temperature.

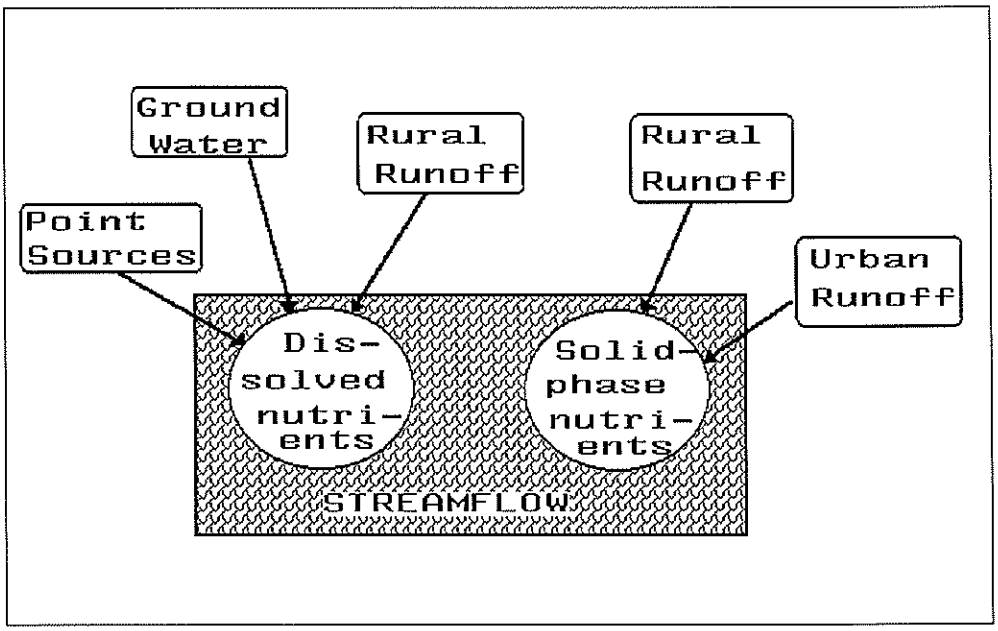


Figure 1. Nutrient Sources in GWLF.

Streamflow consists of runoff and discharge from groundwater. The latter is obtained from a lumped parameter watershed water balance. Daily water balances are calculated for unsaturated and shallow saturated zones. Infiltration to the unsaturated and shallow saturated zones equals the excess, if any, of rainfall and snowmelt less runoff and evapotranspiration. Percolation occurs when unsaturated zone water exceeds field capacity. The shallow saturated zone is modeled as a linear groundwater reservoir.

Model structure, including mathematics, is discussed in more detail in Appendix A.

Input Data

The GWLF model requires daily precipitation and temperature data, runoff sources and transport and chemical parameters. Transport parameters include areas, runoff curve numbers for antecedent moisture condition II and the erosion product KLSCP for each runoff source. Required watershed transport parameters are groundwater recession and seepage coefficients, the available water capacity of the unsaturated zone, the

sediment delivery ratio and monthly values for evapotranspiration cover factors, average daylight hours, growing season indicators and rainfall erosivity coefficients. Initial values must also be specified for unsaturated and shallow saturated zones, snow cover and 5-day antecedent rain fall plus snowmelt.

Input nutrient data for rural source areas are dissolved nitrogen and phosphorus concentrations in runoff and solid-phase nutrient concentrations in sediment. If manure is spread during winter months on any rural area, dissolved concentrations in runoff are also specified for each manured area. Daily nutrient accumulation rates are required for each urban land use. Septic systems need estimates of the per capita nutrient load in septic system effluent and per capita nutrient losses due to plant uptake, as well as the number of people served by each type of system. Point sources of nitrogen and phosphorus are assumed to be in dissolved form and must be specified for each month. The remaining nutrient data are dissolved nitrogen and phosphorus concentrations in groundwater.

Procedures for estimating transport and nutrient parameters are described in Appendix B. Examples are given in Appendix C and in subsequent sections of this manual.

Model Output

The GWLF program provides its simulation results in tables as well as in graphs. The following principal variables are given:

Monthly Streamflow
Monthly Watershed Erosion and Sediment Yield
Monthly Total Nitrogen and Phosphorus Loads in Streamflow
Annual Erosion from Each Land Use
Annual Nitrogen and Phosphorus Loads from Each Land Use

The program also provides

Monthly Precipitation and Evapotranspiration
Monthly Ground Water Discharge to Streamflow
Monthly Watershed Runoff
Monthly Dissolved Nitrogen and Phosphorus Loads in Streamflow
Annual Dissolved Nitrogen and Phosphorus Loads from Each Land Use
Annual Dissolved Nitrogen and Phosphorus Loads from Septic Systems

GWLF PROGRAM

Required Files

Simulations by GWLF require four program modules and three data files on the default drive. The three necessary data files are **WEATHER.DAT**, **TRANSPRT.DAT** and **NUTRIENT.DAT**. The four compiled modules, **GWLF20.EXE**, **TRAN20.EXE**, **NUTR20.EXE**, and **OUTP20.EXE** are run by typing *GWLF20*.

Two daily weather files for Walton, NY are included on the disks. **WALT478.382** is the four year (4/78-3/92) record used for model validation and in Examples 1 and 2. **WALT462.392** is the 30 year (4/62- 3/92) record used in Example 3. Prior to running the programs, the appropriate weather record should be copied to **WEATHER.DAT**.

The final two data files on the disks (**RESULTS.DAT**, and **SUMMARY.DAT**) are output files from Example 1. **GWLF20.BAS**, **TRAN20.BAS**, **NUTR20.BAS**, and **OUTP20.BAS** are the uncompiled, Quick-BASIC files for the modules, and can be used to modify the existing program.

Program Structure

The structure of GWLF is illustrated in Figure 2. Once the program has been activated, the main control page appears on the screen, as shown in DISPLAY 1.This page is the main menu page that leads to the four major options of the program. The selection of a program option provides access to another set of menu pages within the chosen option. After completing an option, the program returns the user to the main menu page for further actions.

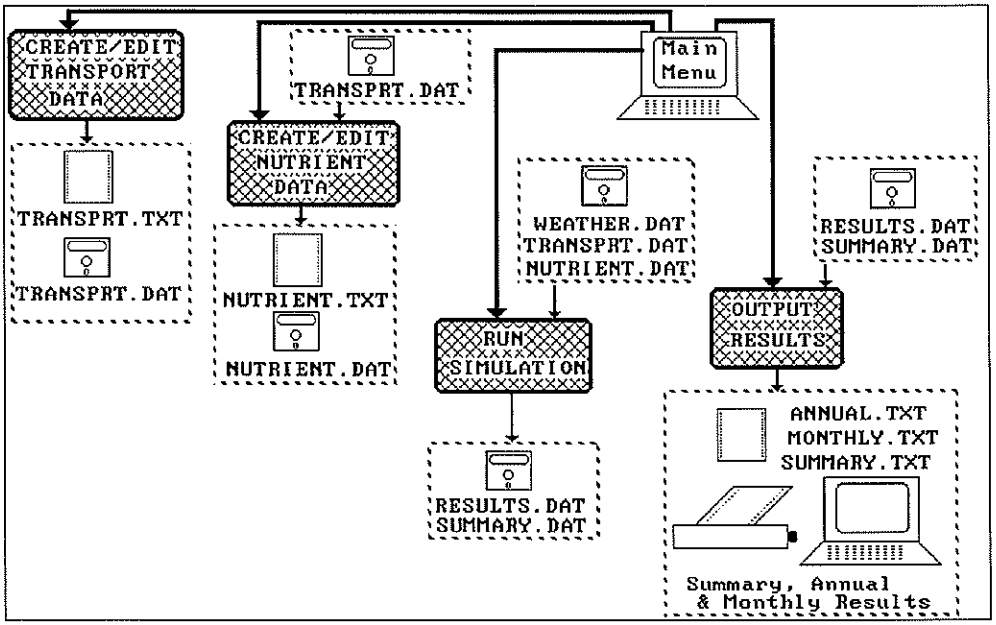


Figure 2. Structure of the GWLF Program.

The selection of the menu options is done by typing the number indicating a choice and then *Enter*. For example, selection of Run simulation is done by typing *3* and *Enter*.

```
Select one of the following :
      1      Create or print TRANSPRT.DAT (Transport parameters)
      2      Create or print NUTRIENT.DAT (nutrient parameters)
               (TRANSPRT.DAT must be created before NUTRIENT.DAT)
      3      Run simulation
      4      Obtain output
      5      Stop (End)
?
```

DISPLAY 1. The Main Menu Page of the GWLF Program.

Transport Data Manipulation

The first step in using the program is to define transport parameters either by creating a new transport data file or modifying an existing one. Options are shown in DISPLAY 2. If the user wishes to create a new transport data file, selection of Create new TRANSPRT.DAT file leads to the input mode. On the other hand, if the user wishes to modify an existing transport data file, selection of Modify existing TRANSPRT.DAT file leads to the modification mode. After input/modification, the user can obtain a hard copy of the transport data by selecting Print TRANSPORT data.

```
Select :
      1       Create new TRANSPRT.DAT file
      2       Modify existing TRANSPRT.DAT file
      3       Print TRANSPORT data
  otherwise   Return
?
```

DISPLAY 2. The Menu Page for Manipulation of Transport Parameters.

Create a New TRANSPRT.DAT File. New values of transport parameters are input one by one in this mode. Values are separated by *Enter* keys. After the number of land uses are input, a table is displayed in the screen to help the user to input data. The line in the bottom of the screen provides on-line help which indicates the expected input data type.

In cases when a serious error has been made, the user can always restart this process by hitting *F1*, then *Enter*. Alternatively, the user may save current input and modify the data in the modification mode.

After all input is complete, the user is asked whether to save or abort the changes. An input of *Y* will overwrite the existing, if any, transport data file.

Modify an Existing TRANSPRT.DAT File. An existing transport data file can be modified in this mode. This is convenient when only minor modification of transport data is needed, e.g., in the case of studying impacts of changes of land use on a watershed.

In this mode, the user is expected to hit *Enter* if no change would be made and *Space bar* if a new value would be issued. The two lines at the bottom of screen provide on-line help.

Print TRANSPORT Data. The user can choose one or more of the three types of print out of transport parameters, namely, to display to screen, print a hard copy, or create a ASCII text file named **TRANSPRT.TXT**. The text file can later be imported to a word processor to generate reports.

Nutrient Data Manipulation

0When nutrient loads are of concern, the nutrient data file (**NUTRIENT.DAT**) must be available before a simulation can be run. This is done by either creating a new nutrient data file or modifying an existing one. Options are shown in DISPLAY 3. Procedures for creating, modifying or printing nutrient data are similar to those described for the transport data. The ASCII text file is **NUTRIENT.TXT**.

```
Select :
      1       Create new NUTRIENT.DAT file
      2       Modify existing NUTRIENT.DAT file
      3       Print NUTRIENT data
      4       Return
?
```

DISPLAY 3. The Menu Page for Manipulation of Nutrient Parameters.

Simulation

Four categories of simulation can be performed, as shown in DISPLAY 4. To simulate streamflow or sediment yield, two data files, **WEATHER.DAT** and **TRANSPRT.DAT** must be in the default directory. An additional data file, **NUTRIENT.DAT**, is required when nutrient loads are simulated.

```
Select program options:
       1      Streamflow simulation only
       2      Streamflow and sediment yield only
       3      Streamflow, sediment yield, and nutrient loads
       4      Streamflow, sediment yield, nutrient loads, and septic systems
  otherwise   Return
?
```

DISPLAY 4. The Menu Page for Simulation Options.

After choosing the type of simulation, the user inputs the title of this specific simulation. This title can be a word, a sentence, or a group of words. The user then decides the length, in years, of the simulation run (not to exceed the number of years of weather data in **WEATHER.DAT**).

Results Output

Simulation output can be reported in three categories, namely, overall means, annual values, and monthly values. Either tables or graphs can be generated, as shown in DISPLAY 5. In producing tables, i.e., when one of the first three options is selected, the user can choose to display it on screen, print it on a printer, or save it as an ASCII text file. When one of the graph options is selected, the user is able to see the graph on the screen. If the computer has suitable printer driver, a hard copy of the graph can be obtained by pressing *Shift-PrtSc* keys together.

```
Select :
       1       Print summary
       2       Print annual results
       3       Print monthly results
       4       Graph summary (average)
       5       Graph annual results
       6       Graph monthly results
               (PrtSc for hard copy, carriage return to continue)
  otherwise    Return
?
```

DISPLAY 5. The Menu Page for Output Generation.

EXAMPLE 1: 4-YEAR STUDY IN WEST BRANCH DELAWARE BASIN

This example is designed to allow the user to become familiar with the operation of the program and the way results are presented. The data set and results are those described in Appendix C for the GWLF validation for the West Branch Delaware River Watershed in New York.

The programs **GWLF20.EXE, TRAN20.EXE, NUTR20.EXE,** and **OUTP20.EXE**, and the data files **WEATHER.DAT, TRANSPRT.DAT,** and **NUTRIENT.DAT** must be on the default drive. The weather file can be obtained by copying **WALT478.382** to **WEATHER.DAT**.

Simulation

To start the program, type *GWLF20* then *Enter*. The first screen is the main menu (see DISPLAY 1). To select Run simulation, type *3* and *Enter*. This will lead to the simulation option menu (see DISPLAY 4). Since nutrient fluxes and septic system loads are of interest, type *4* and *Enter*. This will start the simulation.

The user is then asked to input the title of this simulation. Type *Example 1* and *Enter*. Finally the user is expected to specify the length of the simulation. Type *4*, then *Enter*. This concludes the information required for a simulation run. The input section described above is shown in DISPLAY 6.

```
Select one of the following :
      1     Create or print TRANSPRT.DAT (Transport parameters)
      2     Create or print NUTRIENT.DAT (nutrient parameters)
              (TRANSPRT.DAT must be created before NUTRIENT.DAT)
      3     Run simulation
      4     Obtain output
      5     Stop (End)
? 3

Select program options:
      1     Streamflow simulation only
      2     Streamflow and sediment yield only
      3     Streamflow, sediment yield, and nutrient loads
      4     Streamflow, sediment yield, nutrient loads, and septic systems
  otherwise Return
? 3

TITLE OF SIMULATION? Example 1
LENGTH OF RUN IN YEARS? 4
```

DISPLAY 6. Input Section in Example 1. User Input is Indicated by Italics.

The screen is now switched to graphic mode. During the computation, part of the result will be displayed. This is to provide a sample of the result and to monitor the progress of the simulation. As shown in Figure 3, the line on the top of the screen reports the length of simulation and the current simulated month/year.

The main menu is displayed at the end of the simulation. From here, the user can generate several types of results.

Results Generation

Type *4*, then *Enter* to generate results. For printing out monthly streamflows, sediment yields, and nutrient loads, type *3*, then *Enter*. The user is asked whether to specify the range of the period to be reported. Type *N*, then *Enter* to select the default full period.

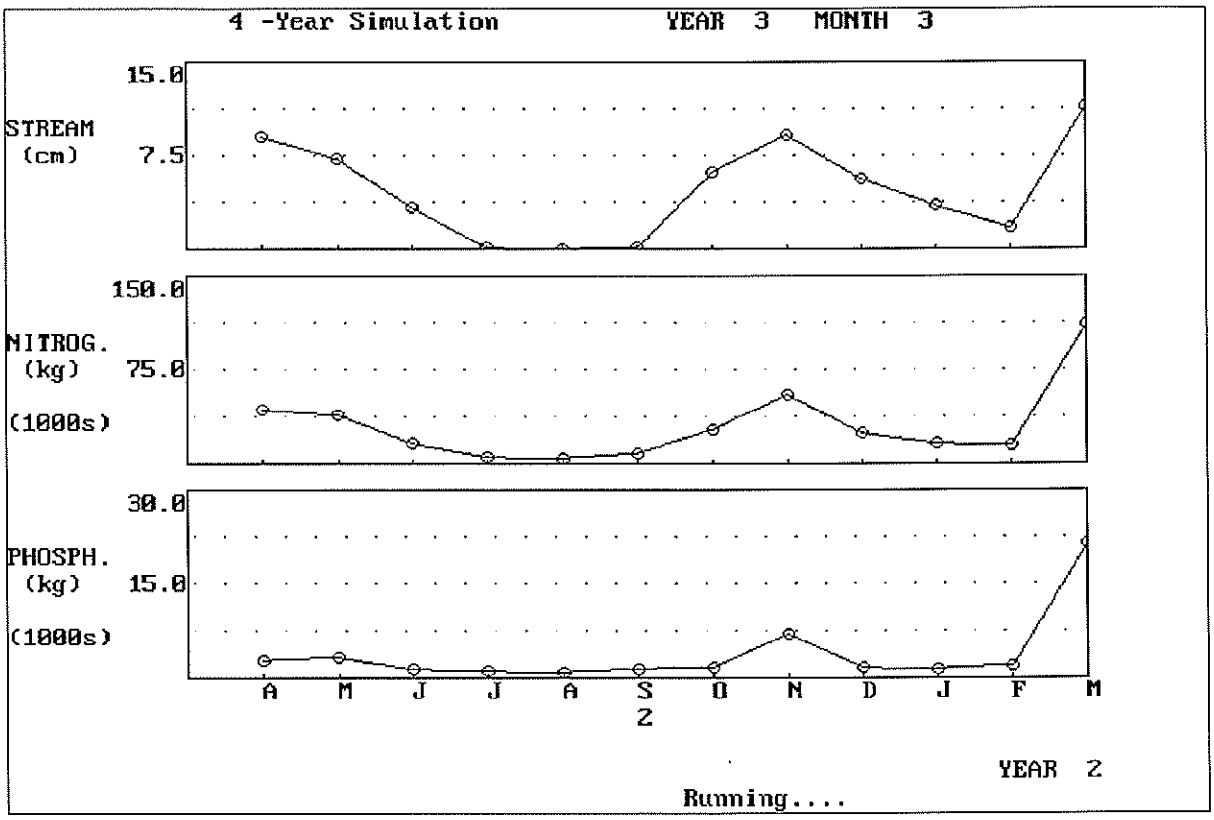


Figure 3. Screen Display during Simulation.

The user decides on the type of output. Type *1*, then *Enter* to print to the screen. The result is displayed in nine screens. After reading a screen, press *Enter* to bring up the next screen. To generate a hard copy, turn on the printer, type *2* and *Enter*. Alternatively, the user can save the result in a text file, **MONTHLY.TXT**. The user can go back to the previous page menu to select another option of results generation by pressing *Enter*. Part of the process described above is shown in DISPLAY 7. To generate graphs of the monthly results, type *6* and *Enter*. This produces graphs such as Figure 4 and Figure 5. The user can call up the main menu again by pressing *Enter* keys. The data input files **TRANSPRT.DAT**, **NUTRIENT.DAT** and **WEATHER.DAT** for this example are listed in Appendix E with the various **.TXT** files that may be generated.

EXAMPLE 2: EFFECTS OF ELIMINATION OF WINTER MANURE SPREADING

In this example, nutrient parameters are modified to investigate effects of winter manure applications. The example involves manipulation of the data file **NUTRIENT.DAT**. If the user wishes to save the original file, it should first be copied to a new file, say **NUTRIENT.EX1**.

Nutrient Parameters Modification

From the main menu, type *2*, *Enter*. This leads to the nutrient data manipulation option. Type *2*, *Enter* to modify **NUTRIENT.DAT** (see DISPLAY 8).

Type *Enter* to accept the original dissolved nutrient concentrations. Repeat this procedure until the cursor is in the line, Number of Land Uses on Which Manure is Spread (see DISPLAY 9), hit *Space-bar*, type *0*, and hit *Enter*.

Accept all the rest of original data by hitting *Enter* key until the end of the file. Type *Y* to save the

changes. This concludes the modification of **NUTRIENT.DAT**.

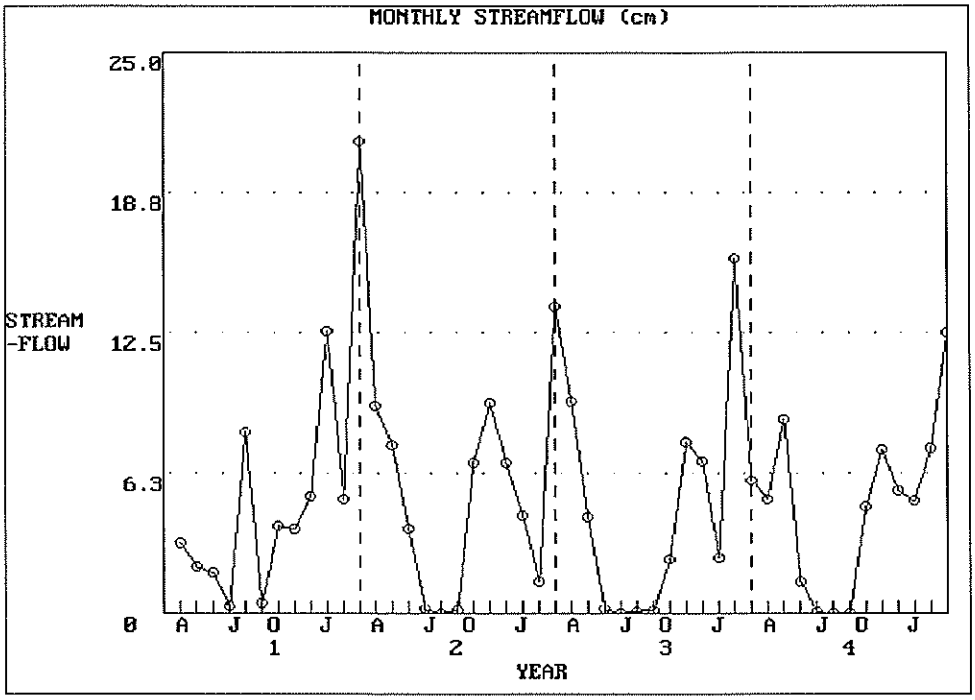


Figure 4. Monthly Streamflows for Example 1.

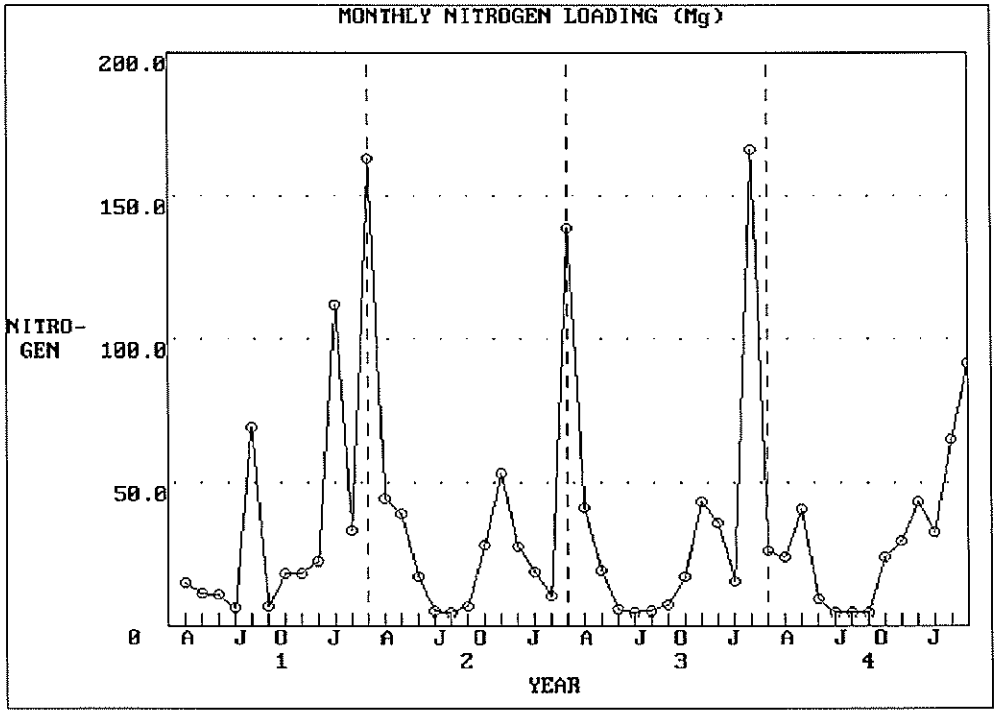


Figure 5. Monthly Nitrogen Loads for Example 1.

The user may print out nutrient data to make sure these changes have been made. To do so, the user selects Print NUTRIENT data in the nutrient data manipulation page (see DISPLAY 3). Then select Print to screen to display the current nutrient parameters.

```
 Select one of the following :
       1      Create or print TRANSPRT.DAT (Transport parameters)
       2      Create or print NUTRIENT.DAT (nutrient parameters)
                (TRANSPRT.DAT must be created before NUTRIENT.DAT)
       3      Run simulation
       4      Obtain output
       5      Stop (End)
? 4

 Select :
       1      Print summary
       2      Print annual results
       3      Print monthly results
       4      Graph summary (average)
       5      Graph annual results
       6      Graph monthly results
              (PrtSc for hard copy, carriage return to continue)
  otherwise   Return
? 3
      Want to specify the range of years in output?   ( Type  Y  or  N )
? N

 Select : (For printing MONTHLY data)
       1      Print to screen (carriage return to continue)
       2      Print a hard copy (turn on printer first)
       3      Print to a file named MONTHLY.TXT
  otherwise   Return
? 1
```

DISPLAY 7. Result Generating Menu in Example 1.

```
 Select one of the following :
       1      Create or print TRANSPRT.DAT (Transport parameters)
       2      Create or print NUTRIENT.DAT (nutrient parameters)
                (TRANSPRT.DAT must be created before NUTRIENT.DAT)
       3      Run simulation
       4      Obtain output
       5      Stop (End)
? 2

 Select :
       1      Create new NUTRIENT.DAT file
       2      Modify existing NUTRIENT.DAT file
       3      Print NUTRIENT data
  otherwise   Return
? 2
```

DISPLAY 8. Modification of Nutrient Parameters.

Simulation and Results Generation

Following the procedures described in Example 1, the results of a 3-year simulation are shown in Figure 6.

```
Number of Land Uses on Which Manure is Spread: -1

                                To redo from start, Hit <F1> then <ENTER> key
Hint: Press Space-Bar to Input Value or Enter-Key to Accept Current Value
```

DISPLAY 9. The First Screen for Modifying Nutrient Parameters. The Original Number is 1. Hit the *Space Bar*, Type *0*, and then Hit *Enter* Key to Change this Number to 0.

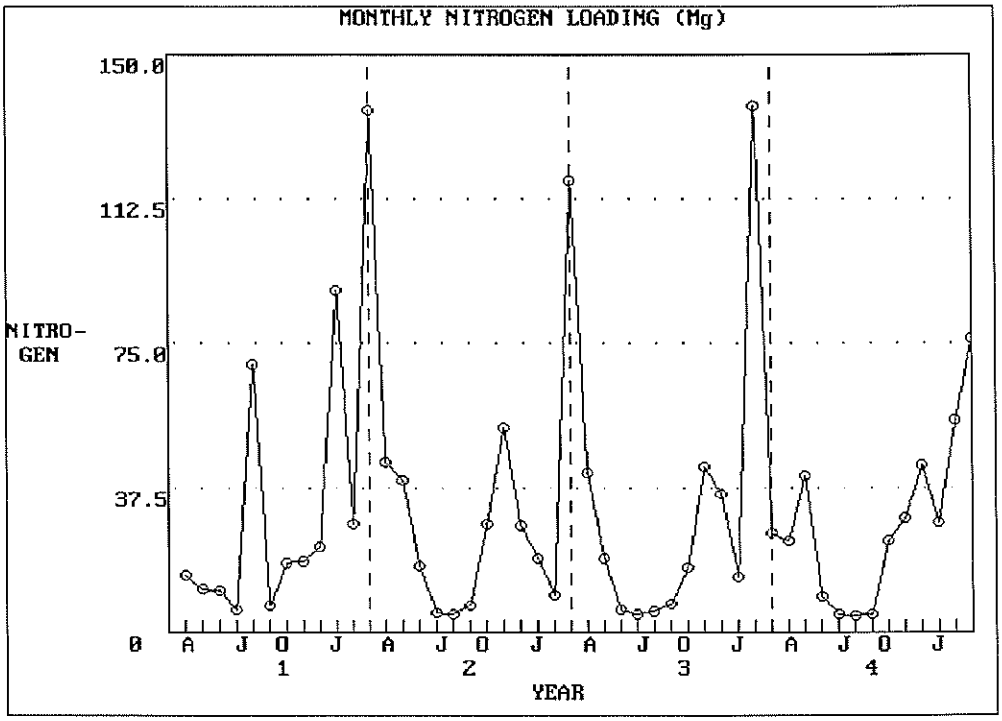


Figure 6. Monthly Nitrogen Loads with no Manure Spreading .

EXAMPLE 3: A 30-YEAR SIMULATION STUDY

In Example 3, a simulation of the West Branch Delaware River Basin is based on a 30-yr (4/62-3/92) weather record given in the file **WALT462.392**.

Simulation and Results Generation

The simulation is run by following procedures as in Example 1 (see DISPLAY 6). Answer LENGTH OF RUN IN YEARS by typing *30* and then *Enter*.

At the end of the computation, the main menu is displayed. From here, the user can generate several types of results by typing *4*, then *Enter*. For a summary of the results, type *1* and *Enter*. To display the summary in screen, type *1* and *Enter*. The summary is displayed in three screens. After reading a screen, press *Enter* to bring up next screen. To generate a hard copy from the printer, turn on the printer, select Print a hard copy. Hit *Enter* to obtain the output option menu.

From the output generation menu (see DISPLAY 5), to obtain a graphical description of the summary, type *4* and then *Enter*. This brings up a screen of options (see DISPLAY 10). Eighteen types of graphs can be generated. For example, to investigate the relative magnitudes of average monthly streamflow, type *5* and *Enter*. This produces the bar chart shown in Figure 7. Similarly, to investigate the nitrogen loads from each source, type *15* and then *Enter*. This generates another bar chart as shown in Figure 8.

```
Select :
    1     Mean Monthly Precipitation
    2     Mean Monthly Evapotranspiration
    3     Mean Monthly Groundwater Flow
    4     Mean Monthly Runoff
    5     Mean Monthly Streamflow
    6     Mean Monthly Erosion
    7     Mean Monthly Sediment
    8     Mean Monthly Dissolved Nitrogen
    9     Mean Monthly Total Nitrogen
   10     Mean Monthly Dissolved Phosphorus
   11     Mean Monthly Total Phosphorus
   12     Mean Annual Runoff from Sources
   13     Mean Annual Erosion from Sources
   14     Mean Annual Dissolved Nitrogen Loads from Sources
   15     Mean Annual Total Nitrogen Loads from Sources
   16     Mean Annual Dissolved Phosphorus Loads from Sources
   17     Mean Annual Total Phosphorus Loads from Sources
   18     Areas of Sources
otherwise Return
?
```

DISPLAY 10. The Options for Plotting Summary

For plotting annual streamflows, sediment yields and nutrient loads, type *5*, then *Enter*. The graphs will be displayed on several screens. For example, Figure 9 shows the predicted annual streamflows.

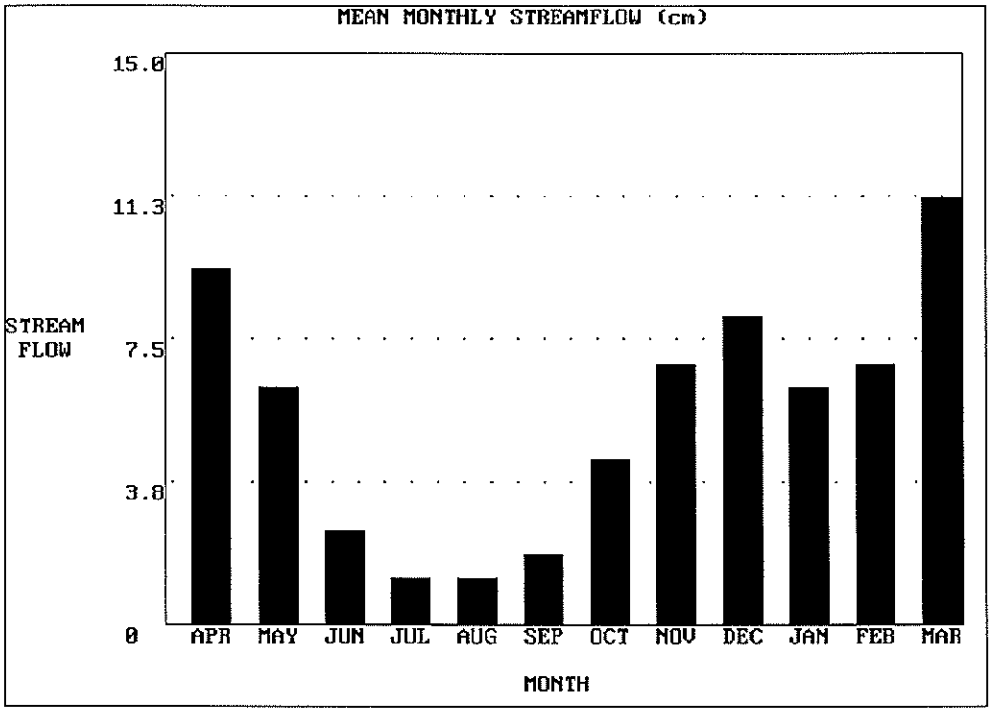


Figure 7. Mean Monthly Streamflows for 30-yr Simulation.

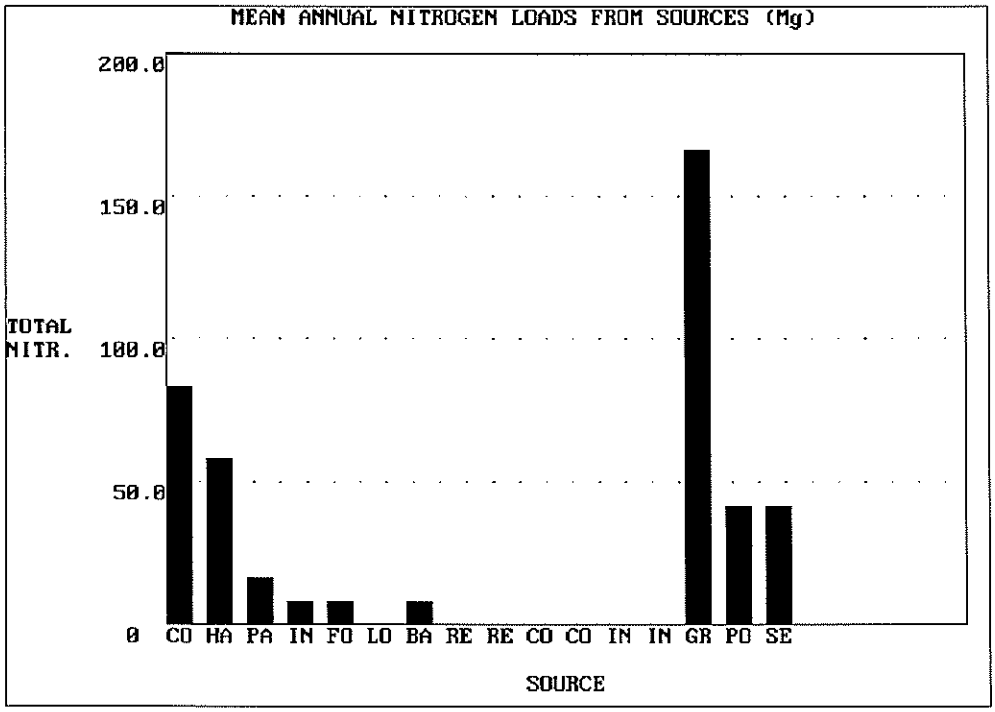


Figure 8. Mean Annual Nitrogen Load from Sources for 30-yr Simulation.

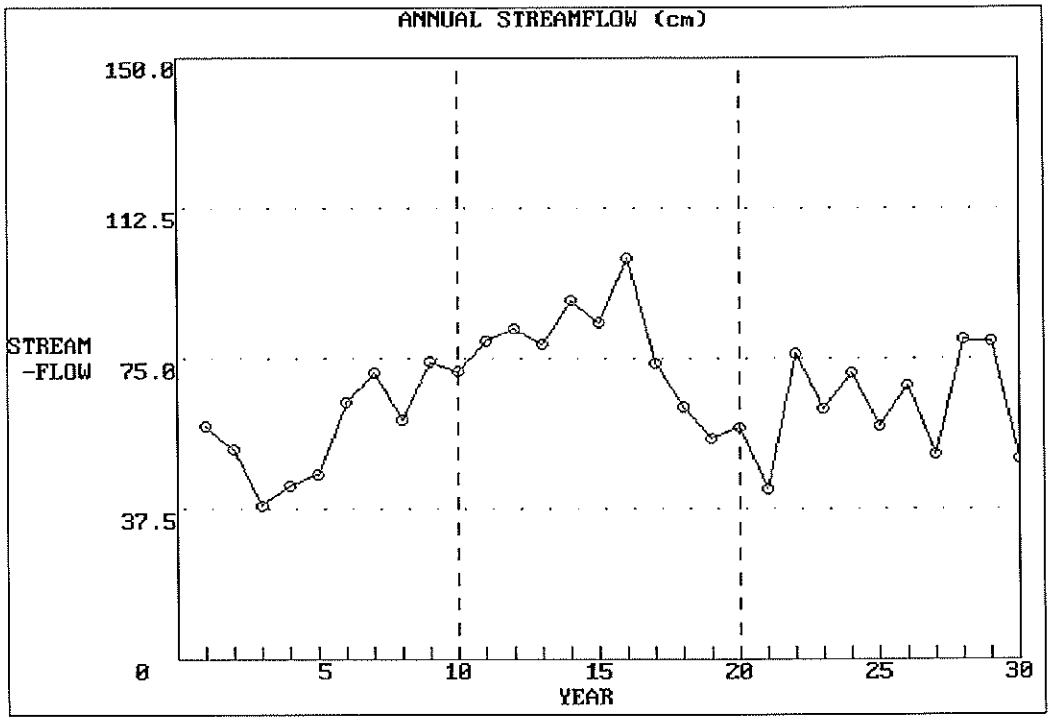


Figure 9. Annual Streamflows for 30-yr Simulation.

APPENDIX A: MATHEMATICAL DESCRIPTION OF GWLF

General Structure

Streamflow nutrient flux contains dissolved and solid phases. Dissolved nutrients are associated with runoff, point sources and groundwater discharges to the stream. Solid-phase nutrients are due to point sources, rural soil erosion or wash off of material from urban surfaces. The GWLF model describes nonpoint sources with a distributed model for runoff, erosion and urban wash off, and a lumped parameter linear reservoir groundwater model. Point sources are added as constant mass loads which are assumed known. Water balances are computed from daily weather data but flow routing is not considered. Hence, daily values are summed to provide monthly estimates of streamflow, sediment and nutrient fluxes (It is assumed that streamflow travel times are much less than one month).

Monthly loads of nitrogen or phosphorus in streamflow in any year are

$$LD_m = DP_m + DR_m + DG_m + DS_m \quad \text{(A-1)}$$

$$LS_m = SP_m + SR_m + SU_m \quad \text{(A-2)}$$

In these equations, LD_m is dissolved nutrient load, LS_m is solid-phase nutrient load, DP_m, DR_m, DG_m and DS_m are point source, rural runoff, groundwater and septic system dissolved nutrient loads, respectively, and SP_m, SR_m and SU_m and are solid-phase point source, rural runoff and urban runoff nutrient loads (kg), respectively, in month m (m = 1,2,...12). Note that the equations assume (i) point source, groundwater and septic system loads are entirely dissolved; and (ii) urban nutrient loads are entirely solid.

Rural Runoff Loads

Rural nutrient loads are transported in runoff water and eroded soil from numerous source areas, each of which is considered uniform with respect to soil and cover.

Dissolved Loads. Dissolved loads from each source area are obtained by multiplying runoff by dissolved concentrations. Monthly loads for the watershed are obtained by summing daily loads over all source areas:

$$LD_m = 0.1 \sum_{k} \sum_{t=1}^{d_m} Cd_k \, Q_{kt} \, AR_k \quad \text{(A-3)}$$

where Cd_k = nutrient concentration in runoff from source area k (mg/*l*), Q_{kt} = runoff from source area k on day t (cm) and AR_k = area of source area k (ha) and d_m = number of days in month m.

Runoff is computed from daily weather data by the U.S. Soil Conservation Service's Curve Number Equation (Ogrosky & Mockus, 1964):

$$Q_{kt} = \frac{(R_t + M_t - 0.2\, DS_{kt})^2}{R_t + M_t + 0.8\, DS_{kt}} \quad \text{(A-4)}$$

Rainfall R_t (cm) and snowmelt M_t (cm of water) on day t are estimated from daily precipitation and temperature data. Precipitation is assumed to be rain when daily mean air temperature T_t (°C) is above 0 and snow fall otherwise. Snowmelt water is computed by a degree-day equation (Haith, 1985):

$$M_t = 0.45\, T_t, \text{ for } T_t > 0 \quad \text{(A-5)}$$

The detention parameter DS_{kt} (cm) is determined from a curve number CN_{kt} as

$$DS_{kt} = \frac{2540}{CN_{kt}} - 25.4 \qquad \text{(A-6)}$$

Curve numbers are selected as functions of antecedent moisture as described in Haith (1985), and shown in Figure A-1. Curve numbers for antecedent moisture conditions 1 (driest), 2 (average) and 3 (wettest) are $CN1_k$, $CN2_k$ and $CN3_k$ respectively. The actual curve number for day t, CN_{kt}, is selected as a linear function of A_t, 5-day antecedent precipitation (cm):

$$A_t = \sum_{n=t-5}^{t-1} (R_n + M_n) \qquad \text{(A-7)}$$

Recommended values (Ogrosky & Mockus, 1964) for the break points in Figure A-1 are AM1 = 1.3, 3.6 cm, and AM2 = 2.8, 5.3 cm, for dormant and growing seasons, respectively. For snowmelt conditions, it is assumed that the wettest antecedent moisture conditions prevail and hence regardless of A_t, $CN_{kt} = CN3_k$ when $M_t > 0$.

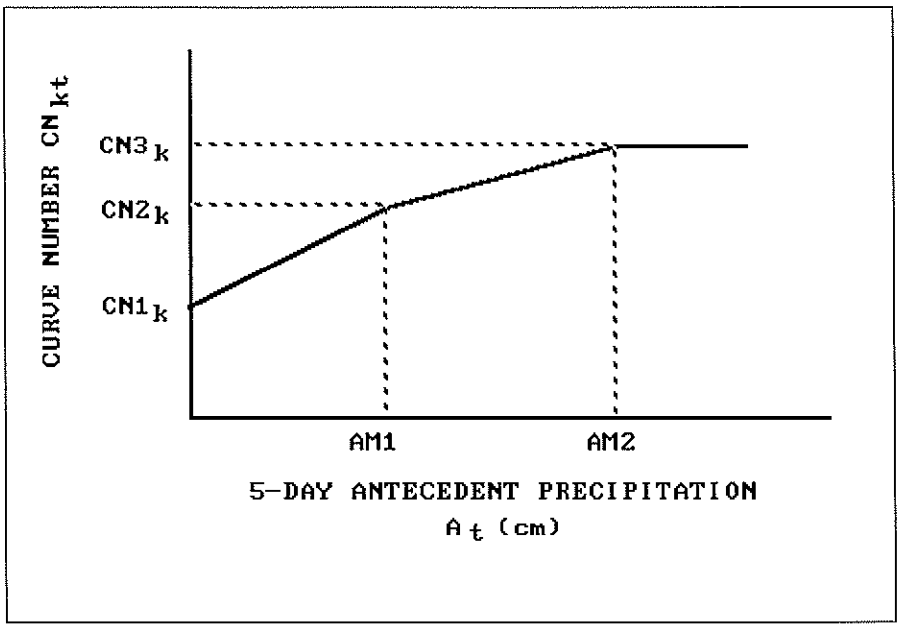


Figure A-1. Curve Number as Function of Antecedent Moisture.

The model requires specification of $CN2_k$. Values for $CN1_k$ and $CN3_k$ are computed from Hawkins (1978) approximations:

$$CN1_k = \frac{CN2_k}{2.334 - 0.01334\ CN2_k} \qquad \text{(A-8)}$$

$$CN3_k = \frac{CN2_k}{} \qquad \text{(A-9)}$$

$0.4036 + 0.0059\ CN2_k$

Solid-Phase Loads. Solid-phase rural nutrient loads (SR_m) are given by the product of monthly watershed sediment yields (Y_m, Mg) and average sediment nutrient concentrations (c_s, mg/kg):

$$SR_m = 0.001\ c_s\ Y_m \qquad \text{(A-10)}$$

Monthly sediment yields are determined from the model developed by Haith (1985). The model is based on three principal assumptions: (i) sediment originates from sheet and rill erosion (gully and stream bank erosion are neglected); (ii) sediment transport capacity is proportional to runoff to the 5/3 power (Meyer & Wischmeier, 1969); and (iii) sediment yields are produced from soil which erodes in the current year (no carryover of sediment supply from one year to the next).

Erosion from source area k on day t (Mg) is given by

$$X_{kt} = 0.132\ RE_t\ K_k\ (LS)_k\ C_k\ P_k\ AR_k \qquad \text{(A-11)}$$

in which K_k, $(LS)_k$, C_k and P_k are the standard values for soil erodibility, topographic, cover and management and supporting practice factors as specified for the Universal Soil Loss Equation (Wischmeier & Smith, 1978). RE_t is the rainfall erosivity on day t (MJ-mm/ha-h). The constant 0.132 is a dimensional conversion factor associated with the SI units of rainfall erosivity. Erosivity can be estimated by the deterministic portion of the empirical equation developed by Richardson et al. (1983) and subsequently tested by Haith & Merrill (1987):

$$RE_t = 64.6\ a_t\ R_t^{1.81} \qquad \text{(A-12)}$$

where the coefficient a_t varies with season and geographical location.

The total watershed sediment supply generated in month j (Mg) is

$$SX_j = DR \sum_k \sum_{t=1}^{d_j} X_{kt} \qquad \text{(A-13)}$$

where DR is the watershed sediment delivery ratio. The transport of this sediment from the watershed is based on the transport capacity of runoff during that month. A transport factor TR_j is defined as

$$TR_j = \sum_{t=1}^{d_j} Q_t^{5/3} \qquad \text{(A-14)}$$

The sediment supply SX_j is allocated to months j, j + 1, ... , 12 in proportion to the transport capacity for each month. The total transport capacity for months j, j + 1, ... , 12 is proportional to B_j, where

$$B_j = \sum_{h=j}^{12} TR_h \qquad \text{(A-15)}$$

For each month m, the fraction of available sediment X_j which contributes to Y_m, the monthly sediment yield (Mg), is TR_m/B_j. The total monthly yield is the sum of all contributions from preceding months:

$$Y_m = TR_m \sum_{j=1}^{m} (X_j/B_j) \qquad \text{(A-16)}$$

Urban Runoff

The urban runoff model is based on general accumulation and wash off relationships proposed by Amy et al. (1974) and Sartor & Boyd (1972). The exponential accumulation function was subsequently used in SWMM (Huber & Dickinson, 1988) and the wash off function is used in both SWMM and STORM (Hydrologic Engineering Center, 1977). The mathematical development here follows that of Overton and Meadows (1976).

Nutrients accumulate on urban surfaces over time and are washed off by runoff events. Runoff volumes are computed by equations A-4 through A-7.

If $N_k(t)$ is the accumulated nutrient load on source area (land use) k on day t (kg/ha), then the rate of accumulation during dry periods is

$$\frac{dN_k}{dt} = n_k - \beta N_k \qquad \text{(A-17)}$$

where n_k is a constant accumulation rate (kg/ha-day) and β is a depletion rate constant (day^{-1}). Solving equation A-17, we obtain

$$N_k(t) = N_{k0}\, e^{-\beta t} + (n_k/\beta)\,(1 - e^{-\beta t}) \qquad \text{(A-18)}$$

in which $N_{k0} = N_k(t)$ at time $t = 0$.

Equation A-18 approaches an asymptotic value $N_{k,max}$:

$$N_{k,max} = \lim_{t \to \infty} N_k(t) = n_k/\beta \qquad \text{(A-19)}$$

Data given in Sartor & Boyd (1972) and shown in Figure A-2 indicates that $N_k(t)$ approaches its maximum value in approximately 12 days. If we conservatively assume that $N_k(t)$ reaches 90% of $N_{k,max}$ in 20 days, then for $N_{k0} = 0$,

$$0.90\,(n_k/\beta) = (n_k/\beta)\,(1 - e^{-20\beta}), \text{ or } \beta = 0.12$$

Equation A-18 can also be written for a time interval $\Delta t = t_2 - t_1$ as

$$N_k(t_2) = N_k(t_1)\, e^{-0.12\Delta t} + (n_k/0.12)\,(1 - e^{-0.12\Delta t}) \qquad \text{(A-20)}$$

or, for a time interval of one day,

$$N_{k,t+1} = N_{kt}\, e^{-0.12} + (n_k/0.12)\,(1 - e^{-0.12}) \qquad \text{(A-21)}$$

where N_{kt} is the nutrient accumulation at the beginning of day t (kg/ha).

Equation A-21 can be modified to include the effects of wash off:

$$N_{k,t+1} = N_{kt}\, e^{-0.12} + (n_k/0.12)\,(1 - e^{-0.12}) - W_{kt} \qquad \text{(A-22)}$$

in which W_{kt} = runoff nutrient load from land use k on day t(kg/ha).

The runoff load is

$$W_{kt} = w_{kt}\,[N_{kt}\, e^{-0.12} + (n_k/0.12)\,(1 - e^{-0.12})] \qquad \text{(A-23)}$$

where w_{kt} is the first-order wash off function suggested by Amy et al. (1974):

$$w_{kt} = 1 - e^{-1.81Q_{kt}} \quad \text{(A-24)}$$

Equation A-24 is based on the assumption that 1.27 cm (0.5 in) of runoff will wash off 90% of accumulated pollutants. Monthly runoff loads of urban nutrients are thus given by

$$SU_m = \sum_k \sum_{t=1}^{d_m} W_{kt} AR_k \quad \text{(A-25)}$$

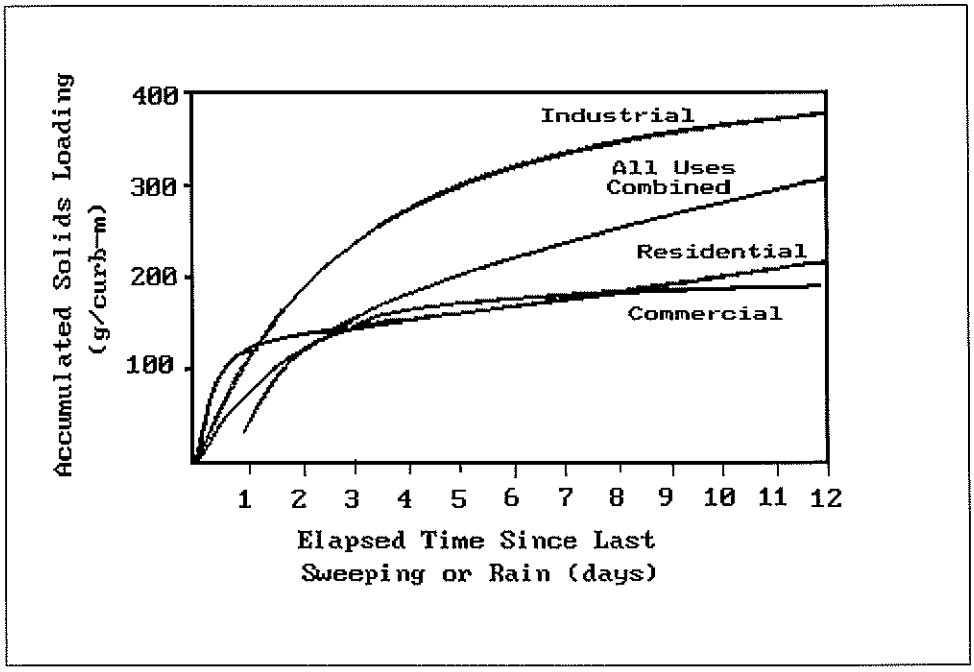


Figure A-2. Accumulation of Pollutants on Urban Surfaces (Sartor & Boyd, 1972; redrawn in Novotny & Chesters, 1981).

Groundwater Sources

The monthly groundwater nutrient load to the stream is

$$DG_m = 0.1\, C_g\, AT \sum_{t=1}^{d_m} G_t \quad \text{(A-26)}$$

in which C_g = nutrient concentration in groundwater (mg/l), AT = watershed area (ha), and G_t = groundwater discharge to the stream on day t (cm).

Groundwater discharge is described by the lumped parameter model shown in Figure A-3. Streamflow consists of total watershed runoff from all source areas plus groundwater discharge from a shallow saturated zone. The division of soil moisture into unsaturated, shallow saturated and deep saturated zones is similar to that used by Haan (1972).

Daily water balances for the unsaturated and shallow saturated zones are

$$U_{t+1} = U_t + R_t + M_t - Q_t - E_t - PC_t \quad \text{(A-27)}$$

$$S_{t+1} = S_t + PC_t - G_t - D_t \quad \text{(A-28)}$$

In these equations, U_t and S_t are the unsaturated and shallow saturated zone soil moistures at the beginning of day t and Q_t, E_t, PC_t, G_t and D_t are watershed runoff, evapotranspiration, percolation into the shallow saturated zone, groundwater discharge to the stream and seepage flow to the deep saturated zone, respectively, on day t (cm).

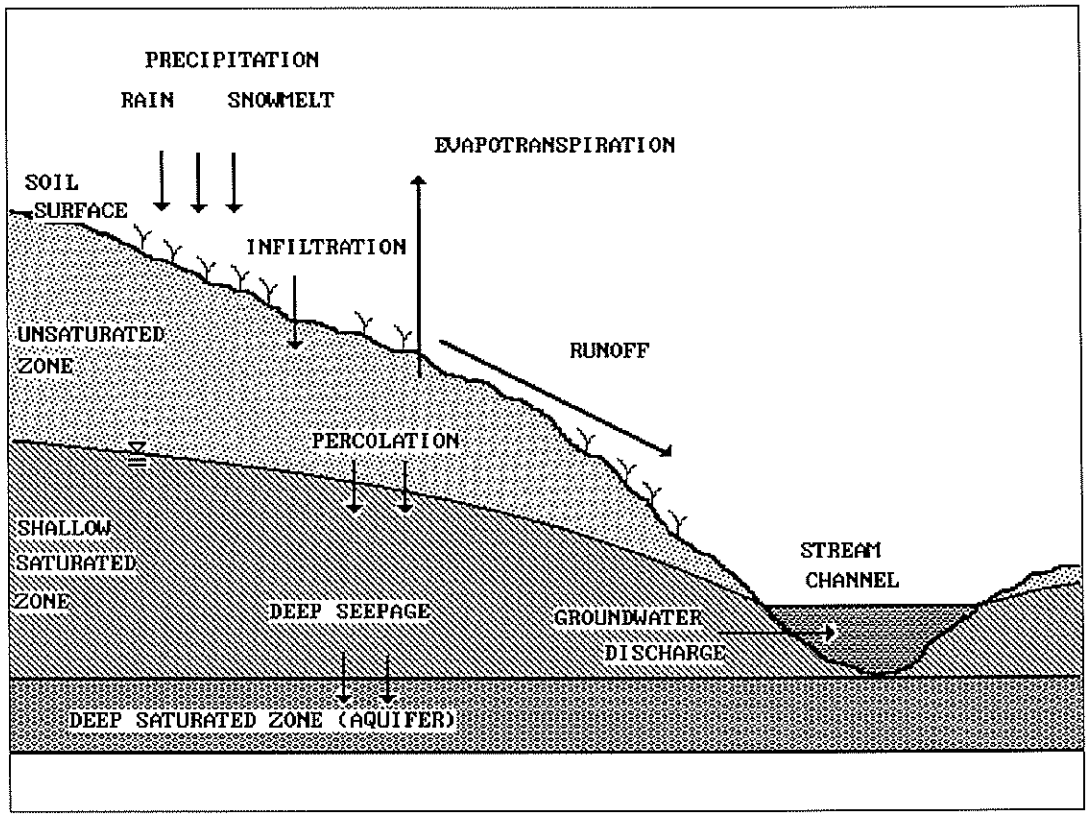


Figure A-3. Lumped Parameter Model for Groundwater Discharge.

Percolation occurs when unsaturated zone water exceeds available soil water capacity U^* (cm):

$$PC_t = \text{Max}\,(0;\ U_t + R_t + M_t - Q_t - E_t - U^*) \quad \text{(A-29)}$$

Evapotranspiration is limited by available moisture in the unsaturated zone:

$$E_t = \text{Min}\,(CV_t\, PE_t;\ U_t + R_t + M_t - Q_t) \quad \text{(A-30)}$$

for which CV_t is a cover coefficient and PE_t is potential evapotranspiration (cm) as given by Hamon (1961):

$$PE_t = \frac{0.021\, H_t^2\, e_t)}{T_t + 273} \quad \text{(A-31)}$$

In this equation, H_t is the number of daylight hours per day during the month containing day t, e_t is the saturated water vapor pressure in millibars on day t and T_t is the temperature on day t (°C). When $T_t \leq 0$, PE_t is set to zero. Saturated vapor pressure can be approximated as in (Bosen, 1960):

$$e_t = 33.8639\ [\ (0.00738\ T_t + 0.8072)^8 - 0.000019\ (1.8\ T_t + 48) + 0.001316\ ]\ ,\ T_t \geq 0 \quad \text{(A-32)}$$

As in Haan (1972), the shallow unsaturated zone is modeled as a simple linear reservoir. Groundwater discharge and deep seepage are

$$G_t = r\ S_t \quad \text{(A-33)}$$

and

$$D_t = s\ S_t \quad \text{(A-34)}$$

where r and s are groundwater recession and seepage constants, respectively (day^{-1}).

Septic (On-site Wastewater Disposal) Systems

The septic system component of GWLF is based on the model developed by Mandel (1993). For purposes of assessing watershed water quality impacts, septic systems loads can be divided into four types:

$$DS_m = DS_{1m} + DS_{2m} + DS_{3m} + DS_{4m} \quad \text{(A-35)}$$

where DS_{1m}, DS_{2m}, DS_{3m} and DS_{4m} are the dissolved nutrient load to streamflow from normal, short-circuited, ponded and direct discharge systems, respectively in month m (kg). These loads are computed from per capita daily effluent loads and monthly populations served a_{jm} for each system (j =1,2,3,4).

Normal Systems. A normal septic system is a system whose construction and operation conforms to recommended procedures such as those suggested by the EPA design manual for on-site wastewater disposal systems (U. S. Environmental Protection Agency, 1980). Effluents from such systems infiltrate into the soil and enter the shallow saturated zone. Effluent nitrogen is converted to nitrate, and except for removal by plant uptake, the nitrogen is transported to the stream by groundwater discharge. Conversely, phosphates in the effluent are adsorbed and retained by the soil and hence normal systems provide no phosphorus loads to streamflow. The nitrogen load to groundwater from normal systems in month m (kg) is

$$SL_{1m} = 0.001\ a_{1m}\ d_m\ (e - u_m) \quad \text{(A-36)}$$

in which e = per capita daily nutrient load in septic tank effluent (g/day) and u_m = per capita daily nutrient uptake by plants in month m (g/day).

Normal systems are generally some distance from streams and their effluent mixes with other groundwater. Monthly nutrient loads are thus proportional to groundwater discharge to the stream. The portion of the annual load delivered in month m is equivalent to the portion of annual groundwater discharge which occurs in that month. Thus the load in month m of any year is

$$DS_{1m} = \frac{GR_m \sum_{m=1}^{12} SL_{1m}}{\sum_{m=1}^{12} GR_m} \quad \text{(A-37)}$$

where GR_m = total groundwater discharge to streamflow in month m (cm), obtained by summing the daily values G_t for the month. Equation A-37 applies only for nitrogen. In the case of phosphorus, $DS_{1m} = 0$.

Short-Circuited Systems. These systems are located close enough to surface waters (< 15 m) so that negligible adsorption of phosphorus takes place. The only nutrient removal mechanism is plant uptake, and the watershed load for both nitrogen and phosphorus is

$$DS_{2m} = 0.001\ a_{2m}\ d_m\ (e - u_m) \qquad \text{(A-38)}$$

Ponded Systems. These systems exhibit hydraulic failure of the tank's absorption field and resulting surfacing of the effluent. Unless the surfaced effluent freezes, ponding systems deliver their nutrient loads to surface waters in the same month that they are generated through overland flow. If the temperature is below freezing, the surfacing effluent is assumed to freeze in a thin layer at the ground surface. The accumulated frozen effluent melts when the snowpack disappears and the temperature is above freezing. The monthly nutrient load is

$$DS_{3m} = 0.001 \sum_{t=1}^{d_m} PN_t \qquad \text{(A-39)}$$

where PN_t = watershed nutrient load in runoff from ponded systems on day t (g). Nutrient accumulation under freezing conditions is

$$FN_{t+1} = \begin{cases} FN_t + a_{3m}\ e\ , & SN_t > 0 \text{ or } T_t \le 0 \\ 0\ , & \text{otherwise} \end{cases} \qquad \text{(A-40)}$$

where FN_t = frozen nutrient accumulation in ponded systems at the beginning of day t (g). The runoff load is thus

$$PN_t = \begin{cases} a_{3m}\ e + FN_t - u_m\ , & SN_t = 0 \text{ and } T_t > 0 \\ 0\ , & \text{otherwise} \end{cases} \qquad \text{(A-41)}$$

Direct Discharge Systems. These illegal systems discharge septic tank effluent directly into surface waters. Thus,

$$DS_{4m} = 0.001\ a_{4m}\ d_m\ e \qquad \text{(A-42)}$$

APPENDIX B: DATA SOURCES & PARAMETER ESTIMATION

Four types of information must be assembled for GWLF model runs. Land use data consists of the areas of the various rural and urban runoff sources. Required weather data are daily temperature (°C) and precipitation (cm) records for the simulation period. Transport parameters are the necessary hydrologic, erosion and sediment data and nutrient parameters are the various nitrogen and phosphorus data required for loading calculations. This appendix discusses general procedures for estimation of these parameters. Examples of parameter estimation are provided in Appendix C.

Land Use Data

Runoff source areas are identified from land use maps, soil surveys and aerial or satellite photography (Haith & Tubbs, 1981; Delwiche & Haith, 1983). In principle, each combination of soil, surface cover and management must be designated. For example, each corn field in the watershed can be considered a source area, and its area determined and estimates made for runoff curve number and soil erodibility and topographic, cover and supporting practice factors. In practice, these fields can often be aggregated, as in Appendix C into one "corn" source area with area-weighted parameters. Each urban land use is broken down into impervious and pervious areas. The former are solid surfaces such as streets, driveways, parking lots and roofs.

Weather Data

Daily precipitation and temperature data are obtained from meteorological records and assembled in the data file **WEATHER.DAT**. An example of this file is given in Appendix D. Weather data must be organized in "weather years" which are consistent with model assumptions. Both the groundwater and sediment portions of GWLF require that simulated years begin at a time when soil moisture conditions are known and runoff events have "flushed" the watershed of the previous year's accumulated sediment. In the eastern U.S. this generally corresponds to early spring and hence in such locations an April - March weather year is appropriate.

Transport Parameters

A sample set of hydrologic, erosion and sediment parameters required for the data file **TRANSPRT.DAT** is given in Appendix D.

Runoff Curve Numbers. Runoff curve numbers for rural and urban land uses have been assembled in the U.S. Soil Conservation Service's Technical Release No. 55, 2nd edition (Soil Conservation Service, 1986). These curve numbers are based on the soil hydrologic groups given in Table B-1. Curve numbers for average antecedent moisture conditions ($CN2_k$) are listed in Tables B-2 through B-5. Barnyard curve numbers are given by Overcash & Phillips (1978) as $CN2_k$ = 90, 98 and 100 for earthen areas, concrete pads and roof areas draining into the barnyard, respectively.

Evapotranspiration Cover Coefficients. Estimation of evapotranspiration cover coefficients for watershed studies is problematic. Cover coefficients may be determined from published seasonal values such as those given in Tables B-6 and B-7. However, their use often requires estimates of crop development (planting dates, time to maturity, etc.) which may not be available. Moreover, a single set of consistent values is seldom available for all of a watershed's land uses.

Soil Hydrologic Group	Description
A	Low runoff potential and high infiltration rates even when thoroughly wetted. Chiefly deep, well to excessively drained sands or gravels. High rate of water transmission (> 0.75 cm/hr).
B	Moderate infiltration rates when thoroughly wetted. Chiefly moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. Moderate rate of water transmission (0.40-0.75 cm/hr).
C	Low infiltration rates when thoroughly wetted. Chiefly soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. Low rate of water transmission (0.15-0.40 cm/hr).
D	High runoff potential. Very low infiltration rates when thoroughly wetted. Chiefly clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, or shallow soils over nearly impervious material. Very low rate of water transmission (0-0.15 cm/hr).
Disturbed Soils (Major altering of soil profile by construction, development):	
A	Sand, loamy sand, sandy loam.
B	Silt loam, loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, clay.

Table B-1. Descriptions of Soil Hydrologic Groups (Soil Conservation Service, 1986)

A simplified procedure can be developed, however, based on a few general observations:

1. Cover coefficients should in principle vary between 0 and 1.
2. Cover coefficients will approach their maximum value when plants have developed full foliage.
3. Because evapotranspiration measures both transpiration and evaporation of soil water, the lower limit for cover coefficients will be greater than zero. This lower limit essentially represents a situation without any plant cover.
4. The protection of soil by impervious surfaces prevents evapotranspiration.

The cover coefficients given for annual crops in Table B-6 fall to approximately 0.3 before planting and after harvest. Similarly, cover coefficients for forests reach minimum values of 0.2 to 0.3 when leaf area indices approach zero. This suggests that monthly cover coefficients for can be given the value 0.3 when foliage is absent and 1.0 otherwise. Perennial crops, such as grass, hay, meadow, and pasture, crops grown in flooded soil, such as rice, and conifers can be given a cover coefficient of 1.0 year round.

Land Use/Cover		Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Fallow	Bare Soil	-		77	86	91	94
Crop residue cover (CR)		Poor[a/]	76	85	90	93	
		Good		74	83	88	90
Row Crops	Straight row (SR)	Poor		72	81	88	91
		Good		67	78	85	89
	SR + CR	Poor		71	80	87	90
		Good		64	75	82	85
	Contoured (C)	Poor		70	79	84	88
		Good		65	75	82	86
	C + CR	Poor		69	78	83	87
		Good		64	74	81	85
	Contoured & terraced (C&T)	Poor		66	74	80	82
		Good		62	71	78	81
	C&T + CR	Poor		65	73	79	81
		Good		61	70	77	80
Small Grains	SR	Poor		65	76	84	88
		Good		63	75	83	87
	SR + CR	Poor		64	75	83	86
		Good		60	72	80	84
	C	Poor		63	74	82	85
		Good		61	73	81	84
	C + CR	Poor		62	73	81	84
		Good		60	72	80	83
	C&T	Poor		61	72	79	82
		Good		59	70	78	81
	C&T + CR	Poor		60	71	78	81
		Good		58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor		66	77	85	89
		Good		58	72	81	85
	C	Poor		64	75	83	85
		Good		55	69	78	83
	C&T	Poor		63	73	80	83
		Good		51	67	76	80

[a/] Hydrologic condition is based on a combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good $ 20%), and (e) degree of surface roughness.

Table B-2. Runoff Curve Numbers (Antecedent Moisture Condition II) for Cultivated Agricultural Land (Soil Conservation Service, 1986).

Land Use/Cover	Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Pasture, grassland or range - continuous forage for grazing	Poor[a/]	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow - continuous grass, protected from grazing, generally mowed for hay	-	30	58	71	78
Brush - brush/weeds/grass mixture with brush the major element	Poor[b/]	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods/grass combination (orchard or tree farm)[c/]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor[/d]	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads - buildings, lanes, driveways and surrounding lots	-	59	74	82	86

[a/] Poor: < 50% ground cover or heavily grazed with no mulch; Fair: 50 to 75% ground cover and not heavily grazed; Good: > 75% ground cover and lightly or only occasionally grazed.

[b/] Poor: < 50% ground cover; Fair: 50 to 75% ground cover; Good: > 75% ground cover.

[c/] Estimated as 50% woods, 50% pasture.

[d/] Poor: forest litter, small trees and brush are destroyed by heavy grazing or regular burning; Fair: woods are grazed but not burned and some forest litter covers the soil; Good: Woods are protected from grazing and litter and brush adequately cover the soil.

Table B-3. Runoff Curve Numbers (Antecedent Moisture Condition II) for other Rural Land (Soil Conservation Service, 1986).

Land Use/Cover	Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Herbaceous - grass, weeds & low-growing brush; brush the minor component	Poor[a/]	-	80	87	93
	Fair	-	71	81	89
	Good	-	62	74	85
Oak/aspen - oak brush, aspen, mountain mahogany, bitter brush, maple and other brush	Poor	-	66	74	79
	Fair	-	48	57	63
	Good	-	30	41	48
Pinyon/juniper - pinyon, juniper or both; grass understory	Poor	-	75	85	89
	Fair	-	58	73	80
	Good	-	41	61	71
Sagebrush with grass understory	Poor	-	67	80	85
	Fair	-	51	63	70
	Good	-	35	47	55
Desert scrub - saltbush, greasewood, creosotebrush, blackbrush, bursage, palo verde, mesquite and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[a/] Poor: < 30% ground cover (litter, grass and brush overstory); Fair: 30 to 70% ground cover; Good: > 70% ground cover.

Table B-4. Runoff Curve Numbers (Antecedent Moisture Condition II) for Arid and Semiarid Rangelands (Soil Conservation Service, 1986).

Land Use	Soil Hydrologic Group A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.):				
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50-75%)	49	69	79	84
Good condition (grass cover > 75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc.)	98	98	98	98
Streets and roads:				
Paved with curbs & storm sewers	98	98	98	98
Paved with open ditches	83	89	92	93
Gravel	76	85	89	91
Dirt	72	82	87	89
Western desert urban areas:				
Natural desert landscaping (pervious areas, only)	63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1-2 in sand or gravel mulch and basin borders)	96	96	96	96

Table B-5. Runoff Curve Numbers (Antecedent Moisture Condition II) for Urban Areas (Soil Conservation Service, 1986).

Crop	% of Growing Season 0	10	20	30	40	50	60	70	80	90	100

Field corn	0.45	0.51	0.58	0.66	0.75	0.85	0.96	1.08	1.20	1.08	0.70
Grain sorghum	0.30	0.40	0.65	0.90	1.10	1.20	1.10	0.95	0.80	0.65	0.50
Winter wheat	1.08	1.19	1.29	1.35	1.40	1.38	1.36	1.23	1.10	0.75	0.40
Cotton	0.40	0.45	0.56	0.76	1.00	1.14	1.19	1.11	0.83	0.58	0.40
Sugar beets	0.30	0.35	0.41	0.56	0.73	0.90	1.08	1.26	1.44	1.30	1.10
Cantaloupe	0.30	0.30	0.32	0.35	0.46	0.70	1.05	1.22	1.13	0.82	0.44
Potatoes	0.30	0.40	0.62	0.87	1.06	1.24	1.40	1.50	1.50	1.40	1.26
Papago peas	0.30	0.40	0.66	0.89	1.04	1.16	1.26	1.25	0.63	0.28	0.16
Beans	0.30	0.35	0.58	1.05	1.07	0.94	0.80	0.66	0.53	0.43	0.36
Rice	1.00	1.06	1.13	1.24	1.38	1.55	1.58	1.57	1.47	1.27	1.00

Table B-6. Evapotranspiration Cover Coefficients for Annual Crops - Measured as Ratio of Evapotranspiration to Lake Evaporation (Davis & Sorensen, 1969; cited in Novotny & Chesters, 1981).

	Alfalfa	Pasture	Grapes	Citrus Orchards	Deciduous Orchards	Sugarcane
Jan	0.83	1.16	-	0.58	-	0.65
Feb	0.90	1.23	-	0.53	-	0.50
Mar	0.96	1.19	0.15	0.65	-	0.80
Apr	1.02	1.09	0.50	0.74	0.60	1.17
May	1.08	0.95	0.80	0.73	0.80	1.21
June	1.14	0.83	0.70	0.70	0.90	1.22
July	1.20	0.79	0.45	0.81	0.90	1.23
Aug	1.25	0.80	-	0.96	0.80	1.24
Sept	1.22	0.91	-	1.08	0.50	1.26
Oct	1.18	0.91	-	1.03	0.20	1.27
Nov	1.12	0.83	-	0.82	0.20	1.28
Dec	0.86	0.69	-	0.65	-	0.80

Table B-7. Evapotranspiration Cover Coefficients for Perennial Crops - Measured as Ratio of Evapotranspiration to Lake Evaporation (Davis & Sorensen, 1969; cited in Novotny & Chesters, 1981).

In urban areas, ground cover is a mixture of trees and grass. It follows that cover factors for pervious areas are weighted averages of the perennial crop, hardwood, and softwood cover factors. It may be difficult to determine the relative fractions of urban areas with these covers. Since these covers would have different values only during dormant seasons, it is reasonable to assume a constant month value of 1.0 for urban pervious surfaces and zero for impervious surfaces.

These approximate cover coefficients are given in Table B-8. Table B-9 list mean monthly values of daylight hours (H_t) for use in Equation A-31.

Cover	Dormant Season	Growing Season
Annual crops (foliage only in growing season)	0.3	1.0
Perennial crops (year-round foliage: grass, pasture, meadow, etc.)	1.0	1.0

Saturated crops (rice)	1.0	1.0
Hardwood (deciduous) forests & orchards	0.3	1.0
Softwood (conifer) forests & orchards	1.0	1.0
Disturbed areas & bare soil (barn yards, fallow, logging trails, construction and mining)	0.3	0.3
Urban areas (I = impervious fraction)	1 - I	1 - I

Table B-8. Approximate Values for Evapotranspiration Cover Coefficients.

	Latitude North (E)						
	48	46	44	42	40	38	36
	(---------- hr/day ----------)						
Jan	8.7	8.9	9.2	9.3	9.5	9.7	9.9
Feb	10.0	10.2	10.3	10.4	10.5	10.6	10.7
Mar	11.7	11.7	11.7	11.7	11.8	11.8	11.8
Apr	13.4	13.3	13.2	13.1	13.0	13.0	12.9
May	14.9	14.7	14.5	14.3	14.1	14.0	13.8
Jun	15.7	15.4	15.2	15.0	14.7	14.5	14.3
Jul	15.3	15.0	14.8	14.6	14.4	14.3	14.1
Aug	14.0	13.8	13.7	13.6	13.6	13.4	13.3
Sep	12.3	12.3	12.3	12.3	12.2	12.2	12.2
Oct	10.6	10.7	10.8	10.9	11.0	11.0	11.1
Nov	9.1	9.3	9.5	9.7	9.8	10.0	10.1
Dec	8.3	8.5	8.8	9.0	9.2	9.4	9.6

	34	32	30	28	26	24
Jan	10.0	10.2	10.3	10.5	10.6	10.7
Feb	10.8	10.9	11.0	11.1	11.1	11.2
Mar	11.8	11.8	11.8	11.8	11.8	11.9
Apr	12.8	12.8	12.7	12.7	12.6	12.6
May	13.7	13.6	13.5	13.4	13.2	13.1
Jun	14.2	14.0	13.9	13.7	13.6	13.4
Jul	14.0	13.8	13.7	13.5	13.4	13.3
Aug	13.2	13.3	13.0	13.0	12.9	12.8
Sep	12.2	12.2	12.2	12.1	12.1	12.1
Oct	11.2	11.2	11.3	11.3	11.4	11.4
Nov	10.2	10.4	10.5	10.6	10.7	10.9
Dec	9.8	10.0	10.1	10.3	10.4	10.6

Table B-9. Mean Daylight Hours (Mills et al., 1985).

Groundwater. The groundwater portion of GWLF requires estimates of available unsaturated zone available soil moisture capacity U^*, recession constant r and seepage constant s.

In principle, U^* is equivalent to a mean watershed maximum rooting depth multiplied by a mean volumetric soil available water capacity. The latter also requires determination of a mean unsaturated zone depth, and this is probably impractical for most watershed studies. A default value of 10 cm can be assumed for pervious areas, corresponding to a 100 cm rooting depth and a 0.1 cm/cm volumetric available water

capacity. These values appear typical for a wide range of plants (Jensen et al., 1989; U.S. Forest Service, 1980) and soils (Rawls et al., 1982).

Estimates of the recession constant r can be estimated from streamflow records by standard hydrograph separation techniques (Chow, 1964). During a period of hydrograph recession, the rate of change in shallow saturated zone water S(t) (cm) is given by the linear reservoir relationship

$$\frac{dS}{dt} = -rS \qquad \text{(B-1)}$$

or,

$$S(t) = S(0)\, e^{-rt} \qquad \text{(B-2)}$$

where S(0) is the shallow saturated zone moisture at t = 0. Groundwater discharge to the stream G(t) (cm) at time t is

$$G(t) = r\,S(t) = r\,S(0)\, e^{-rt} \qquad \text{(B-3)}$$

During periods of streamflow recession, it is assumed that runoff is negligible, and hence streamflow F(t) (cm) consists of groundwater discharge given by Equation B-3; i.e., F(t) = G(t). A recession constant can be estimated from two streamflows $F(t_1)$, $F(t_2)$ measured on days t_1 and t_2 ($t_2 > t_1$) during the hydrograph recession. The ratio $F(t_1)/F(t_2)$ is

$$\frac{F(t_1)}{F(t_2)} = \frac{r\,S(0)\, e^{-rt_1}}{r\,S(0)\, e^{-rt_2}} = e^{r(t_2 - t_1)} \qquad \text{(B-4)}$$

The recession constant is thus given by

$$r = \frac{\ln [F(t_1)/F(t_2)]}{t_2 - t_1} \qquad \text{(B-5)}$$

Recession constants are measured for a number of hydrographs and an average value is used for the simulations. Typical values range from 0.01 to 0.2

No standard techniques are available for estimating the rate constant for deep seepage loss (s). The most conservative approach is to assume that s = 0 (all precipitation exits the watershed in evapotranspiration or streamflow). Otherwise the constant must be determined by calibration.

Erosion and Sediment. The factors K_k, $(LS)_k$, C_k and P_k for the Universal Soil Loss Equation must be specified as the product $K_k\,(LS)_k\,C_k\,P_k$ for each rural runoff source area. Values K_k, C_k and P_k are given for a range of soils and conditions in Tables B-10 - B-13. More complete sets of values are provided in Mills et al. (1985) and Wischmeier & Smith (1978). The $(LS)_k$ factor is calculated for each source area k as in Wischmeier & Smith (1978):

$$LS = (0.045 x_k)^b\,(65.41 \sin^2 \theta_k + 4.56 \sin \theta_k + 0.065) \qquad \text{(B-6)}$$

$$\theta_k = \tan^{-1}(ps_k/100) \qquad \text{(B-7)}$$

in which x_k = slope length (m) and ps_k = per cent slope. The exponent in Equation B-6 is given by b = 0.5 for $ps_k \geq 5$, b = 0.4 for $5 > ps_k > 3$, b = 0.3 for $3 \leq ps_k \leq 1$, and b = 0.2 for $ps_k < 1$ (Wischmeier & Smith, 1978).

The rainfall erosivity coefficient a_t for Equation A-12 can be estimated using methods developed by Selker et al. (1990). General values for the rainfall erosivity zones shown in Figure B-1 are given in Table B-14. Watershed sediment delivery ratios are most commonly obtained from the area-based relationship shown in

Figure B-2.

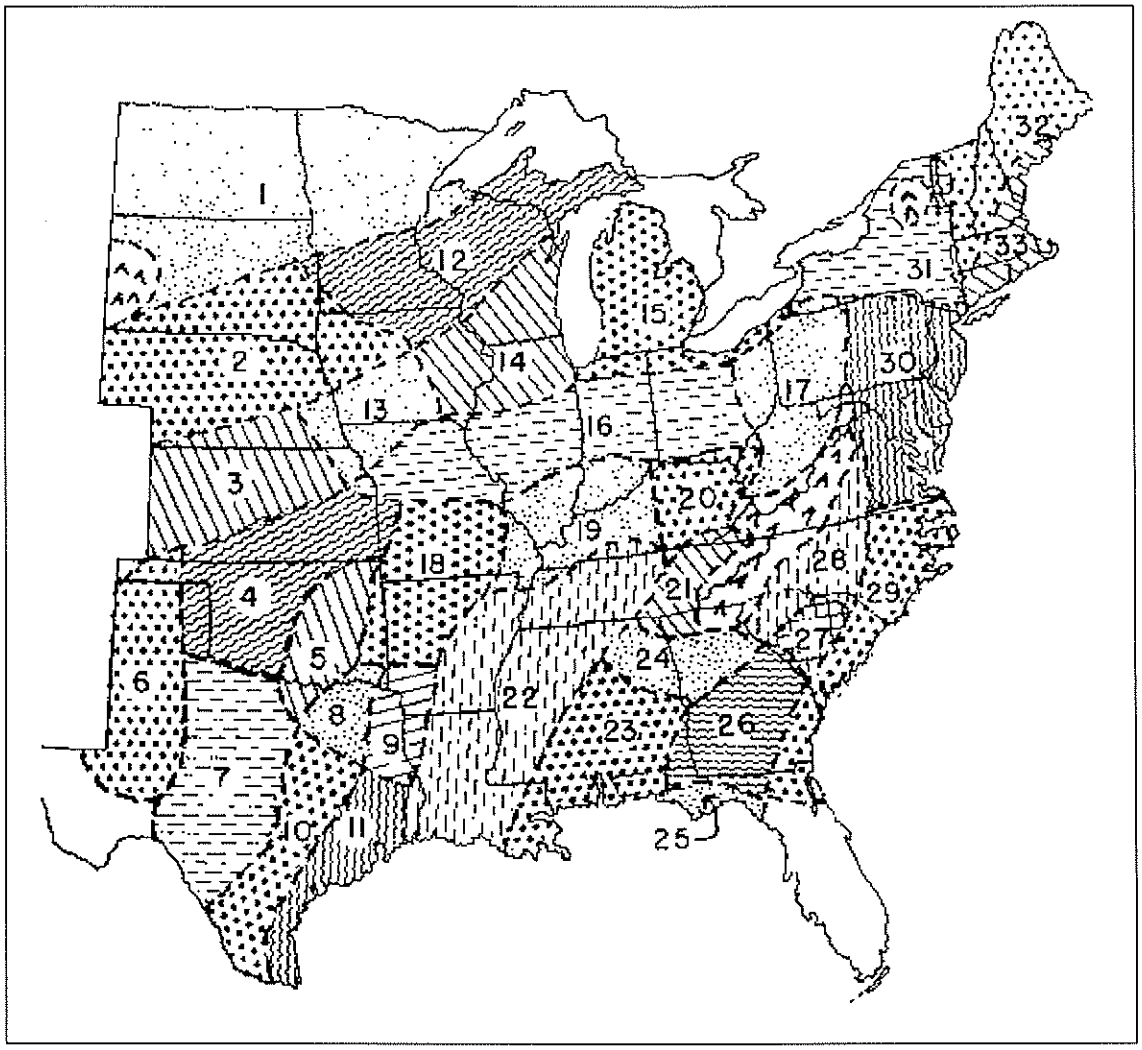


Figure B-1. Rainfall Erosivity Zones in Eastern U.S. (Wischmeier & Smith, 1978).

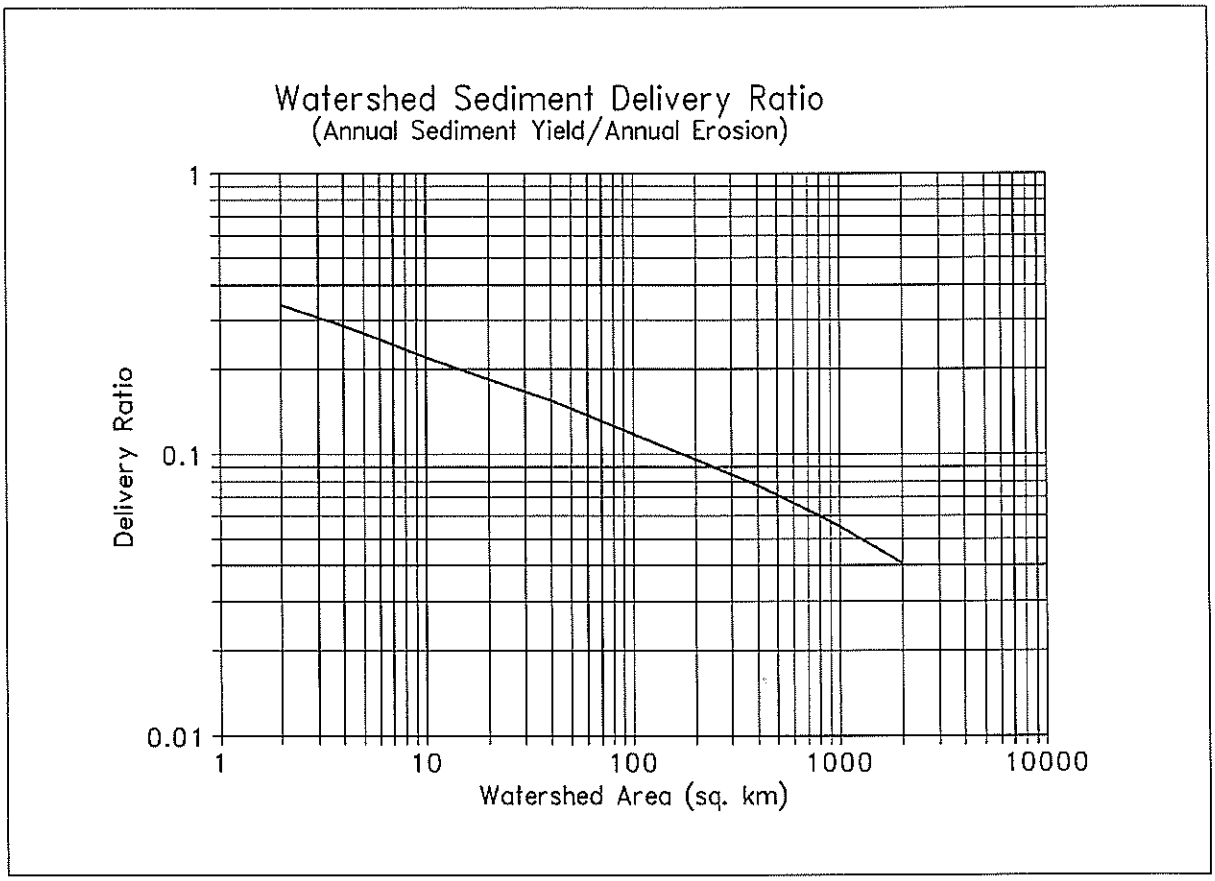


Figure B-2. Watershed Sediment Delivery Ratios (Vanoni, 1975).

	Organic Matter Content (%)		
Texture	<0.5	2	4
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay	-	0.13-0.29	-

Table B-10. Values of Soil Erodibility Factor (K) (Stewart et al., 1975).

	Crop, rotation & management[b/]		Productivity[a/] High	Moderate
	Continuous fallow, tilled up and down slope		1.00	1.00
	CORN			
1	C, RdR, fall TP, conv (1)		0.54	0.62
2	C, RdR, spring TP, conv (1)	0.50		0.59
3	C, RdL, fall TP, conv (1)		0.42	0.52
4	C, RdR, wc seeding, spring TP, conv (1)		0.40	0.49
5	C, RdL, standing, spring TP, conv (1)		0.38	0.48
6	C, fall shred stalks, spring TP, conv (1)		0.35	0.44
7	C(silage)-W(RdL,fall TP) (2)		0.31	0.35
8	C, RdL, fall chisel, spring disk, 40-30% re (1)		0.24	0.30
9	C(silage), W wc seeding, no-till pl in c-k W (1)		0.20	0.24
10	C(RdL)-W(RdL,spring TP) (2)		0.20	0.28
11	C, fall shred stalks, chisel pl, 40-30% re (1)		0.19	0.26
12	C-C-C-W-M, RdL, TP for C, disk for W (5)		0.17	0.23
13	C, RdL, strip till row zones, 55-40% re (1)		0.16	0.24
14	C-C-C-W-M-M, RdL, TP for C, disk for W (6)		0.14	0.20
15	C-C-W-M, RdL, TP for C, disk for W (4)		0.12	0.17
16	C, fall shred, no-till pl, 70-50% re (1)		0.11	0.18
17	C-C-W-M-M, RdL, TP for C, disk for W (5)		0.087	0.14
18	C-C-C-W-M, RdL, no-till pl 2nd & 3rd C (5)		0.076	0.13
19	C-C-W-M, RdL, no-till pl 2d C (4)		0.068	0.11
20	C, no-till pl in c-k wheat, 90-70% re (1)		0.062	0.14
21	C-C-C-W-M-M, no-till pl 2d & 3rd C (6)		0.061	0.11
22	C-W-M, RdL, TP for C, disk for W (3)		0.055	0.095
23	C-C-W-M-M, RdL, no-till pl 2d C (5)		0.051	0.094
24	C-W-M-M, RdL, TP for C, disk for W (4)		0.039	0.074
25	C-W-M-M-M, RdL, TP for C, disk for W (5)		0.032	0.061
26	C, no-till pl in c-k sod, 95-80% re (1)		0.017	0.053
	COTTON[/c]			
27	Cot, conv (western plains) (1)		0.42	0.49
28	Cot, conv (south) (1)		0.34	0.40
	MEADOW (HAY)			
29	Grass & legume mix		0.004	0.01
30	Alfalfa, lespedeza or sericia		0.020	-
31	Sweet clover		0.025	-
	SORGHUM, GRAIN (western plains)			
32	RdL, spring TP, conv (1)		0.43	0.53
33	No-till pl in shredded 70-50% re		0.11	0.18
	SOYBEANS[/c]			
34	B, RdL, spring TP, conv (1)		0.48	0.54
35	C-B, TP annually, conv (2)		0.43	0.51
36	B, no-till pl		0.22	0.28
37	C-B, no-till pl, fall shred C stalks (2)		0.18	0.22

Table B-11. CONTINUED

Crop, rotation & management[b/]	Productivity[a/] High	Moderate
WHEAT		
38 W-F, fall TP after W (2)	0.38	-
39 W-F, stubble mulch, 500 lb re (2)	0.32	-
40 W-F, stubble mulch, 1000 Lb re (2)	0.21	-
41 Spring W, RdL, Sept TP, conv (ND,SD) (1)	0.23	-
42 Winter W, RdL, Aug TP, conv (KS) (1)	0.19	-
43 Spring W, stubble mulch, 750 lb re (1)	0.15	-
44 Spring W, stubble mulch, 1250 lb re (1)	0.12	-
45 Winter W, stubble mulch, 750 lb re (1)	0.11	-
46 Winter W, stubble mulch, 1250 lb re (1)	0.10	-
47 W-M, conv (2)	0.054	-
48 W-M-M, conv (3)	0.026	-
49 W-M-M-M, conv (4)	0.021	-

[a/] High level exemplified by long-term yield averages greater than 75 bu/ac corn or 3 ton/ac hay or cotton management that regularly provides good stands and growth.

[b/] Numbers in parentheses indicate numbers of years in the rotation cycle. (1) indicates a continuous one-crop system.

[c/] Grain sorghum, soybeans or cotton may be substituted for corn in lines 12, 14, 15, 17-19, 21-25 to estimate values for sod-based rotations.

Abbreviations:

B	soybeans	F	fallow
C	corn	M	grass & legume hay
c-k	chemically killed	pl	plant
conv	conventional	W	wheat
cot	cotton	wc	winter cover

lb re	pounds of residue per acre remaining on surface after new crop seeding
% re	percentage of soil surface covered by residue mulch after new crop seeding
xx-yy% re	xx% cover for high productivity, yy% for moderate
RdR	residues (corn stover, straw, etc.) removed or burned
RdL	residues left on field (on surface or incorporated)
TP	turn plowed (upper 5 or more inches of soil inverted, covering residues

Table B-11. Generalized Values of Cover and Management Factor (C) for Field Crops East of the Rocky Mountains (Stewart et al., 1975).

Cover	Value
Permanent pasture, idle land, unmanaged woodland	
95-100% ground cover	
as grass	0.003
as weeds	0.01
80% ground cover	
as grass	0.01
as weeds	0.04
60% ground cover	
as grass	0.04
as weeds	0.09
Managed woodland	
75-100% tree canopy	0.001
40-75% tree canopy	0.002-0.004
20-40% tree canopy	0.003-0.01

Table B-12. Values of Cover and Management Factor (C) for Pasture and Woodland (Novotny & Chesters, 1981).

Practice	Slope(%):	1.1-2	2.1-7	7.1-12	12.1-18	18.1-24
No support practice		1.00	1.00	1.00	1.00	1.00
Contouring		0.60	0.50	0.60	0.80	0.90
Contour strip cropping						
R-R-M-M[a/]		0.30	0.25	0.30	0.40	0.45
R-W-M-M		0.30	0.25	0.30	0.40	0.45
R-R-W-M		0.45	0.38	0.45	0.60	0.68
R-W		0.52	0.44	0.52	0.70	0.90
R-O		0.60	0.50	0.60	0.80	0.90
Contour listing or ridge planting		0.30	0.25	0.30	0.40	0.45
Contour terracing[b/]		0.6/%n	0.5/%n	0.6/%n	0.8/%n	0.9/%n

[a/] R = row crop, W = fall-seeded grain, M = meadow. The crops are grown in rotation and so arranged on the field that row crop strips are always separated by a meadow or winter-grain strip.

[b/] These factors estimate the amount of soil eroded to the terrace channels. To obtain off-field values, multiply by 0.2. n = number of approximately equal length intervals into which the field slope is divided by the terraces. Tillage operations must be parallel to the terraces.

Table B-13. Values of Supporting Practice Factor (P) (Stewart et al., 1975).

Zone[a/]	Location	Season[b/] Cool	Warm
1	Fargo ND	0.08	0.30
2	Sioux City IA	0.13	0.35
3	Goodland KS	0.07	0.15
4	Wichita KS	0.20	0.30
5	Tulsa OK	0.21	0.27
6	Amarillo TX	0.30	0.34
7	Abilene TX	0.26	0.34
8	Dallas TX	0.28	0.37
9	Shreveport LA	0.22	0.32
10	Austin TX	0.27	0.41
11	Houston TX	0.29	0.42
12	St. Paul MN	0.10	0.26
13	Lincoln NE	0.26	0.24
14	Dubuque IA	0.14	0.26
15	Grand Rapids MI	0.08	0.23
16	Indianapolis IN	0.12	0.30
17	Parkersburg WV	0.08	0.26
18	Springfield MO	0.17	0.23
19	Evansville IN	0.14	0.27
20	Lexington KY	0.11	0.28
21	Knoxville TN	0.10	0.28
22	Memphis TN	0.11	0.20
23	Mobile AL	0.15	0.19
24	Atlanta GA	0.15	0.34
25	Apalachacola FL	0.22	0.31
26	Macon GA	0.15	0.40
27	Columbia SC	0.08	0.25
28	Charlotte NC	0.12	0.33
29	Wilmington NC	0.16	0.28
30	Baltimore MD	0.12	0.30
31	Albany NY	0.06	0.25
32	Caribou ME	0.07	0.13
33	Hartford CN	0.11	0.22

[a/] Zones given in Figure B-1.

[b/] Cool season: Oct - Mar; Warm season: Apr - Sept.

Table B-14. Rainfall Erosivity Coefficients (a) for Erosivity Zones in Eastern U.S. (Selker et al., 1990).

Initial Conditions. Several initial conditions must be provided in the **TRANSPRT.DAT** file: initial unsaturated and shallow saturated zone soil moistures (U_1 and S_1), snowmelt water (SN_1) and antecedent rain + snowmelt for the five previous days. It is likely that these values will be uncertain in many applications. However, they will not affect model results for more than the first month or two of the simulation period. It is generally most practical to assign arbitrary initial values (U^* for U_1 and zero for the remaining variables) and to discard the first year of the simulation results.

Nutrient Parameters

A sample set of nutrient parameters required for the data file **NUTRIENT.DAT** is given in Appendix D.

Although the GWLF model will be most accurate when nutrient data are calibrated to local conditions, a set of default parameters has been developed to facilitate uncalibrated applications. Obviously these parameters, which are average values obtained from published water pollution monitoring studies, are only approximations of conditions in any watershed.

Rural and Groundwater Sources. Solid-phase nutrients in sediment from rural sources can be estimated as the average soil nutrient content multiplied by an enrichment ratio. Soil nutrient levels can be determined from soil samples, soil surveys or general maps such as those given in Figures B-3 and B-4. A value of 2.0 for the enrichment ratio falls within the mid-range of reported ratios and can be used in absence of more specific data (McElroy et al., 1976; Mills et al., 1985).

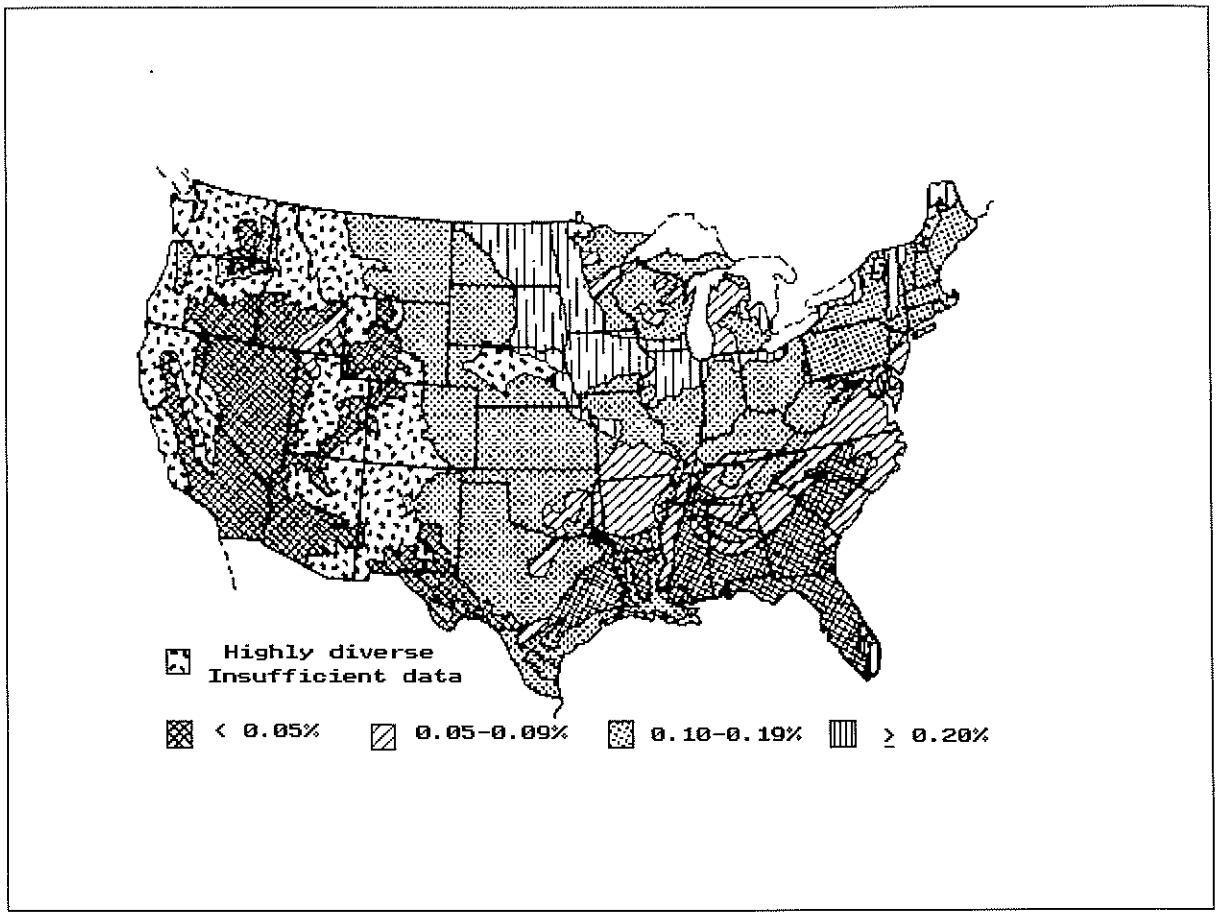


Figure B-3. Nitrogen in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

Default flow-weighted mean concentrations of dissolved nitrogen and phosphorus in agricultural runoff are given in Table B-15. The cropland and barnyard data are from multi-year storm runoff sampling studies in South Dakota (Dornbush et al., 1974) and Ohio (Edwards et al., 1972). The concentrations for snowmelt runoff from fields with manure on the soil surface are taken from a manual prepared by U. S. Department of Agriculture scientists (Gilbertson et al., 1979).

Default values for nutrient concentrations in groundwater discharge can be inferred from the U.S. Eutrophication Survey results (Omernik, 1977) given in Table B-16. These data are mean concentrations

computed from 12 monthly streamflow samples in watersheds free of point sources. Since such limited sampling is unlikely to capture nutrient fluxes from storm runoff, the streamflow concentrations can be assumed to represent groundwater discharges to streams.

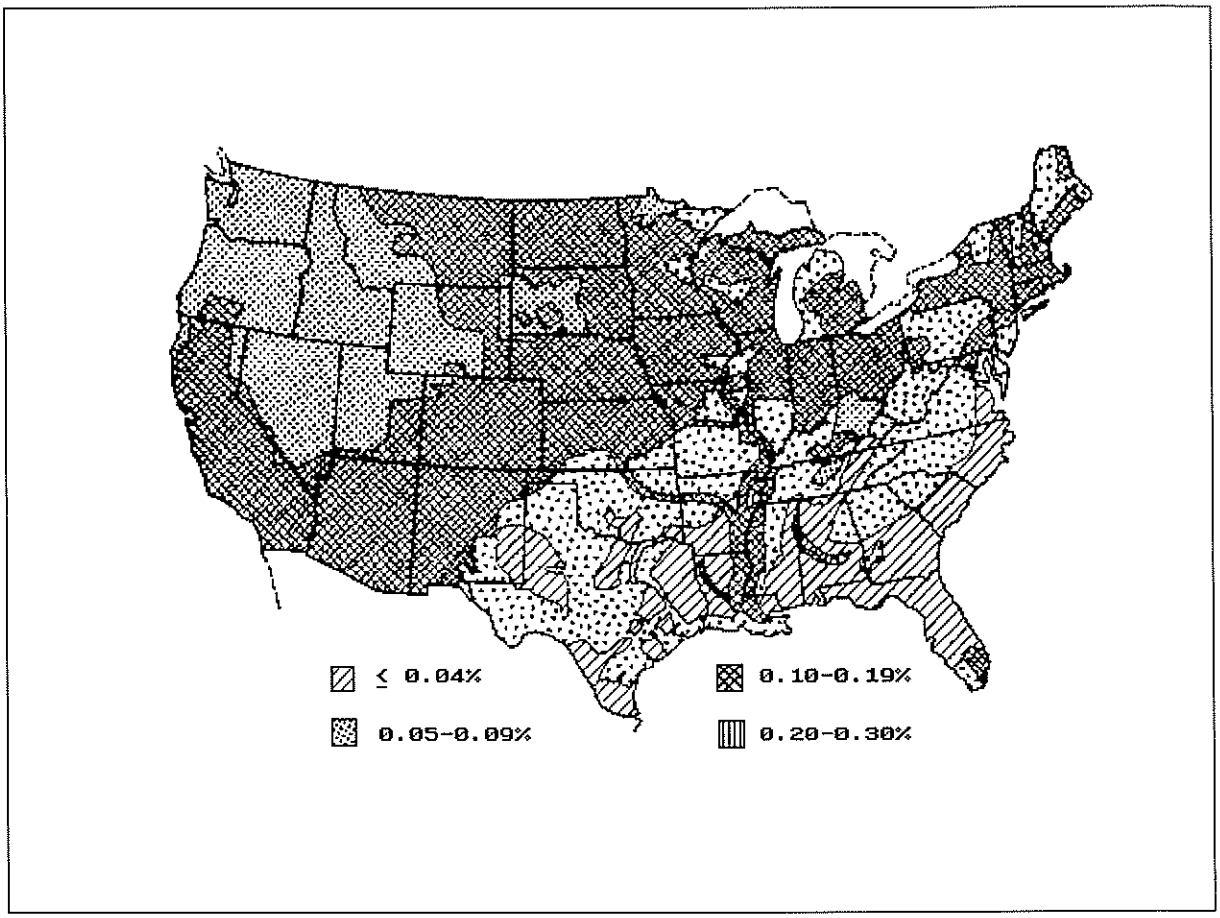


Figure B-4. P_2O_5 (44% phosphorus) in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

Dissolved nutrient data for forest runoff are essentially nonexistent. Runoff is a small component of streamflow from forest areas and studies of forest nutrient flux are based on streamflow rather than runoff sampling. Hence the only possible default option is the use of the streamflow concentrations from the "$ 90% Forest" category in Table B-16 as estimates of runoff concentrations.

Default values for urban nutrient accumulation rates are provided in Table B-17. These values were developed for Northern Virginia conditions and are probably suitable for smaller and relatively new urban areas. They would likely underestimate accumulations in older large cities.

Septic Systems. Representative values for septic system nutrient parameters are given in Table B-18. Per capita nutrient loads in septic tank effluent were estimated from typical flows and concentrations. The EPA Design Manual (U.S. Environmental Protection Agency, 1980) indicates 170 *l*/day as a representative wastewater flow from on-site wastewater disposal systems. Alhajjar et al. (1989) measured mean nitrogen and phosphorus concentrations in septic tank effluents of 73 and 14 mg/*l*, respectively. The latter concentration is based on use of phosphate detergents. When non-phosphate detergents are used, the concentration dropped to 7.9 mg/*l*. These concentrations were combined with the 170 *l*/day flow to produce the effluent nutrient loads given in Table B-18.

Nutrient uptake by plants (generally grasses) growing over the septic system adsorption field are frankly speculative. Brown & Thomas (1978) suggest that if the grass clippings are harvested, nutrients from a septic system effluent can support at least twice the normal yield of grass over the absorption field. Petrovic & Cornman (1982) suggest that retention of turf grass clippings can reduce required fertilizer applications by 25%, thus implying nutrient losses of 75% of uptakes. It appears that a conservative estimate of nutrient losses from plant cover would be 75% of the nutrient uptake of from a normal annual yield of grass. Reed et al. (1988) reported that Kentucky bluegrass annually utilizes 200-270 kg/ha nitrogen and 45 kg/ha phosphorus. Using the 200 kg/ha nitrogen value, and assuming a six month growing season and a 20 m^2 per capita absorption area, an estimated 1.6 g/day nitrogen and 0.4 g/day phosphorus are lost by plant uptake on a per capita basis during the growing season. The 20 m^2 adsorption area was based on per bedroom adsorption area recommendations by the U.S. Public Health Service for a soil with average percolation rate (.12 min/cm) (U.S. Public Health Service, 1967).

The remaining information needed are the numbers of people served by the four different types of septic systems (normal, short-circuited, ponded and direct discharge). A starting point for this data will generally be estimates of the unsewered population in the watershed. Local public health officials may be able to estimate the fractions of systems within the area which are of each type. However, the most direct way of generating the information is through a septic systems survey.

Land Use	Nitrogen (mg/l)	Phosphorus (mg/l)
Fallow[a/]	2.6	0.10
Corn[a/]	2.9	0.26
Small grains[a/]	1.8	0.30
Hay[a/]	2.8	0.15
Pasture[a/]	3.0	0.25
Barn yards[b/]	29.3	5.10
Snowmelt runoff from manured land[c/]:		
Corn	12.2	1.90
Small grains	25.0	5.00
Hay	36.0	8.70

[a/]Dornbush et al. (1974)

[b/]Edwards et al. (1972)

[c/]Gilbertson et al. (1979); manure left on soil surface.

Table B-15. Dissolved Nutrients in Agricultural Runoff.

Watershed Type	Concentrations (mg/l) Eastern U.S.	Central U.S.	Western U.S.
Nitrogen[a/]:			
$ 90% Forest	0.19	0.06	0.07
$ 75% Forest	0.23	0.10	0.07
$ 50% Forest	0.34	0.25	0.18
$ 50% Agriculture	1.08	0.65	0.83
$ 75% Agriculture	1.82	0.80	1.70
$ 90% Agriculture	5.04	0.77	0.71
Phosphorus[b/]:			
$ 90% Forest	0.006	0.009	0.012
$ 75% Forest	0.007	0.012	0.015
$ 50% Forest	0.013	0.015	0.015
$ 50% Agriculture	0.029	0.055	0.083
$ 75% Agriculture	0.052	0.067	0.069
$ 90% Agriculture	0.067	0.085	0.104

[a/]Measured as total inorganic nitrogen.

[b/]Measured as total orthophosphorus

Table B-16. Mean Dissolved Nutrients Measured in Streamflow by the National Eutrophication Survey (Omernik, 1977).

Land Use	Suspended Solids	BOD	Total Nitrogen	Total Phosphorus
	(---------- kg/ha-day ----------)			
Impervious Surfaces				
Single family residential				
Low density (units/ha < 1.2)	2.5	0.15	0.045	0.0045
Medium density (units/ha ≥ 1.2)	6.2	0.22	0.090	0.0112
Townhouses & apartments	6.2	0.22	0.090	0.0112
High rise residential	3.9	0.71	0.056	0.0067
Institutional	2.8	0.39	0.056	0.0067
Industrial	2.8	0.71	0.101	0.0112
Suburban shopping center	2.8	0.71	0.056	0.0067
Central business district	2.8	0.85	0.101	0.0112
Pervious Surfaces				
Single family residential				
Low density (units/ha < 1.2)	1.3	0.08	0.012	0.0016
Medium density (units/ha ≥ 1.2)	1.1	0.15	0.022	0.0039
Townhouses & apartments	2.2	0.29	0.045	0.0078
High rise residential	0.8	0.08	0.012	0.0019
Institutional	0.8	0.08	0.012	0.0019
Industrial	0.8	0.08	0.012	0.0019
Suburban shopping center	0.8	0.08	0.012	0.0019
Central business district	0.8	0.08	0.012	0.0019

Table B-17. Contaminant Accumulation Rates for Northern Virginia Urban Areas (Kuo, et al., 1988).

Parameter		Value
e, per capita daily nutrient load in septic tank effluent (g/day)		
Nitrogen		12.0
Phosphorus		
Phosphate detergents use		2.5
Non-phosphate detergents use		1.5
u_m, per capita daily nutrient uptake by plants during month m (g/day)		
Nitrogen:	Growing season	1.6
	Non-growing season	0.0
Phosphorus:	Growing season	0.4
	Non-growing season	0.0

Table B-18. Default Parameter Values for Septic Systems.

APPENDIX C: VALIDATION STUDY

The GWLF model was tested by comparing model predictions with measured streamflow, sediment and nutrient loads from the West Branch Delaware River Basin during a three-year period (April, 1979 - March, 1982). The model was run using the four-year period April, 1978 - March, 1982 and first year results were ignored to eliminate effects of arbitrary initial conditions.

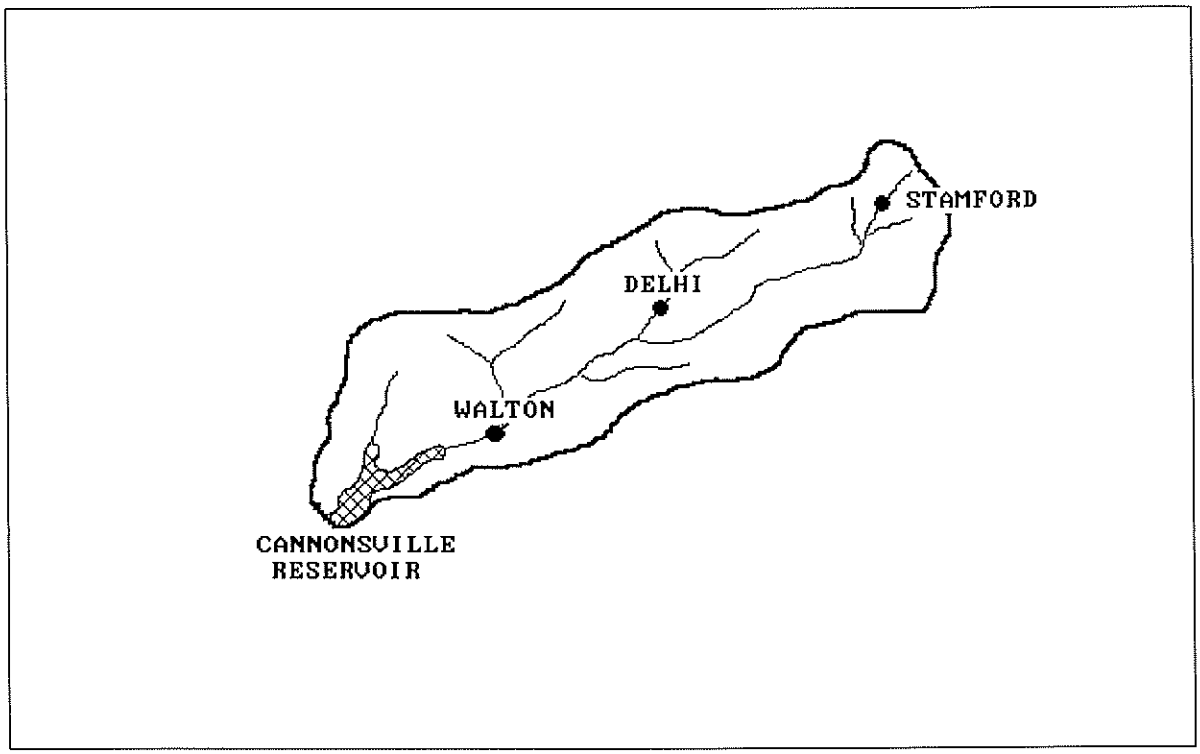


Figure C-1. West Branch Delaware River Watershed.

The 850 km^2 watershed, which is shown in Figure C-1, is in a dairy farming area in southeast New York which consists of 30% agricultural, 67% forested and 2% urban land uses. The river empties into Cannonsville Reservoir, which is a water supply source for the City of New York.

The model was run for the four-year period using daily precipitation and temperature records from the U.S. Environmental Data and Information service weather station at Walton, NY. To test the usefulness of the default parameters presented previously, no attempt was made to calibrate the model. No water quality data from the watershed were used to estimate parameters. All transport and chemical parameters were obtained by the general procedures described in the Appendix B.

Water Quality Observations

Continuous streamflow records were available from a U.S. Geological Survey gauging station at Walton, NY. Nutrient and sediment data were collected, analyzed and summarized by the N.Y. State Department of Environmental Conservation (Brown et al., 1985). During base flow conditions, samples were collected at approximately one-week intervals. During storm events, samples were collected at 2-4 hour intervals during hydrograph rise and at 6-8 hour intervals in the 2-3 days following flow peak. More frequent sampling was carried out during major snowmelt events. Total and dissolved phosphorus and sediment (suspended solids) data were collected from March, 1980 through March, 1982. The sampling periods for dissolved and total nitrogen were less extensive: March, 1980 - September, 1981 and January, 1981 - September, 1981, respectively.

Mass fluxes were computed by multiplying sediment or nutrient concentrations in a sample by "a volume of water determined by numerically integrating flow over the period of time from half of the preceding sampling time interval through half of the following sampling time interval" (Brown et al., 1985).

Watershed Data

Land Uses. The parameters needed for the agricultural and forest source areas were estimated from a land use sampling procedure similar to that described by Haith & Tubbs (1981). U.S. Geological Survey 1:24,000 topographic maps of the watershed were overlain by land use maps derived from 1971-1974 aerial photography. The maps were then overlain by a grid with 1-ha cells which was the basis of the sampling procedure. The land uses were divided into two general categories: forest and agriculture. Forest areas were subdivided into forest brushland and mature forest, and agricultural areas were subdivided into cropland, pasture and inactive agriculture. A random sample of 500 cells was taken, stratified over the two major land uses to provide more intense sampling of agricultural areas (390 samples vs. 110 for forest).

For each agricultural sample, the following were recorded: land use (cropland, pasture or inactive), soil type and length and gradient of the slope of the field in which the 1-ha sample was located. Crops were separated into two categories, corn or hay, since these two crops make up 99% of the county cropland.

Barnyard areas were identified from examination of conservation plans for 30 watershed dairy farm barnyards. Average earthen and roof drainage areas were 0.1306 ha and 0.0369 ha, respectively. These values were assumed representative of the watershed's 245 barnyards, producing total earth and roof drainage areas of 32 and 9 ha, respectively.

Urban land uses (low-density residential, commercial and industrial) were calculated from Delaware County tax maps. The impervious portions of these areas were 16%, 54% and 34% for residential, commercial and industrial land uses, respectively.

Runoff Curve Numbers. In forest areas, curve numbers were selected by soil type, assuming "good" hydrologic condition. Agricultural curve numbers were selected based on soil type, crop, management practice (e.g., strip cropping) and hydrologic condition. All pasture, hay and corn-hay rotations were assumed to be in good condition. Inactive agricultural areas were assumed to be the same as pasture. Corn grown in continuous rotation was considered in poor condition. Cropland breakdown into hay, continuous corn and rotated corn was determined from county data assembled by Soil Conservation Service (1976) and confirmed from Bureau of the Census (1980).

Rural source areas and curve numbers are listed in Table C-1. These areas were subsequently aggregated for the GWLF input files into the large areas given in Table C-2. Urban and barnyard areas are also given in Table C-2. Curve numbers are area-weighted averages for each source area.

Erosion and Sediment Parameters. Data required for estimation of soil loss parameters for logging sites were obtained from a forestry survey (Slavicek, 1980). Logging areas were located from a 1979 aerial survey. Transects of the logging roads at these sites were measured for soil loss parameters K_k, $(LS)_k$, C_k and P_k, and from this information an average K_k $(LS)_k$ C_k P_k value was calculated.

Soil erodibility factors (K_k) for agricultural land were obtained from the Soil Conservation Service. Cover factors (C) were selected Table B-10 based on several assumptions. For corn, the assumptions were that all residues are removed from the fields (91% of the corn in the county is used for silage (Bureau of the Census, 1980)), and all fields are spring turn-plowed and in the high productivity class (Knoblauch, 1976). A moderate productivity was assumed for hay (Knoblauch, 1976). Supporting practice factors of P = 1 were used for all source areas except strip crop corn. Area-weighted K_k $(LS)_k$ C_k P_k values are given in Table C-2. Coefficients for daily rainfall erosivity were selected from Table B-13 for Zone 31 (Figure B-1) . A watershed sediment delivery ratio of 0.065 was determined from Figure B-2.

Source Area	Soil Hydrologic Group	Area(ha)	Curve Number[a]
Continuous corn	B	414	81
	C	878	88
Rotated corn	B	620	78
	C	1316	85
Strip crop corn	C	202	82
Hay	B	2319	72
	C	10690	81
	D	76	85
Pasture	B	378	61
	C	4639	74
	D	76	80
Inactive agriculture	B	328	61
	C	3227	74
	D	126	80
Forest brushland	B	3118	48
	C	24693	65
	D	510	73
Mature forest	B	510	55
	C	27851	70

[a/] Antecedent moisture condition 2 ($CN2_k$)

Table C-1. Areas and Curve Numbers for Agricultural and Forest Runoff Sources for West Branch Delaware River Basin.

Land Use	Area(ha)	Curve Number[a/]	Erosion Product[b/]
Corn	3430	83.8	0.214
Hay	13085	79.4	0.012
Pasture	5093	73.1	0.016
Inactive Agriculture	3681	73.1	0.017
Barnyards	41	92.2	--
Forest	56682	66.5	--
Logging Trails	20	--	0.217
Residential (Low Density)			
Impervious	104	98.0	--
Pervious	546	74.0	--
Commercial			
Impervious	49	98.0	--
Pervious	41	74.0	--
Industrial			
Impervious	34	98.0	--
Pervious	67	74.0	--

[a/]Antecedent moisture condition 2 ($CN2_k$).

[b/]$K_k\ (LS)_k\ C_k\ P_k$

Table C-2. Aggregated Runoff Source Areas in West Branch Delaware River Basin.

Land Use	Area(ha)	Cover Coefficient May-Oct	Cover Coefficient Nov-Apr
Corn	3430	1.0	0.3
Hay	13085	1.0	1.0
Pasture	5093	1.0	1.0
Inactive Agriculture	3681	1.0	1.0
Forest	56682	1.0	0.3
Logging	20	0.3	0.3
Barn Yards	41	0.3	0.3
Residential	650	0.84	0.84
Commercial	90	0.46	0.46
Industrial	101	0.66	0.66
Watershed Weighted Mean	82873	1.00	0.49

Table C-3. Evapotranspiration Cover Coefficients for West Branch Delaware River Basin.

Other Transport Parameters. For purpose of curve number and evapotranspiration cover coefficient selection, the growing season was assumed to correspond to months during which mean air temperature is at least 10EC (May-October). Cover coefficients were selected from Table B-8 and are listed in Table C-3 along with the area-weighted watershed values. An average groundwater recession constant of r = 0.1 was determined from analysis of 30 hydrograph recessions from the period 1971 - 1978. The seepage constant (s) was assumed to be zero, and the default value of 10 cm was used for unsaturated zone available soil moisture capacity U*.

Nutrient Concentrations and Accumulation Rates. Using the soil nutrient values given in Figures B-3 and B-4 and the previously suggested enrichment ratio of 2.0 produced sediment nutrient concentrations of 3000 mg/kg nitrogen and 1300 mg/kg phosphorus. Rural dissolved nutrient concentrations were selected from Tables B-15 and B-16. Manure is spread on corn land in the watershed and hence the manured land concentrations were used for corn land runoff in snowmelt months (January - March). Inactive agricultural land was assumed to have nutrient concentrations midway between pasture and forest values. Urban nutrient accumulation rates from Table B-17 were used, with "Central business district" values used for commercial land.

Septic System Parameters. The default values for nutrient loads and plant uptake given in Table B-18 were used to model septic systems. The population served by each type of septic system was estimated by determining the percentage of the total number of systems falling within each class and multiplying by the year-round and seasonal (June - August) unsewered populations in the watershed. Table C-4 summarizes the population data for septic systems.

System Type	Percent of Total Population Served		
	Population	Year-round	Seasonal[a/]
Normal	86	7572	1835
Short-circuited	1	88	21
Ponded	10	881	213
Direct discharge	3	264	64

[a/] June - August

Table C-4. Estimated Populations Served by Different Septic System Types in West Branch Delaware River Basin.

The year-round unsewered population estimate for the watershed was based on 1980 Census data. These data were also used to determine the average number of people per household and the number of housing units used on a part-time basis. The seasonal population was then calculated by assuming the number of people per household was the same for seasonal and year-round residents.

A range of values for the current (1991) percentage of each type of system was supplied by the New York City Department of Environmental Protection (Personal Communication, J. Kane, New York City Department of Environmental Protection). A estimate of the percentages for the study period was determined by comparing the range of current values with the percentages from a survey of a neighboring area of Delaware County with construction practices and code enforcement similar to the West Branch Delaware River Watershed at the time of the study (Personal Communication, A. Lemley, Cornell University).

Point Sources. Point sources of nutrients are dissolved loads from five municipal and two industrial wastewater treatment plants. These inputs are 3800 kg/mo nitrogen and 825 kg/mo phosphorus (Brown & Rafferty, 1980; Dickerhoff, 1981).

Complete data inputs for the validation simulation run are given in Appendix D.

Validation Results

The GWLF streamflow predictions are compared with observations in Figure C-2. It is apparent that although the model mirrors the timing of observed streamflow, predictions for any particular month may have substantial errors. Accuracy is poorest for low flows, when predicted streamflows are essentially zero due to the very simple lumped parameter groundwater model.

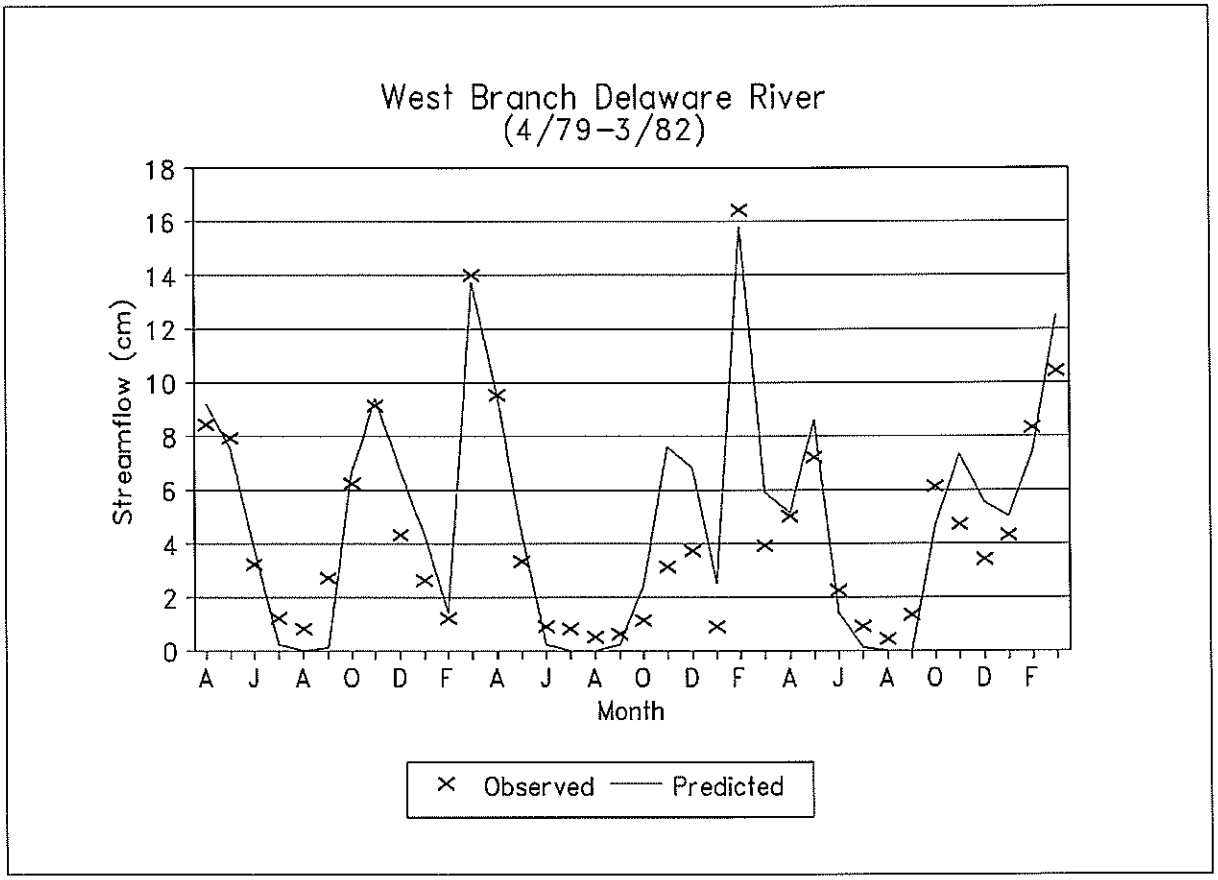


Figure C-2. Observed and Predicted Monthly Streamflow.

Model predictions and observations for total phosphorus and nitrogen are compared in Figures C-3 and C-4. Both sets of predictions match the variations in observations but under-predict the February, 1981 peak values by 35% and 26% for phosphorus and nitrogen, respectively. A quantitative summary of the comparisons of predictions with observations is given in Table C-5. Monthly mean predictions are within 10% of observation means for five of the six model outputs. The predicted mean total nitrogen flux is 73% of the observed mean. No coefficient of determination (R^2) is less than 0.88, indicating that the model explains at least 88% of the observed monthly variation in streamflow, sediment yield and nutrient fluxes.

Mean annual nutrient loads from each source for the four-year simulation period are provided in Table C-6. It is apparent that cropland runoff is a major source of streamflow nitrogen and phosphorus. Groundwater discharge is the largest source of nitrogen, accounting for 41% of dissolved and 36% of total nitrogen loads. Point sources constitute 11% of total nitrogen and 20% of total phosphorus. Septic tank drainage provides nearly as much nitrogen as point sources, but is a minor phosphorus source.

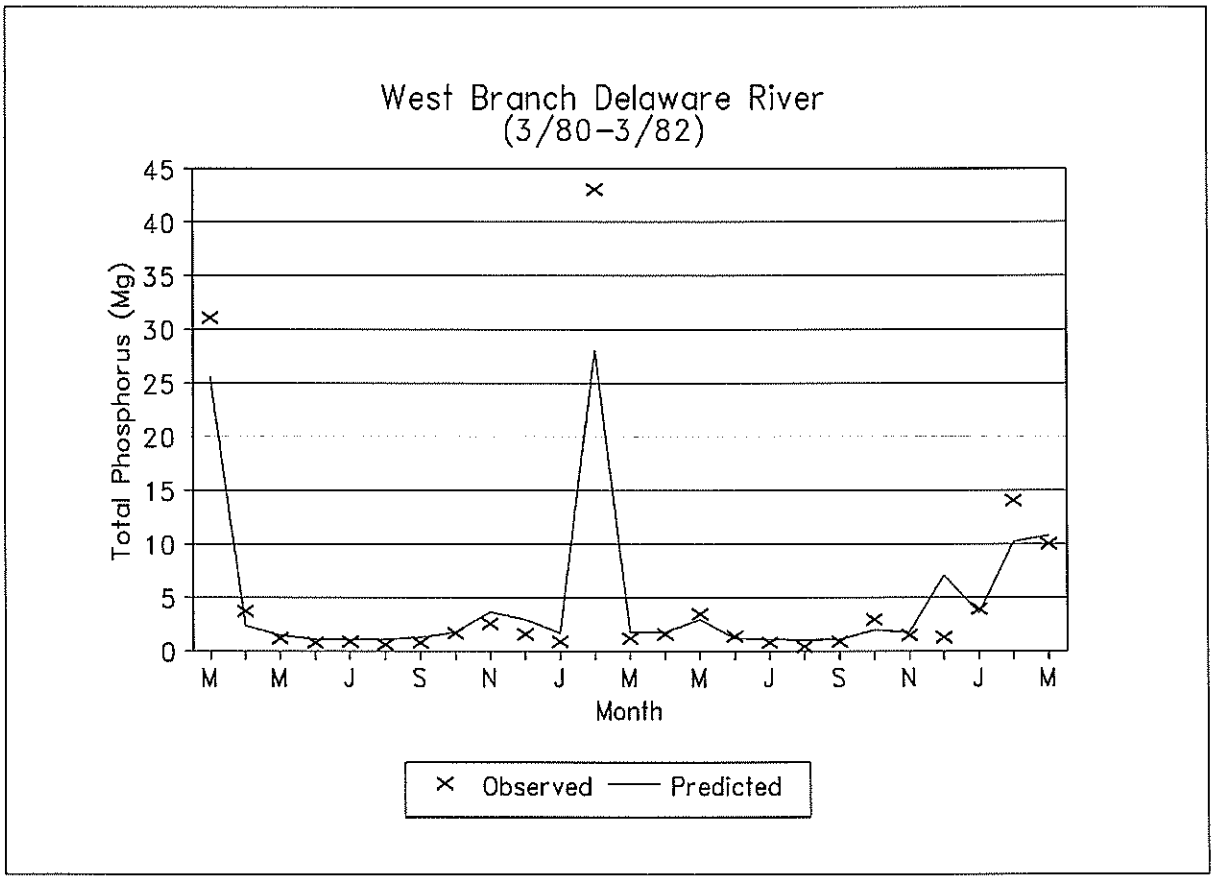


Figure C-3. Observed and Predicted Total Phosphorus in Streamflow.

Constituent	Period	Validation Predicted	Monthly Means Observed	Coefficient of Determination (R^2)
Streamflow (cm)	4/79-3/82	4.9	4.5	0.88
Sediment (1000 Mg)	3/80-3/82	1.6	1.7	0.95
Nitrogen (Mg)				
Dissolved	3/80-9/81	27.8	27.8	0.94
Total	1/81-9/81	32.9	44.8	0.99
Phosphorus (Mg)				
Dissolved	3/80-3/82	2.6	2.4	0.95
Total	3/80-3/82	4.7	5.2	0.95

Table C-5. Comparison of GWLF Predictions and Observations for the West Branch Delaware River Watershed.

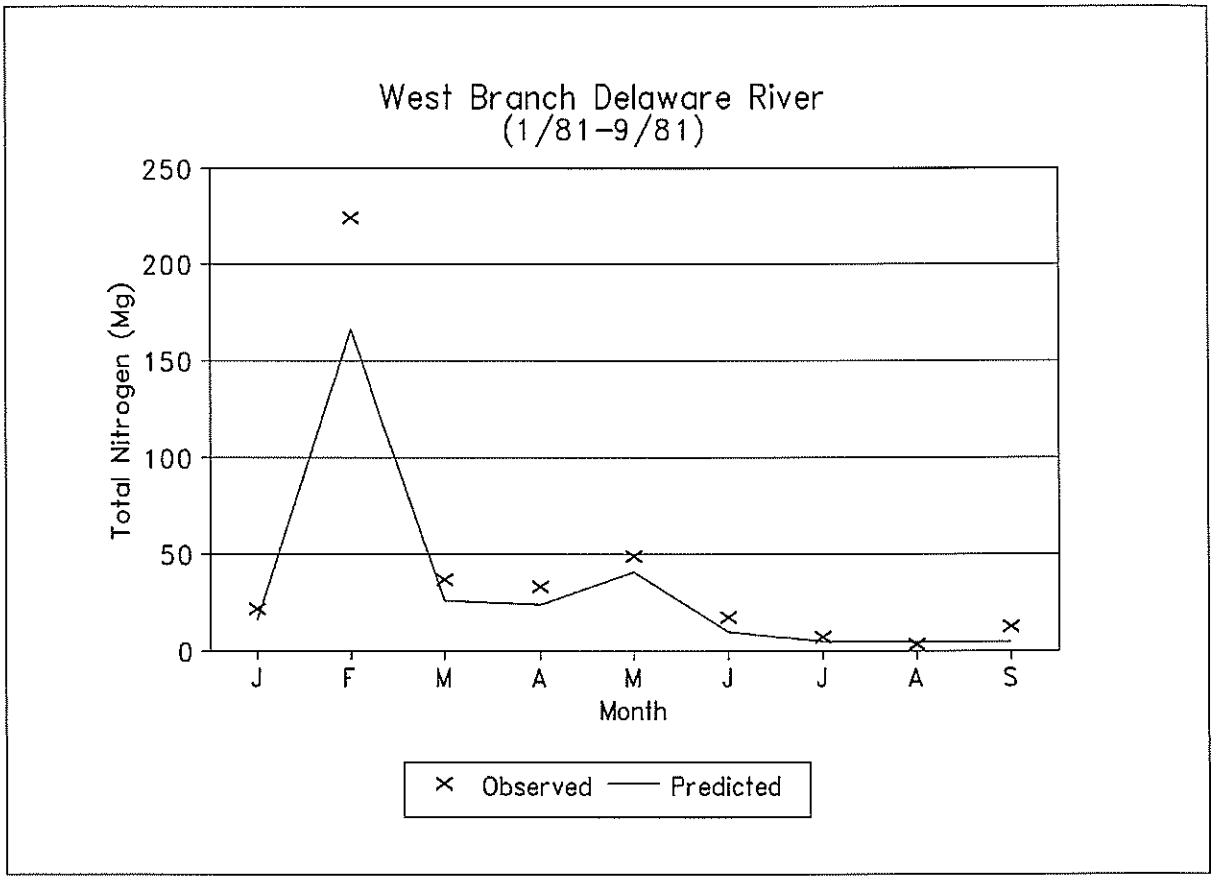


Figure C-4. Observed and Predicted Total Nitrogen in Streamflow.

Conclusions

The watershed loading functions model GWLF is based on simple runoff, sediment and groundwater relationships combined with empirical chemical parameters. The model is unique in its ability to estimate monthly nutrient fluxes in streamflow without calibration. Validation studies in a large New York watershed indicated that the model possesses a high degree of predictive accuracy. Although better results could perhaps be obtained by more detailed chemical simulation models, such models have substantially greater data and computational requirements and must be calibrated from water quality sampling data.

The GWLF model has several limitations. Peak monthly nutrient fluxes were underestimated by as much as 35%. Since nutrient chemistry is not modeled explicitly, the model cannot be used to estimate the effects of fertilizer management or urban storm water storage and treatment. The model has only been validated for a largely rural watershed in which agricultural runoff and groundwater discharge provided most of the nutrient load. Although the urban runoff component is based on well-known relationships which have been used previously in such models as STORM and SWMM, GWLF performance in more urban watersheds is uncertain.

Source	Nitrogen (Mg) Dissolved	Total	Phosphorus (Mg) Dissolved	Total
Runoff				
Corn	52.9	84.6	7.8	21.5
Hay	48.6	55.4	2.6	5.5
Pasture	13.2	16.7	1.1	2.6
Inactive Agriculture	5.1	7.8	0.4	1.6
Forest & logging	5.9	6.1	0.2	0.3
Barn yards	4.3	4.3	0.8	0.8
Urban	--	2.8	--	0.3
Groundwater, Point Sources, & Septic Systems				
Groundwater Discharge	149.6	149.6	5.7	5.7
Point sources	45.6	45.6	9.9	9.9
Septic systems	38.1	38.1	1.1	1.1
Watershed Total	363.4	411.1	29.6	48.3

Table C-6. Mean Annual Nutrient Loads Estimated from GWLF for the West Branch Delaware River Watershed: 4/78 - 3/82.

APPENDIX D: DATA AND OUTPUT LISTINGS FOR VALIDATION STUDY (EXAMPLE 1)

The first listing in this appendix is the set of sequential data input files **TRANSPRT.DAT**, **NUTRIENT.DAT** and **WEATHER.DAT** used in the validation study and Example 1. The first two files are constructed by selecting the appropriate option from GWLF menus. The weather file is arranged by months (April - March, in this application) with the first entry for each month being the number of days in the month, and subsequent entries being temperature (EC) and precipitation (cm) for each day. Only a partial listing of **WEATHER.DAT** is given. The next listings are the text files for the transport and nutrient data (**TRANSPRT.TXT** and **NUTRIENT.TXT**). The remaining listings are text files of the several program outputs (**SUMMARY.TXT** and **MONTHLY.TXT**).

TRANSPRT.DAT

```
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0
0
0
0
0
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"MAY",1,14.3,1,.25
"JUNE",1,15,1,.25
"JULY",1,14.6,1,.25
"AUG",1,13.6,1,.25
"SEPT",1,12.3,1,.25
"OCT",1,10.9,1,.06
"NOV",.49,9.7,0,.06
"DEC",.49,9,0,.06
"JAN",.49,9.3,0,.06
"FEB",.49,10.4,0,.06
"MAR",.49,11.7,0,.06
"CORN",3430,83.8,.214
"HAY",13085,79.4,.012
"PASTURE",5093,73.1,.016
"INACTIVE",3681,73.1,.017
"FOREST",56682,66.5,0
"LOGGING",20,0,.217
"BARN YARDS",41,92.2,0
"RES-imperv",104,98,0
"RES-perv",546,74,0
"COMM-imperv",49,98,0
"COMM-perv",41,74,0
"INDUS-imperv",34,98,0
"INDUS-perv",67,74,0
```

NUTRIENT.DAT

```
3000,1300,.34,.013
1,10,12
2.9,.26
2.8,.15
3,.25
1.6,.13
.19,.006
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29.3,5.1
0.045,0.0045
0.012,0.0016
0.101,0.0112
0.012,0.0019
0.101,0.0112
0.012,0.0019
12.2,1.9
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3800,825
3800,825
3800,825
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WEATHER.DAT

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10,.2
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14,0
12,.5
11,.4
11,.8
14,.4
17,.2
!
!
!
```

TRANSPRT.TXT

TRANSPRT DATA

LAND USE	AREA(ha)	CURVE NO	KLSCP
CORN	3430.	83.8	0.21400
HAY	13085.	79.4	0.01200
PASTURE	5093.	73.1	0.01600
INACTIVE	3681.	73.1	0.01700
FOREST	56682.	66.5	0.00000
LOGGING	20.	0.0	0.21700
BARN YARDS	41.	92.2	0.00000
RES-imperv	104.	98.0	0.00000
RES-perv	546.	74.0	0.00000
COMM-imperv	49.	98.0	0.00000
COMM-perv	41.	74.0	0.00000
INDUS-imperv	34.	98.0	0.00000
INDUS-perv	67.	74.0	0.00000

MONTH	ET CV()	DAY HRS	GROW. SEASON	EROS. COEF
APR	0.490	13.1	0	.25
MAY	1.000	14.3	1	.25
JUNE	1.000	15	1	.25
JULY	1.000	14.6	1	.25
AUG	1.000	13.6	1	.25
SEPT	1.000	12.3	1	.25
OCT	1.000	10.9	1	.06
NOV	0.490	9.7	0	.06
DEC	0.490	9	0	.06
JAN	0.490	9.3	0	.06
FEB	0.490	10.4	0	.06
MAR	0.490	11.7	0	.06

ANTECEDENT RAIN+MELT FOR DAY -1 TO DAY -5

0	0	0	0	0

INITIAL UNSATURATED STORAGE (cm) = 10
INITIAL SATURATED STORAGE (cm) = 0
RECESSION COEFFICIENT (1/day) = .1
SEEPAGE COEFFICIENT (1/day) = 0
INITIAL SNOW (cm water) = 0
SEDIMENT DELIVERY RATIO = 0.065
UNSAT AVAIL WATER CAPACITY (cm) = 10

NUTRIENT.TXT

NUTRIENT DATA

RURAL LAND USE	DIS.NITR IN RUNOFF(mg/l)	DIS.PHOS IN RUNOFF(mg/l)
CORN	2.9	.26
HAY	2.8	.15
PASTURE	3	.25
INACTIVE	1.6	.13
FOREST	.19	.006
LOGGING	0	0
BARN YARDS	29.3	5.1

NUTRIENT CONCENTRATIONS IN RUNOFF FROM MANURED AREAS

LAND USE	NITROGEN(mg/l)	PHOSPHORUS(mg/l)
CORN	12.2	1.9

URBAN LAND USE	NITR.BUILD-UP(kg/ha-day)	PHOS.BUILD-UP(kg/ha-day)
RES-imperv	.045	.0045
RES-perv	.012	.0016
COMM-imperv	.101	.0112
COMM-perv	.012	.0019
INDUS-imperv	.101	.0112
INDUS-perv	.012	.0019

MONTH	POINT SOURCE NITR.(kg)	POINT SOURCE PHOS.(kg)
APR	3800	825
MAY	3800	825
JUNE	3800	825
JULY	3800	825
AUG	3800	825
SEPT	3800	825
OCT	3800	825
NOV	3800	825
DEC	3800	825
JAN	3800	825
FEB	3800	825
MAR	3800	825

NITROGEN IN GROUNDWATER (mg/l): 0.340
PHOSPHORUS IN GROUNDWATER (mg/l): 0.013
NITROGEN IN SEDIMENT (mg/kg): 3000
PHOSPHORUS IN SEDIMENT (mg/kg): 1300

MANURE SPREADING JAN THRU MAR

SEPTIC SYSTEMS

	POPULATION SERVED			
MONTH	NORMAL SYSTEMS	PONDING SYSTEMS	SHORT-CIRCUIT SYSTEMS	DISCHARGE SYSTEMS
APR	7572	881	88	264
MAY	7572	881	88	264
JUNE	9407	1094	109	328
JULY	9407	1094	109	328
AUG	9407	1094	109	328
SEPT	7572	881	88	264
OCT	7572	881	88	264
NOV	7572	881	88	264
DEC	7572	881	88	264
JAN	7572	881	88	264
FEB	7572	881	88	264
MAR	7572	881	88	264

PER CAPITA TANK EFFLUENT NITROGEN (g/day) = 12
PER CAPITA TANK EFFLUENT PHOSPHORUS (g/day) = 2.5
PER CAPITA GROWING SEASON NITROGEN UPTAKE (g/day) = 1.6
PER CAPITA GROWING SEASON PHOSPHORUS UPTAKE (g/day) = .4

SUMMARY.TXT

W. Branch Delaware River 4/78-3/82 4 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	1.9	6.5	0.3	6.7
MAY	9.8	7.5	5.3	0.3	5.6
JUNE	8.3	9.7	1.8	0.0	1.8
JULY	8.6	11.3	0.1	0.0	0.2
AUG	10.4	9.2	1.2	0.9	2.0
SEPT	11.6	5.8	0.1	0.1	0.2
OCT	11.5	3.1	4.3	0.1	4.4
NOV	8.2	0.7	6.6	0.4	7.0
DEC	8.0	0.2	5.6	0.4	6.0
JAN	8.1	0.1	5.0	1.1	6.1
FEB	8.5	0.2	5.7	1.8	7.4
MAR	9.8	0.8	10.9	2.4	13.3
ANNUAL	112.3	50.7	53.1	7.8	60.8

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	29.2	0.0	30.7	31.1	1.9	2.0
MAY	35.7	0.2	26.9	27.7	1.8	2.1
JUNE	23.5	0.0	10.7	10.9	1.1	1.2
JULY	28.1	0.0	4.9	5.2	1.0	1.0
AUG	45.8	1.2	17.2	21.0	1.7	3.2
SEPT	45.0	0.0	6.2	6.6	1.1	1.1
OCT	11.2	0.1	21.3	21.8	1.6	1.7
NOV	6.3	0.9	33.3	36.1	2.1	3.2
DEC	0.8	1.1	28.9	32.3	1.9	3.3
JAN	0.4	1.1	41.4	45.0	3.6	5.1
FEB	0.5	4.4	55.4	68.8	4.9	10.6
MAR	3.7	6.0	86.6	104.8	7.0	14.8
ANNUAL	230.4	15.0	363.4	411.0	29.6	49.3

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
CORN	3430.	18.03	47.43	52.92	84.64	7.78	21.52
HAY	13085.	13.27	2.66	48.60	55.39	2.60	5.54
PASTURE	5093.	8.65	3.55	13.22	16.74	1.10	2.63
INACTIVE	3681.	8.65	3.77	5.10	7.80	0.41	1.59
FOREST	56682.	5.47	0.00	5.89	5.89	0.19	0.19
LOGGING	20.	0.00	48.10	0.00	0.19	0.00	0.08
BARN YARDS	41.	36.11	0.00	4.34	4.34	0.76	0.76
RES-imperv	104.	74.11	0.00	0.00	0.86	0.00	0.09
RES-perv	546.	9.20	0.00	0.00	0.29	0.00	0.04
COMM-imperv	49.	74.11	0.00	0.00	0.91	0.00	0.10
COMM-perv	41.	9.20	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	74.11	0.00	0.00	0.63	0.00	0.07
INDUS-perv	67.	9.20	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				149.58	149.58	5.72	5.72
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.13	38.13	1.11	1.11
TOTAL				363.37	411.05	29.57	49.34

MONTHLY.TXT

W. Branch Delaware River 4/78-3/82 YEAR 1

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	5.2	1.7	3.1	0.0	3.1
MAY	7.9	7.4	2.1	0.0	2.1
JUNE	10.5	9.7	1.8	0.0	1.8
JULY	10.8	10.9	0.3	0.0	0.4
AUG	17.0	10.4	4.6	3.4	8.1
SEPT	7.6	5.5	0.4	0.1	0.4
OCT	11.6	3.1	3.9	0.0	3.9
NOV	4.7	0.7	3.7	0.1	3.8
DEC	12.6	0.2	5.2	0.0	5.2
JAN	19.1	0.2	8.7	3.8	12.6
FEB	4.0	0.1	4.6	0.5	5.1
MAR	10.9	1.1	16.5	4.6	21.0
YEAR	121.9	50.9	54.9	12.6	67.4

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	8.3	0.0	14.9	15.0	1.3	1.3
MAY	13.3	0.0	11.3	11.5	1.1	1.2
JUNE	29.3	0.0	10.8	11.0	1.2	1.2
JULY	39.4	0.0	5.8	6.1	1.0	1.0
AUG	109.6	4.7	54.9	69.5	3.8	10.0
SEPT	35.4	0.0	6.8	6.9	1.1	1.1
OCT	10.3	0.0	17.8	18.1	1.4	1.4
NOV	1.4	0.0	18.2	18.4	1.4	1.4
DEC	1.8	0.0	22.1	22.3	1.5	1.5
JAN	0.0	3.8	100.4	112.2	8.9	13.9
FEB	0.0	0.2	32.7	33.5	2.8	3.1
MAR	5.0	7.7	139.6	163.2	11.2	21.3
YEAR	253.8	16.5	435.3	487.5	36.6	58.3

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
CORN	3430.	24.70	52.26	81.18	116.13	12.18	27.33
HAY	13085.	19.27	2.93	70.59	78.06	3.78	7.02
PASTURE	5093.	13.86	3.91	21.18	25.06	1.76	3.45
INACTIVE	3681.	13.86	4.15	8.16	11.14	0.66	1.95
FOREST	56682.	9.81	0.00	10.57	10.57	0.33	0.33
LOGGING	20.	0.00	52.99	0.00	0.21	0.00	0.09
BARN YARDS	41.	44.22	0.00	5.31	5.31	0.92	0.92
RES-imperv	104.	82.95	0.00	0.00	0.86	0.00	0.09
RES-perv	546.	14.52	0.00	0.00	0.30	0.00	0.04
COMM-imperv	49.	82.95	0.00	0.00	0.90	0.00	0.10
COMM-perv	41.	14.52	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	82.95	0.00	0.00	0.63	0.00	0.07
INDUS-perv	67.	14.52	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				154.61	154.61	5.91	5.91
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				435.30	487.55	36.58	58.33

W. Branch Delaware River 4/78-3/82 YEAR 2

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	11.0	1.8	8.5	0.7	9.2
MAY	15.3	7.6	6.8	0.6	7.5
JUNE	4.2	9.6	3.8	0.0	3.8
JULY	7.2	11.5	0.2	0.0	0.2
AUG	9.2	7.6	0.0	0.0	0.0
SEPT	14.3	6.0	0.0	0.1	0.1
OCT	11.2	3.4	6.7	0.1	6.7
NOV	13.5	0.9	8.6	0.8	9.4
DEC	5.0	0.4	6.7	0.0	6.7
JAN	3.7	0.2	4.3	0.0	4.3
FEB	4.0	0.1	1.4	0.0	1.4
MAR	14.8	0.7	10.7	3.0	13.7
YEAR	113.4	49.8	57.6	5.4	63.0

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	35.1	0.2	43.4	44.2	2.6	2.8
MAY	66.9	0.5	37.6	39.3	2.4	3.1
JUNE	11.2	0.0	17.2	17.3	1.3	1.4
JULY	15.4	0.0	4.9	5.1	0.9	1.0
AUG	19.1	0.0	4.4	4.6	0.9	1.0
SEPT	64.7	0.1	6.5	7.0	1.1	1.2
OCT	8.2	0.0	27.9	28.2	1.7	1.8
NOV	21.0	2.6	45.2	53.3	2.7	6.1
DEC	0.7	0.0	27.6	27.9	1.7	1.7
JAN	1.7	0.0	18.9	19.0	1.4	1.4
FEB	0.0	0.0	10.2	10.3	1.2	1.2
MAR	8.6	13.0	99.0	138.5	8.5	25.5
YEAR	252.7	16.4	342.6	394.6	26.4	48.1

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR (Mg)	TOT.NITR (Mg)	DIS.PHOS (Mg)	TOT.PHOS (Mg)
CORN	3430.	15.22	52.02	37.28	72.08	5.26	20.34
HAY	13085.	10.54	2.92	38.60	46.05	2.07	5.29
PASTURE	5093.	6.11	3.89	9.33	13.19	0.78	2.45
INACTIVE	3681.	6.11	4.13	3.60	6.56	0.29	1.58
FOREST	56682.	3.26	0.00	3.51	3.51	0.11	0.11
LOGGING	20.	0.00	52.75	0.00	0.21	0.00	0.09
BARN YARDS	41.	33.71	0.00	4.05	4.05	0.70	0.70
RES-imperv	104.	74.86	0.00	0.00	0.88	0.00	0.09
RES-perv	546.	6.62	0.00	0.00	0.28	0.00	0.04
COMM-imperv	49.	74.86	0.00	0.00	0.93	0.00	0.10
COMM-perv	41.	6.62	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	74.86	0.00	0.00	0.64	0.00	0.07
INDUS-perv	67.	6.62	0.00	0.00	0.03	0.00	0.01
GROUNDWATER				162.40	162.40	6.21	6.21
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.21	38.21	1.12	1.12
TOTAL				342.59	394.64	26.44	48.10

W. Branch Delaware River 4/78-3/82 YEAR 3

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	11.9	2.1	9.3	0.2	9.5
MAY	3.2	7.6	4.3	0.0	4.3
JUNE	10.4	9.1	0.2	0.0	0.2
JULY	9.5	11.5	0.0	0.0	0.0
AUG	9.9	10.3	0.0	0.0	0.0
SEPT	10.7	6.3	0.0	0.2	0.2
OCT	10.0	3.0	2.2	0.2	2.4
NOV	8.8	0.5	6.7	0.9	7.6
DEC	6.3	0.1	6.2	0.6	6.8
JAN	2.8	0.0	2.4	0.1	2.5
FEB	16.8	0.6	10.7	5.1	15.8
MAR	4.3	0.8	5.9	0.0	5.9
YEAR	104.6	52.0	47.8	7.4	55.2

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	45.5	0.0	40.9	41.2	2.2	2.3
MAY	6.7	0.0	19.2	19.3	1.4	1.4
JUNE	38.2	0.0	5.4	5.7	1.0	1.0
JULY	37.6	0.0	4.5	4.7	1.0	1.0
AUG	41.7	0.0	5.2	5.4	1.0	1.0
SEPT	36.6	0.1	7.1	7.5	1.1	1.2
OCT	15.9	0.1	16.3	17.0	1.5	1.7
NOV	0.5	0.8	40.3	43.1	2.5	3.6
DEC	0.2	0.6	33.9	35.8	2.1	2.9
JAN	0.0	0.0	15.6	15.8	1.5	1.6
FEB	2.1	13.0	126.8	166.2	11.1	28.0
MAR	0.7	0.0	25.7	26.0	1.7	1.7
YEAR	225.7	14.7	340.9	387.6	28.1	47.5

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
CORN	3430.	17.55	46.48	48.63	79.72	7.06	20.53
HAY	13085.	12.74	2.61	46.69	53.34	2.50	5.38
PASTURE	5093.	8.17	3.47	12.48	15.93	1.04	2.54
INACTIVE	3681.	8.17	3.69	4.81	7.46	0.39	1.54
FOREST	56682.	5.14	0.00	5.54	5.54	0.17	0.17
LOGGING	20.	0.00	47.13	0.00	0.18	0.00	0.08
BARN YARDS	41.	35.45	0.00	4.26	4.26	0.74	0.74
RES-imperv	104.	70.37	0.00	0.00	0.85	0.00	0.08
RES-perv	546.	8.69	0.00	0.00	0.28	0.00	0.04
COMM-imperv	49.	70.37	0.00	0.00	0.90	0.00	0.10
COMM-perv	41.	8.69	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	70.37	0.00	0.00	0.62	0.00	0.07
INDUS-perv	67.	8.69	0.00	0.00	0.03	0.00	0.01
GROUNDWATER				134.79	134.79	5.15	5.15
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				340.89	387.61	28.08	47.45

W. Branch Delaware River 4/78-3/82 YEAR 4

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	10.3	2.1	5.0	0.1	5.1
MAY	13.0	7.4	8.1	0.5	8.6
JUNE	8.1	10.4	1.4	0.0	1.4
JULY	7.0	11.4	0.1	0.0	0.1
AUG	5.4	8.7	0.0	0.0	0.0
SEPT	13.7	5.4	0.0	0.0	0.0
OCT	13.1	2.9	4.6	0.2	4.7
NOV	5.9	0.7	7.3	0.0	7.3
DEC	8.2	0.1	4.3	1.1	5.5
JAN	6.6	0.1	4.6	0.4	5.0
FEB	9.1	0.1	5.9	1.5	7.4
MAR	9.0	0.7	10.7	1.8	12.5
YEAR	109.4	50.0	52.0	5.7	57.7

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	28.0	0.0	23.5	23.9	1.6	1.7
MAY	55.8	0.4	39.3	40.8	2.3	2.9
JUNE	15.4	0.0	9.3	9.4	1.1	1.1
JULY	20.1	0.0	4.6	4.8	0.9	1.0
AUG	12.7	0.0	4.3	4.5	0.9	0.9
SEPT	43.2	0.0	4.6	4.9	1.0	1.0
OCT	10.5	0.2	23.0	23.8	1.6	1.9
NOV	2.4	0.0	29.5	29.7	1.7	1.7
DEC	0.5	3.6	32.0	43.2	2.2	7.0
JAN	0.0	0.7	30.6	32.9	2.6	3.5
FEB	0.0	4.3	51.9	65.1	4.5	10.1
MAR	0.7	3.1	82.0	91.6	6.7	10.7
YEAR	189.3	12.3	334.7	374.4	27.2	43.5

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
CORN	3430.	14.66	38.98	44.57	70.64	6.60	17.89
HAY	13085.	10.52	2.19	38.54	44.12	2.06	4.48
PASTURE	5093.	6.48	2.91	9.90	12.79	0.82	2.08
INACTIVE	3681.	6.48	3.10	3.81	6.04	0.31	1.27
FOREST	56682.	3.67	0.00	3.95	3.95	0.12	0.12
LOGGING	20.	0.00	39.52	0.00	0.15	0.00	0.07
BARN YARDS	41.	31.05	0.00	3.73	3.73	0.65	0.65
RES-imperv	104.	68.27	0.00	0.00	0.87	0.00	0.09
RES-perv	546.	6.96	0.00	0.00	0.30	0.00	0.04
COMM-imperv	49.	68.27	0.00	0.00	0.92	0.00	0.10
COMM-perv	41.	6.96	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	68.27	0.00	0.00	0.64	0.00	0.07
INDUS-perv	67.	6.96	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				146.50	146.50	5.60	5.60
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				334.70	374.40	27.18	43.49

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Appendix E
Calculation Details

This appendix provides details for the computation of GWLF input parameters requiring multiple steps.

Curve Number

The curve number must be developed within an ArcView project named *iepa_prepro.apr*, which contains all of the necessary extensions except Spatial Analyst. The Spatial Analyst extension of ArcView must be available for this calculation.

1. Add the landuse and STATSGO shapefiles and the landuse grid to the View. Open the attribute table for the STATSGO shapefile.
2. Add the attribute tables lookup.dbf and statsgoc.dbf to the project. The lookup table is common to any soil/landuse combination, but the STATSGO table must reflect the area for which the curve number is being calculated. In the statsgoc.dbf table, the field *comppct* identifies the percentage of each soil type in a map unit. This field is a string field and must be converted to a number field.
3. To convert the string field to a number field: add a new number field to the statsgoc.dbf attribute table named *comppct2*, and fill it with the values of the field *comppct* (to fill a number field with values from a string field, the calculation should read "*comppct.AsNumber*"). Delete the field *comppct*. Create a new number field, *comppct*, and fill it with the values of *comppct2*. Delete the field *commct2*. The *comppct* field now exists as a number field.
4. From the CRWR-PrePro menu, select "Soil Group Percentages". When prompted, input statsgo.dbf for the map unit table and statsgoc.dbf for the component table. The script will automatically create an output table, muidjoin.dbf, listing the percentage of each hydrologic soil group in each map unit.
5. From the CRWR-PrePro menu, select "Curve Number Grid". When prompted, select the STATSGO shapefile as the soils theme, the landuse shapefile as the landuse theme, lookup.dbf as the lookup table, muidjoin.dbf as the table with the soil group percentages, and set the analysis extent and the cell size to the landuse grid. The curve number grid can take between 2 and 15 minutes to compute depending on the computer speed and size of the basin.
6. Save the temporary curve number grid as a permanent grid named *CN_grid*.
7. To average the curve number grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table E-1 lists the curve numbers for each landuse in the Kinkaid Lake Watershed.

Table E-1 Curve Numbers in Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
Row-Crop	82.1	81.9	77.5	83.1
Small Grains	80.1	77.7	75.2	79.8
Rural Grassland	68.7	68.6	61.7	72.5
Urban Grassland	74.2	---	---	---
Deciduous1	59.4	62.2	65.5	65
Deciduous2	66.2	82.2	89.4	62.1
Coniferous	61.1	63.6	60.3	---

Cattle Feedlot	74.2	---	---	73.9
Open Water	99.8	100	99.9	100
Shallow Marsh	99.6	89.5	---	100
Deep Marsh	100	---	---	100
Forested Wetland	100	100	100	99.7
Shallow Water Wetland	100	94.6	100	98.8
Barren Land	100	---	---	---
High Density	90.1	---	---	---
Medium Density	81.2	---	---	---

Soil Erodibility Factor (K)

The K factor is developed in ArcView and Excel.

1. In ArcView, add the attribute tables statsgoc.dbf and statsgol.dbf to the Table list. Join the statsgoc.dbf table to the statsgol.dbf table by field *muidsegnum*. This appends the percentage of each soil type to the soils in each layer. Export the joined table as a .dbf named statsgo_kf.dbf.
    1. Open the table statsgo_kf.dbf in Excel. Remove all fields except *muid, layernum, kffact, kfact,* and *comppct*.
    2. Sort the entire table by *layernum* then by *muid*. This promotes all soils in layer 1 to the top of the spreadsheet.
    3. Remove all records for soils below layer 1.
    4. Ensure the sum of the *comppct* field for each muid is equal to 100.
    5. In a new column labeled *product*, multiply *kffact* by *comppct* and divide by 100 for each record. If the value in the *kffact* field is zero, use the value in the *kfact* field
    6. In a new column labeled *kffact_r* (revised), sum *product* over each muid to obtain the revised K factor for each muid.
    7. Copy the *kffact_r* column and use the "Paste Special/Values" option to paste the column into the *layernum* column. This is done so that the *kffact_r* values will be retained when the statsgo_kf.dbf table is saved and used again in ArcView.
    8. Delete all columns except for *muid* and *kffact_r*. Delete any rows without a value in the *kffact_r* field.
    9. Save the table.
    10. In ArcView, add the table statsgo_kf.dbf, the STATSGO shapefile in UTM 16 projection, and the landuse grid. Join the statsgo_kf.dbf table to the statsgo.dbf table by *muid*. This attaches the average K factor to each muid in statsgo.dbf.
    11. Set the analysis extent and cell size to the landuse grid.
    12. Convert the SATSGO shapefile to a grid using the *kffact_r* field as the grid value.
    13. To average the K factor grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table E-2 presents the resulting K-factors associated with each landuse and used in the GWLF program.

Table E-2 Weighted K factors for the Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4

Row Crop	0.39	0.39	0.37	0.40
Small Grains	0.39	0.38	0.37	0.39
Urban Grassland	0.41	---	---	---
Rural Grassland	0.39	0.39	0.37	0.39
Deciduous1	0.38	0.37	0.37	0.37
Deciduous2	0.39	0.37	0.37	0.38

Topographic Factor (LS)

The topographic factor is calculated from a series of equations presented below.

$L = (\Lambda/72.6)^m$

$m = B/(1+B)$

$B = (\sin\Theta/0.0896) / (3.0(\sin\Theta)^{0.8} + 0.56)$

$\Theta = \arctan(\text{slope}/100)$

$S = 10.8\sin\Theta + 0.03$ where slope $\leq$ 9%

$S = 16.8\sin\Theta - 0.50$ where slope > 9%

Computation of the LS factor is done in the ArcView project *iepa_prepro.apr*.

1. In ArcView, add the Digital Elevation Model (DEM) to the View
2. Set the analysis extent and cell size to the DEM.
3. Select "Fill Sinks" from the CRWR-PrePro menu to fill sinks in the DEM. Save the temporary grid as a permanent grid named *Fill_grid*.
4. Open the script "New_Slope" from the project window, and press the "Run" button to compute percent slopes from the filled DEM. Save the temporary grid as a permanent grid named *Slope_grid*.
5. Select "Flow Direction" from the CRWR-PrePro menu to derive the direction of flow through each grid cell. Save the temporary grid as a permanent grid named *Fdr_grid*.
6. Compute the theta grid (in radians) with the map calculator.
   Map Calc. Statement: (([slope_grid] / 100)).Atan
   Save Map Calc 1 as a permanent grid named *Theta_grid*.
7. Compute the S grid with the map calculator and a succession of calculations
   Map Calc. 1: ([slope_grid] <= 9)
   Output: 1 in cells where slope is less or equal to 9; zero elsewhere
   Map Calc. 2: ((([theta_grid].Sin) * 10.8) + 0.03)
   Output: S-value computed for slopes <= 9 in all cells
   Map Calc. 3: ([Map Calculation 2 * [Map Calculation 1])
   Output: Correct S-value in cells with slope <= 9; zero elsewhere
   Map Calc. 4: ([slope_grid] > 9)
   Output: 1 in cells where slope > 9, zero elsewhere
   Map Calc. 5: ((([theta_grid].Sin) * 16.8) - 0.5)
   Output: S-value computed for slopes > 9 in all cells
   Map Calc. 6: ([Map Calculation 5] * [Map Calculation 4])
   Output: Correct S-value in cells with slope > 9; zero elsewhere

Map Calc. 7: ([Map Calculation 3] + [Map Calculation 6])
Output: Correct S-value in each cell
Save Map Calculation 7 as a permanent grid named *S_grid.*

8. Compute the Beta grid with the map calculator.
Map Calc. 1: (([theta_grid].Sin) / 0.0896) /
((([theta_grid].Sin).Pow(0.8)) * 3.0 + 0.56)
Save Map Calculation 1 as a permanent grid named *Beta_grid.*

9. Compute the M grid with the map calculator.
Map Calc. 1: ([beta_grid] / ([beta_grid] + 1))
Save Map Calculation 1 as permanent grid named *M_grid.*

10. Compute the flow length (Lambda) grid with the map calculator and a succession of calculations
Map Calc. 1: ([fdr] = 1 OR [fdr] = 4 OR [fdr] = 16 OF [fdr] = 64)
Output: 1 in cells flowing in cardinal direction and 0 in other cells
Map Calc. 2: ([Map Calculation 1] * 30.8875)
{30.885 = cell length}
Output: 30.885 in cells flowing in cardinal direction and 0 in others.
Map Calc. 3: ([Map Calculation 2] = 0)
Output: 0 in cells flowing in cardinal direction and 1 in others
Map Calc. 4: ([Map Calculation 3] * 43.682)
{43.682= length across cell diagonal}
Output: 43.682 in cells flowing in non-cardinal direction, 0 in others.
Map Calc. 5: ([Map Calculation 4] + [Map Calculation 2])
Output: correct flow lengths in each cell - 30.885 in cardinal, 43.682 in others
Map Calc. 6: ([Map Calculation 5] * 100 / 2.54 / 12
Output: flow length grid in feet
Save Map Calculation 6 as a permanent grid named *Lambda_grid*

11. Compute the L with the map calculator.
Map Calc. Statement: ([lambda_grid] / 72.6).Pow([m_grid])
Save Map Calculation 1 as a permanent grid named *L_grid.*

12. Compute the LS grid with the map calculator.
Map Calc. Statement: ([L-grid] * [S_grid])
Save Map Calculation 1 as a permanent grid named *LS_grid.*

13. To average the LS grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table E-3 presents the resulting LS factors for each rural landuse used in GWLF.

Table E-3 Weighted LS factors for the Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
Row Crop	0.891	1.163	2.105	0.597
Small Grains	0.879	0.793	0.584	0.614
Urban Grassland	0.358	---	---	---

Rural Grassland	1.023	0.819	1.242	0.797
Deciduous1	1.886	2.554	2.890	2.086
Deciduous2	0.931	1.297	2.311	1.571

In the following discussions, fields in bold type represent calculations in Excel. Fields in non-bold type are input fields.

Cropping Management Factor (C factor)

The C factor is calculated in Excel. C factors were selected for each crop by tillage practice and crop rotation from the table provided by the Jackson County NRCS office included as Appendix F. The Jackson County NRCS office also provided an estimate of the percentage of each crop rotation across the Kinkaid Lake Watershed. The spreadsheet used to calculate a weighted c-factor for corn, soybeans, and small grains is shown at the end of this appendix. The values in the Table 1 of the spreadsheet are a weighted average of values from columns C and F. This weighted average allows the influence of crop rotations to be included in the c-factors for the Kinkaid Lake Watershed. The values in the Table 1 are then weighted by the percentage of each tillage practice in Table 2 to determine a single c-factor for corn, soybeans, and small grains.

The weighted C factor for each crop is then appended to the table of Cropland Data Layer landuses and areas in the Kinkaid Lake watershed. Table E-4 shows the Cropland Data Layer landuse areas, and C factors. C factors for landuses other than corn, soybean, and small grains were obtained from the table included as Appendix F.

Table E-4 Cropland Data Layer C factors for Kinkaid Lake Watershed

Landuse	Subbasin 1 C-factor	Subbasin 2 C-factor	Subbasin 3 C-factor	Subbasin 4 C-factor
High Density	---	---	---	---
Medium Density	---	---	---	---
Row Crop	0.14	0.11	0.12	0.14
Small Grains	0.13	0.13	0.13	0.13
Urban Grassland	0.02	---	---	---
Rural Grassland	0.02	0.02	0.02	0.02
Deciduous	0.003	0.003	0.003	0.003
Deciduous	0.003	0.003	0.003	0.003
Coniferous	0.003	0.003	0.003	---

The landuse classes in GWLF are represented by the Critical Trends Land Assessment classes rather than the Cropland Data Layer classes, so an area-weighted average was used to calculate the C factor coefficients for "Row Crop" and "Small Grains" in the Critical Trends Land Assessment landuse file. Table E-5 shows the Critical Trends Land Assessment landuse classes and the calculated C factor coefficients. The coefficient for "Row Crop" was calculated with an area-weighed average of the C factors for corn, soybeans, and half of the double-cropped WW/SB area in the Cropland Data Layer. The coefficient for "Small Grains" was calculated with an area-weighted average of the C factors for winter wheat, other small grains and hay, and half of double-cropped WW/SB area from the Cropland Data Layer.

Table E-5 C Factors by Critical Trends Assessment Landuse Classes in the Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
Row Crop	0.14	0.11	0.12	0.14
Small Grains	0.13	0.13	0.13	0.13
Urban Grassland	0.02	---	---	---
Rural Grassland	0.02	0.02	0.02	0.02
Deciduous	0.003	0.003	0.003	0.003
Coniferous	0.003	0.003	0.003	---

Evapotranspiration (ET) Cover Coefficient

The ET cover coefficient was calculated in an Excel spreadsheet. The cover coefficients for crops available in the GWLF Manual and the crops listed in the Cropland Data Layer landuse file differ. Therefore, crops in the Cropland Data Layer file were summed into classes matching the available crop cover coefficients. Table E-6 shows the original and adjusted areas for Kinkaid Lake. The adjusted sorghum area is the sum of sorghum and other small grains and hay, and the adjusted soybean area represents soybeans plus half of the double-cropped WW/SB area. Adjusted area from winter wheat represents winter wheat plus half the double-cropped WW/SB area.

Table E-6 Cropland Data Layer Landuses, Areas and Adjusted Areas

	Subbasin 1		Subbasin 2		Subbasin 3		Subbasin 4	
Landuse	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)
Corn	4802400	4802400	316800	316800	36000	36000	1279800	1279800
Sorghum	---	4111200	---	295200	---	53100	---	860400
Soybeans	4550400	6004800	897300	1093500	86400	96750	1354500	1793700
Winter Wheat	864900	2319300	96300	292500	19800	30150	117000	556200
Other Small Grains & Hay	4111200		295200		53100		860400	
Double-Cropped WW/SB	2908800		392400		20700		878400	
Idle Cropland/ CRP	61200	61200	1800	1800	900	900	16200	16200
Fallow/ Idle Cropland	5445900	5445900	1684800	1684800	151200	151200	2065500	2065500
Pasture/Grassland/ Nonagricultural	20782800	20782800	3417300	3417300	912600	912600	7005600	7005600
Woods	42413400	42413400	16074900	16074900	7675200	7675200	11617200	11617200
Clouds	203400	203400	63900	63900	8100	8100	78300	78300
Urban	965700	965700	47700	47700	11700	11700	277200	277200
Water	607500	607500	1380600	1380600	1232100	1232100	4717800	4717800
Buildings/Homes/ Subdivisions	1317600	1317600	92700	92700	37800	37800	325800	325800
Wetlands	834300	834300	225000	225000	99900	99900	411300	411300
Total	89869500	89869500	24986700	24986700	10345500	10345500	31005000	31005000

Table E-7 shows the calculation of a single crop coefficient for each 10% of the growing season and for each calendar month. The ET cover coefficients for each crop were obtained from page 29 of the GWLF Manual. To create the coefficient for each 10% of the growing season, each crop coefficient in columns B-E was weighted by its corresponding area in Table A-8. An average monthly ET coefficient (column G) was

calculated from the coefficients in Column F, and then each growing season was assigned to a calendar month (Column H).

Table E-7 Calculation of the Monthly Crop Evapotranspiration Cover Coefficients for Subbasin 1 of the Kinkaid Lake Watershed

A	B	C	D	E	F	G	H
% of Growing Season	Field Corn	Grain Sorghum	Winter Wheat	Soybeans	**Weighted Average ET Coefficient**	**Average Monthly ET Coefficient**	Month
0	0.45	0.3	1.08	0.3	**0.45**	**0.45**	Nov - Apr
10	0.51	0.4	1.19	0.35	**0.52**		
20	0.58	0.65	1.29	0.58	**0.69**	**0.61**	May
30	0.66	0.9	1.35	1.05	**0.95**		
40	0.75	1.1	1.4	1.07	**1.03**	**0.99**	June
50	0.85	1.2	1.38	0.94	**1.04**	**1.04**	July
60	0.96	1.1	1.36	0.8	**0.99**		
70	1.08	0.95	1.23	0.66	**0.92**	**0.96**	August
80	1.2	0.8	1.1	0.53	**0.86**		
90	1.08	0.65	0.75	0.43	**0.71**	**0.78**	September
100	0.7	0.5	0.4	0.36	**0.49**		
					0.45	**0.47**	October

Table E-8 shows the calculation of a single area-weighted crop coefficient for each month. First, the crop coefficients from Table E-7 were entered into Column B of Table E-8. The monthly ET values in Columns C, D, E, F, and G were obtained from the GWLF Manual, pages 29 and 30. A monthly cover coefficient for water and wetlands was assumed to be 0.75. Finally, a single area-weighted crop coefficient for each month was calculated (Column H) from the adjusted areas in Table E-6 and the monthly ET cover coefficients in Table E-8.

Table E-8 Calculation of a Monthly ET Cover Coefficient in Subbasin 1 of the Kinkaid Lake Watershed

A	B	C	D	E	F	G	H
	Crop	Pasture	Forest	68% Urban	30% Urban	Water/ Wetland	**Weighted Average ET**
April	0.45	1.09	0.3	0.32	0.7	0.75	**0.58**
May	0.61	0.95	1	0.32	0.7	0.75	**0.90**
June	0.99	0.83	1	0.32	0.7	0.75	**0.94**
July	1.04	0.79	1	0.32	0.7	0.75	**0.93**
August	0.96	0.8	1	0.32	0.7	0.75	**0.92**
September	0.78	0.91	1	0.32	0.7	0.75	**0.92**
October	0.47	0.91	1	0.32	0.7	0.75	**0.86**
November	0.45	0.83	0.3	0.32	0.7	0.75	**0.50**
December	0.45	0.69	0.3	0.32	0.7	0.75	**0.46**
January	0.45	1.16	0.3	0.32	0.7	0.75	**0.60**
February	0.45	1.23	0.3	0.32	0.7	0.75	**0.62**
March	0.45	1.19	0.3	0.32	0.7	0.75	**0.61**

Table E-9 shows the calculated ET cover coefficients for each subbasin in the Kinkaid Lake Watershed.

Table E-9 ET Cover Coefficients in the Kinkaid Lake Watershed

Month	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
April	0.58	0.50	0.44	0.63
May	0.90	0.94	0.95	0.88
June	0.94	0.95	0.95	0.90
July	0.93	0.94	0.95	0.89
August	0.92	0.93	0.94	0.89
September	0.92	0.94	0.95	0.89
October	0.86	0.92	0.95	0.85
November	0.50	0.45	0.42	0.56
December	0.46	0.42	0.40	0.52
January	0.60	0.52	0.45	0.66
February	0.62	0.53	0.46	0.68
March	0.61	0.52	0.45	0.66

A B C

Corn-Soybean Rotation
75% of watershed

Conventional Till (Spring Plow)	
Corn after Soybean	0.3
Soybean after Corn*	0.25
Reduced-Till (20% Cover)	
Corn after Soybean	0.35
Soybean after Corn*	0.17
Mulch-Till (30% cover)	
Corn after Soybean	0.32
Soybean after Corn*	0.15
No-Till (70%/30% Cover)	
Corn after Soybean	0.16
Soybean after Corn*	0.06

*Assumed Drilled

D E F

Corn-Soybean-Wheat Rotation
25% of watershed

Conventional Till (Spring Plow)	
Corn after Wheat**	0.25
Soybean after Corn*	0.25
Wheat after Soybean#	0.15
Reduced-Till (20% Cover)	
Corn after Wheat**	0.21
Soybean after Corn*	0.17
Wheat after Soybean#	0.13
Mulch-Till (30% cover)	
Corn after Wheat**	0.18
Soybean after Corn*	0.15
Wheat after Soybean#	0.12
No-Till (70%/30% Cover)	
Corn after Wheat**	0.05
Soybean after Corn*	0.06
Wheat after Soybean#	0.09

*Assumed Drilled
**Used Corn after Small Grain
#Used Small Grain after Soybean

G H I J

Table 1 - C-factors Weighted by Percent of Crop Rotation in the Watershed

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	0.29	0.25	0.15
Reduced Till	0.32	0.17	0.13
Mulch-Till	0.29	0.15	0.12
No-Till	0.13	0.06	0.09

Table 2 - Tillage Practice Percentages in Kinkaid Lake Watershed

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	20%	0%	20%
Reduced Till	15%	10%	50%
Mulch-Till	15%	5%	10%
No-Till	50%	85%	20%

C-factors Weighted by Percent of Each Tillage Practice

Corn	Soybeans	Small Grains
0.21	0.08	0.13

R01157

Appendix F
Crop Management "C" Factor Values for Rainfall E.I. Distribution Curve #19

TABLE 3 - CROP MANAGEMENT "C" FACTOR VALUES FOR RAINFALL "E.I." DISTRIBUTION CURVE # 19 1/

CROP SEQUENCE		FALL PLOW	SPRING PLOW	CHISEL - DISK - RIDGE 2/ % Cover After Plant				No-Till % Cover After Plant			
				20%	30%	40%	50%	60%	70%	80%	90%
CORN after Soybeans		.43	.30	.35	.32	.27	---	20% .20	30% .16	40% .12	3/
CORN after Corn		.38	.25	.20	.18	.15	.13	.07	.05	.04	.03
CORN after Small Grain		.39	.25	.21	.18	.16	.14	.07	.05	.04	.03
CORN after Meadow 4/		.17	.11	.11	.09	.08	.07	.03	.02	.01	.01
CORN 2nd yr. after Meadow 4/		.33	.21	.18	.16	.14	.12	.06	.05	.04	.03
SOYBEANS after Soybeans 5/	Wide Row	.48	.37	.37	.36	---	---	20% .22	30% .17	40% .13	3/
	Drill	.42	.29	.34	.33	---	---	.19	.14	.10	
SOYBEANS after Corn 5/	Wide Row	.40	.31	.19	.16	.14	.12	.08	.06	.04	.03
	Drill	.34	.25	.17	.15	.13	.11	.07	.06	.04	.03
SOYBEANS after Sm. Grain 5/	Wide Row	.45	.27	.22	.19	.17	.15	.08	.07	.04	.03
	Drill	.38	.22	.18	.16	.14	.12	.08	.07	.04	.03
SOYBEANS after Meadow 4, 5/	Wide Row	.19	.14	.09	.07	.06	.05	.03	.02	.01	.01
	Drill	.16	.11	.08	.07	.06	.05	.03	.02	.01	.01
SOYBEANS after Corn 2nd year after meadow 5/	Wide Row	.35	.26	.16	.14	.12	.11	.08	.06	.04	.03
	Drill	.30	.21	.15	.13	.11	.10	.07	.06	.04	.03
SMALL GRAIN after Corn (Grain) 6/		.15	.14	.11	.10	.09	.08	.06	.05	.04	.03
SMALL GRAIN after Corn (Silage) 7/		.22	---	.22	---	---	---	.16	---	---	---
SMALL GRAIN after Soybeans 6/		.17	.15	.13	.12	---	---	20% .10	30% .09	40% .08	3/

WHEAT/SOYBEANS (Double Crop)

		Tillage for Soybeans: Plow	Disk	No-Till
Tillage for Wheat	Plow	.32	.20	.16
	Disk	.24	.12	.08
	No-Till	.20	.08	.04

Meadow (Full year-Established)
Grass-Legume .004
Legume only .02

USDA-SCS-Illinois
February, 1982 *

R01159

Footnotes for "C" Factor Tables

1. Values in this table are based on high level management with yields equal to or exceeding the following: corn - 100 bu/ac; soybeans - 40 bu/ac; wheat - 45 bu/ac; oats - 60 bu/ac; meadow - 3 tons/ac. For medium level management multiply factors by 1.2.

2. Values for chisel and disk systems are for fall primary tillage and two secondary tillage operations prior to planting. For primary tillage in the spring and ridge planting up and down hill multiply values by the appropriate factor: E.I. Curve 14-.9; E.I. Curve 16-.8; E.I. Curve 19-.7. For ridge planting on the contour, multiply values by the appropriate factor: E.I. Curve 14-.7; E.I. Curve 16-.6; E.I. Curve 19-.5. (These factors are in addition to the appropriate "P" factor.) Ridge planting is applicable only for row crops following row crops.

3. Percentages apply only to crops following soybeans.

4. Values are based on sod or a grass-legume mixture consisting of at least 50% grass and has been established at least one full growing season. If meadow stand is primarily legume, multiply factor by 1.2.

5. Use wide row factors for row widths greater than 20 inches and drill factors for 20 inches and less.

6. The same factors are applicable for both small grain with and without meadow seedings.

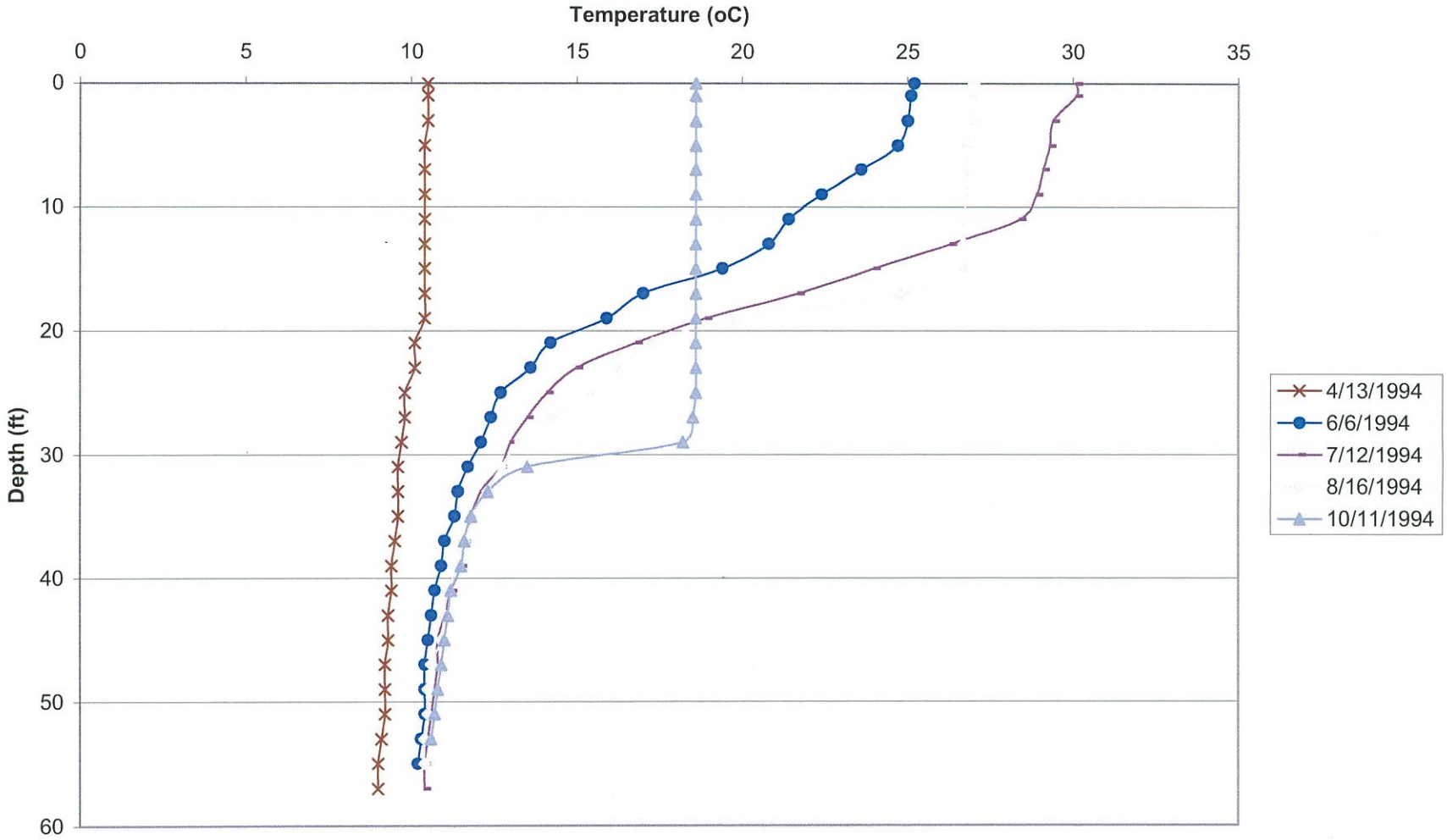
7. Factors for Disk and No-till are for the tillage system with no residue on surface after planting.

RLD:tm:6/7

R01160

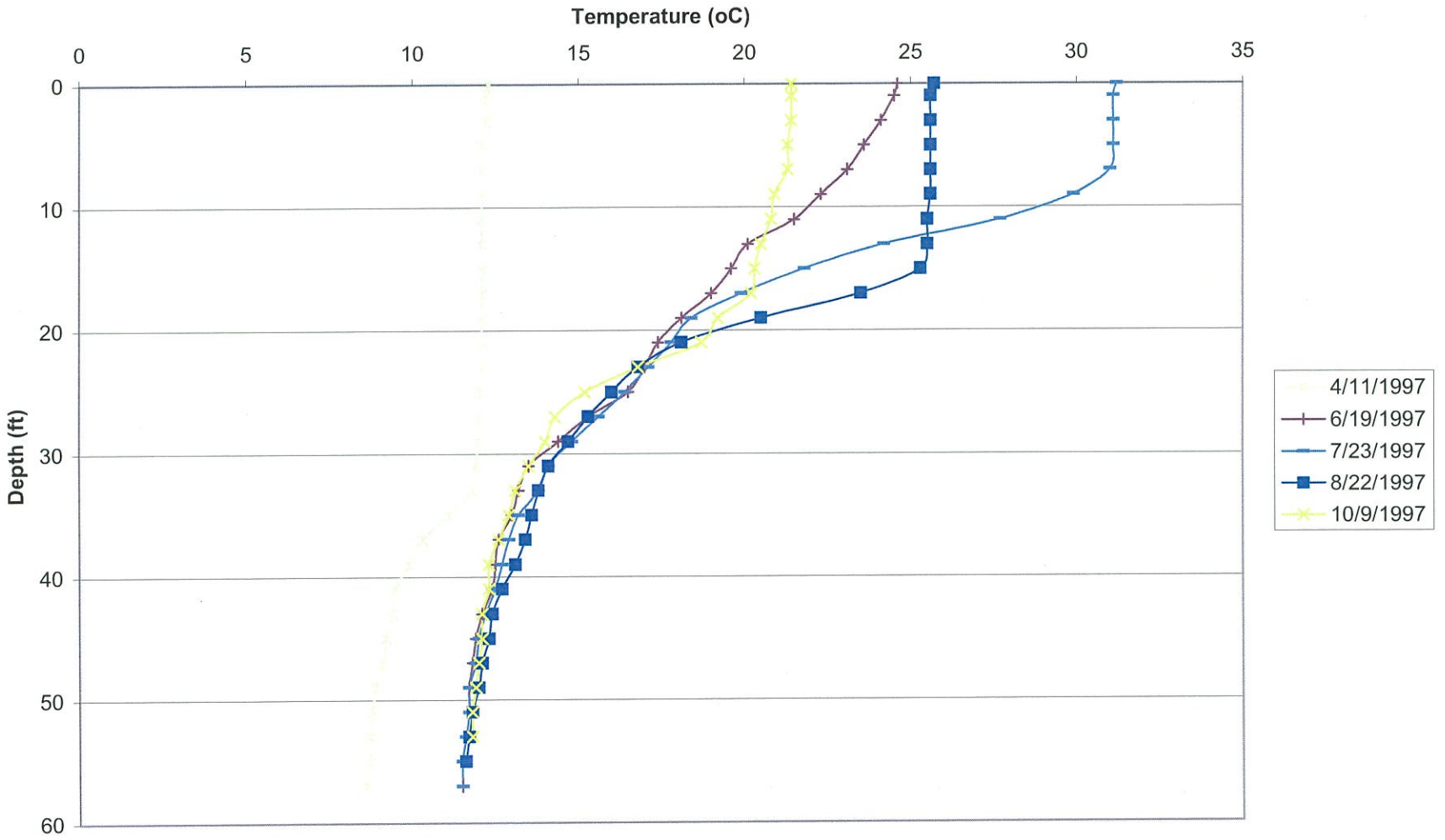
Appendix G
Metalimnion Charts

1994 Temperature Profile
Kinkaid Lake (RNC-1)



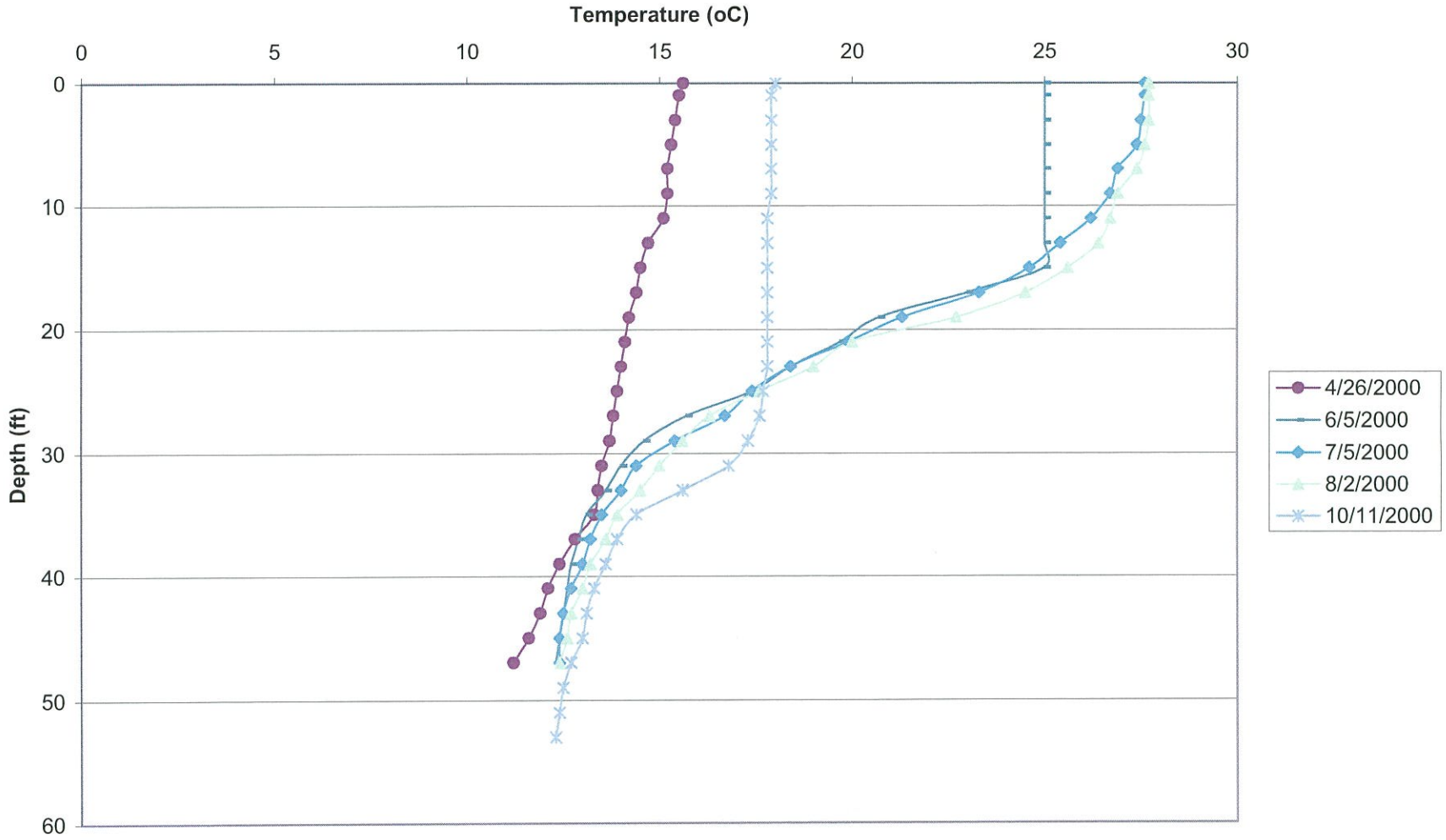
R01162

1997 Temperature Profile
Kinkaid Lake (RNC-1)



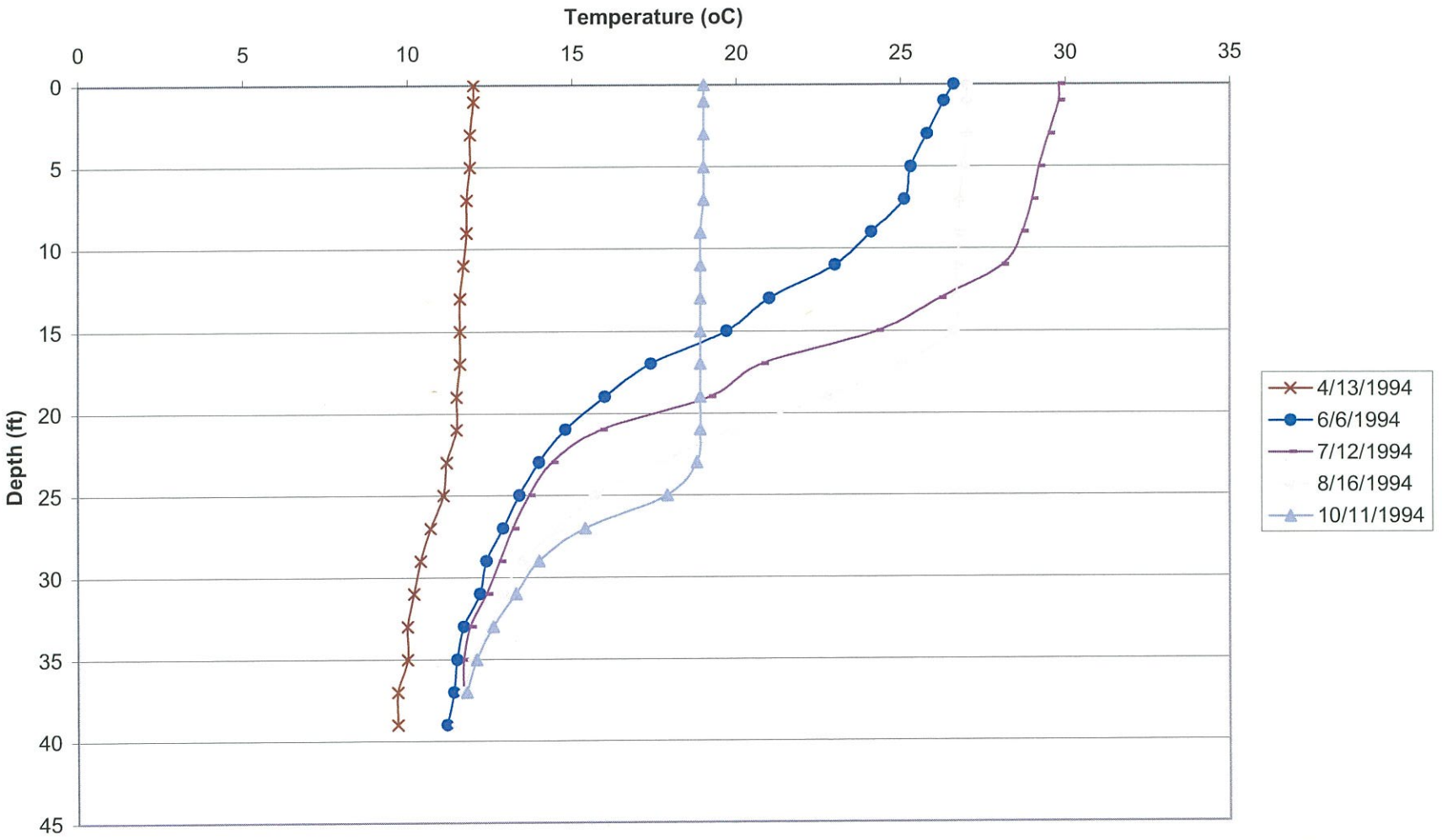
R01163

2000 Temperature Profile
Kinkaid Lake (RNC-1)



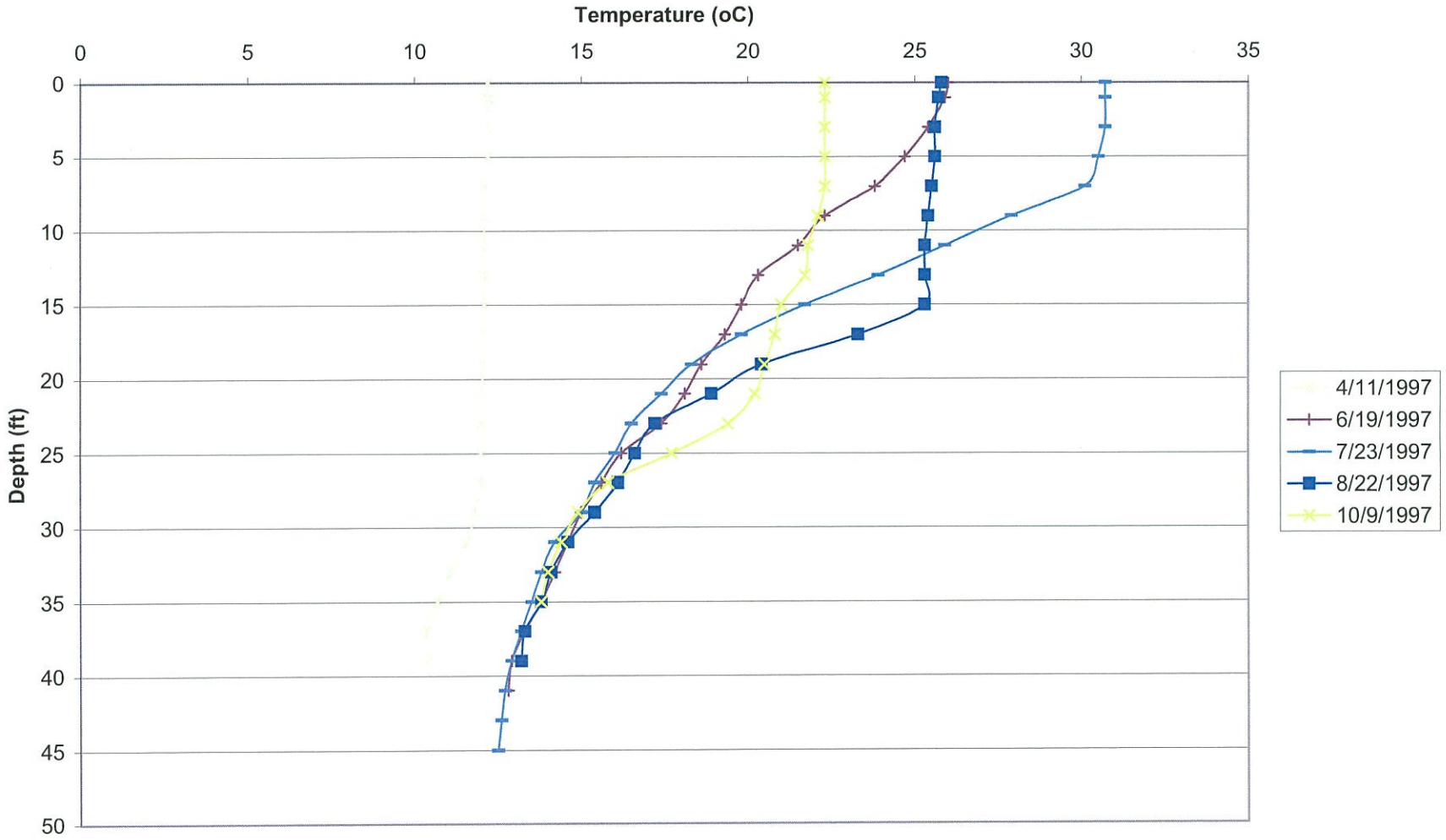
R01164

1994 Temperature Profile
Kincaid Lake (RNC-2)



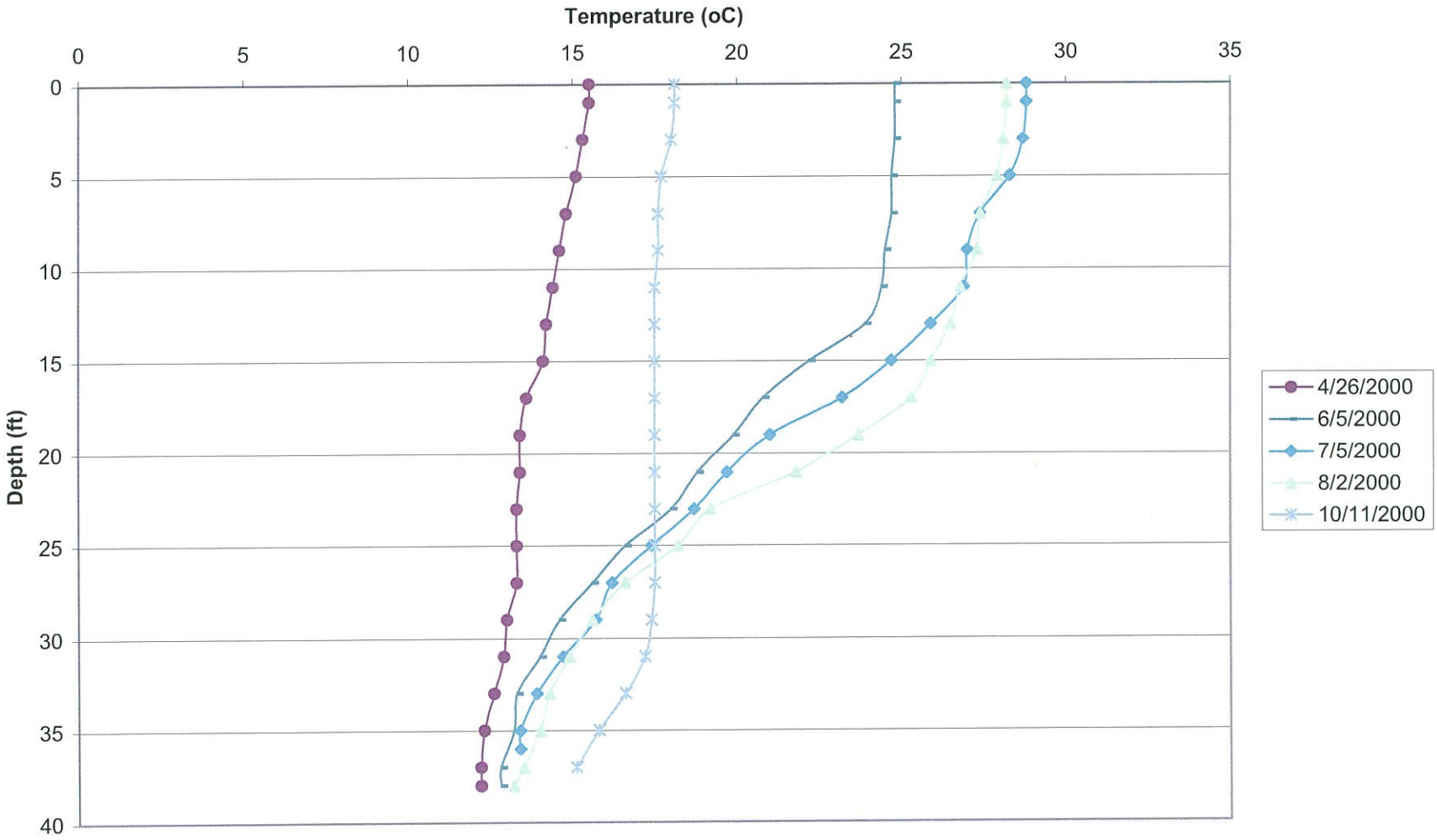
R01165

1997 Temperature Profile
Kincaid Lake (RNC-2)



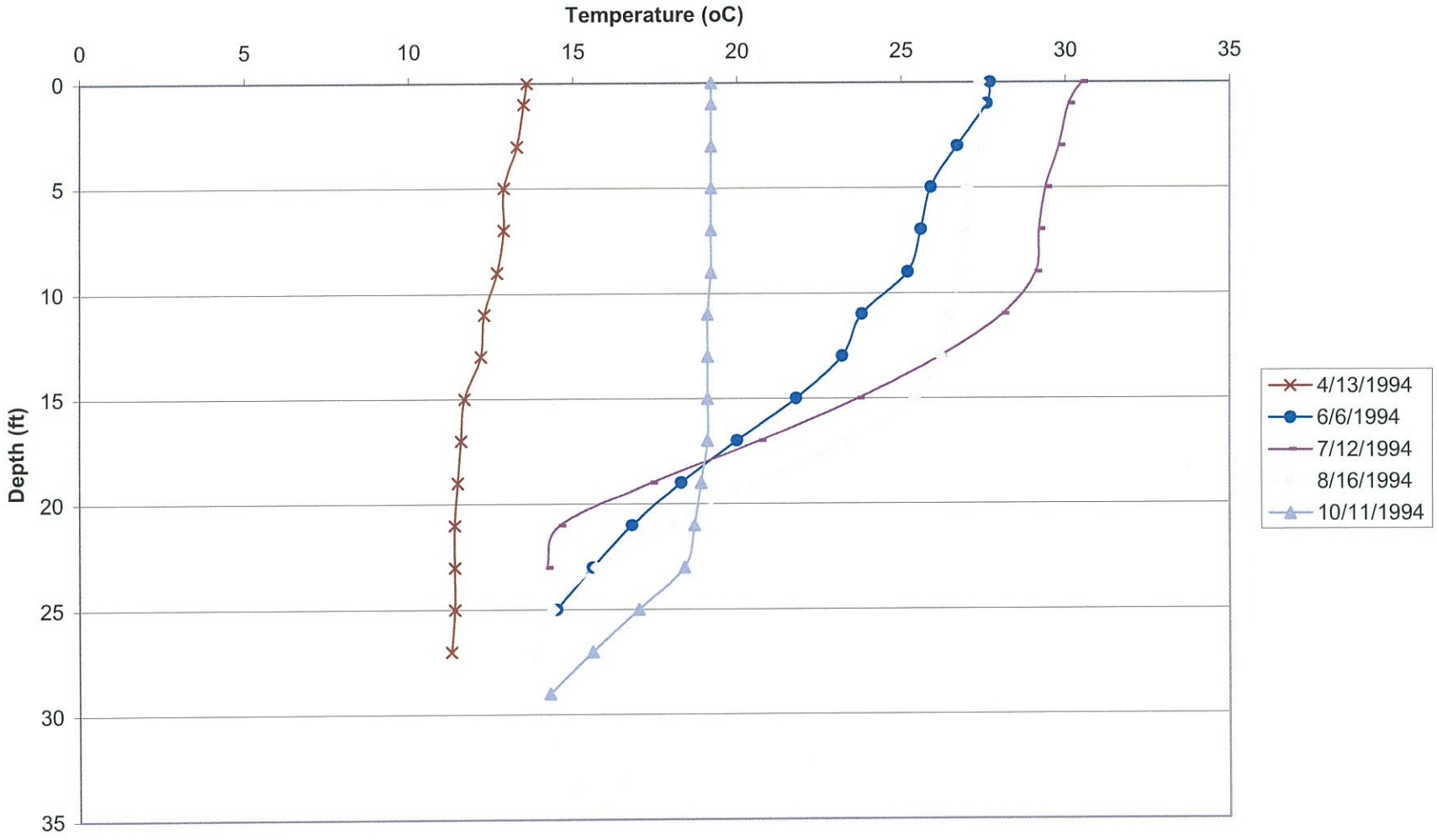
R01166

2000 Temperature Profile
Kincaid Lake (RNC-2)



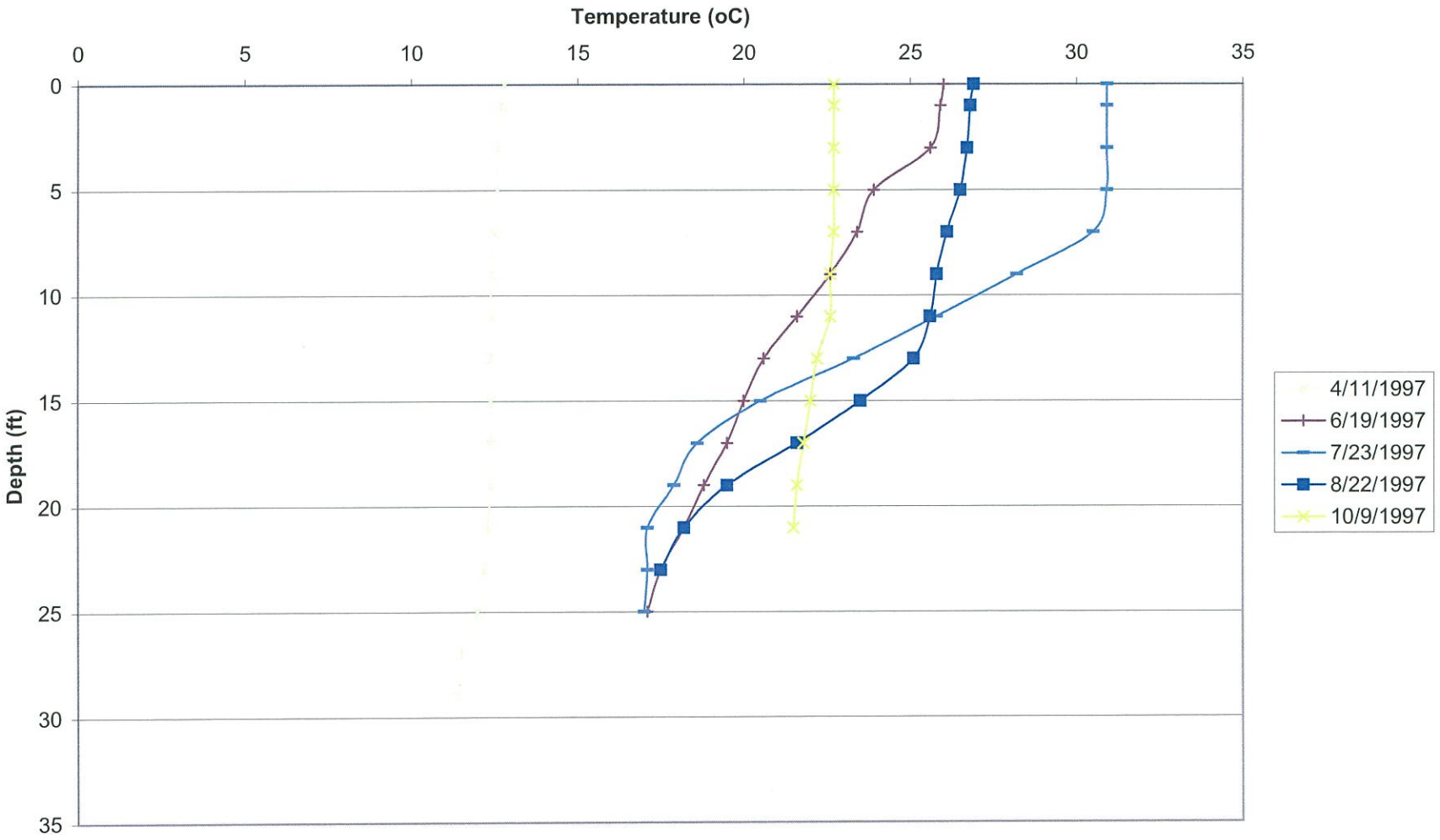
R01167

1994 Temperature Profile
Kincaid Lake (RNC-3)



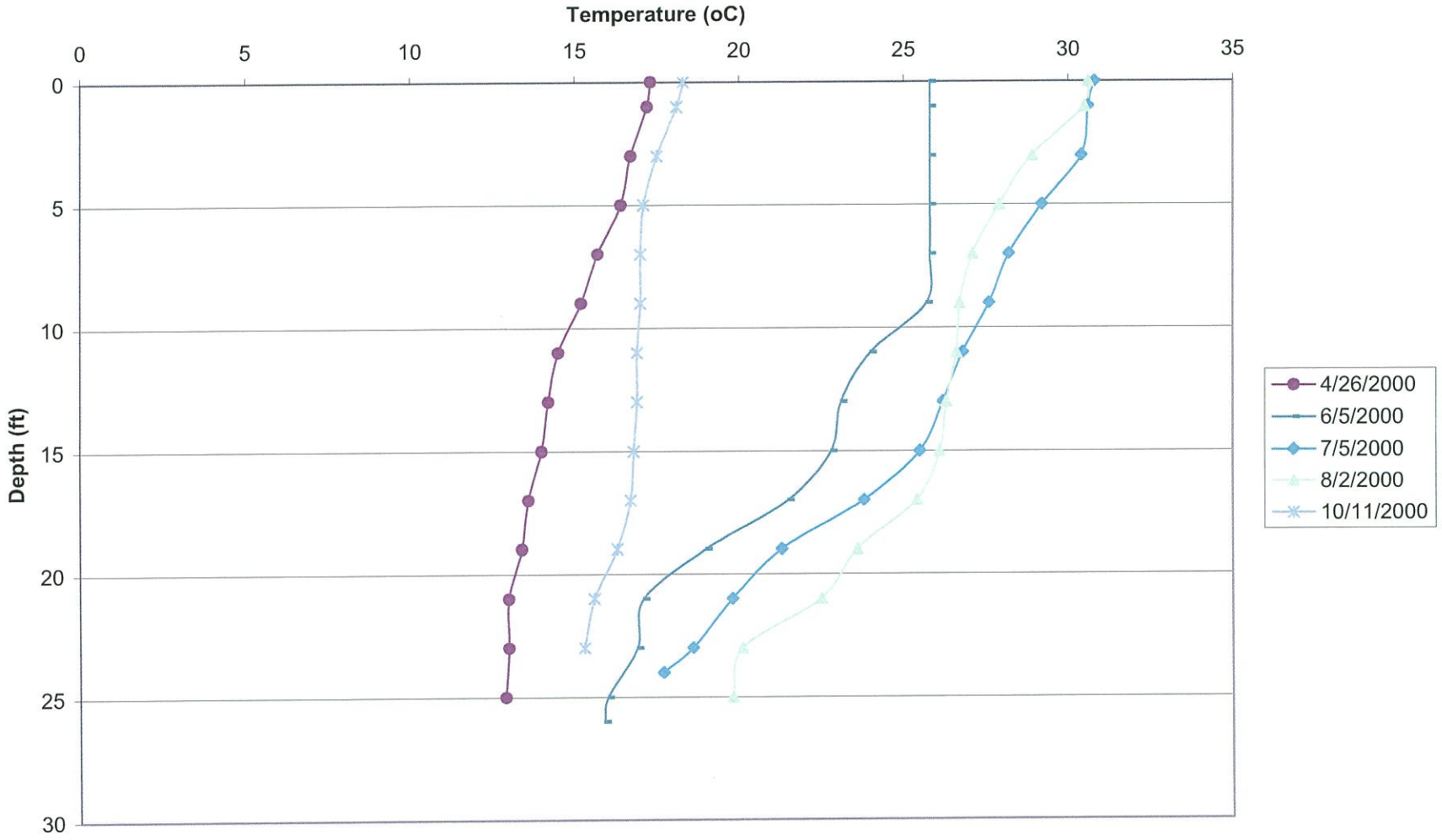
R01168

1997 Temperature Profile
Kincaid Lake (RNC-3)



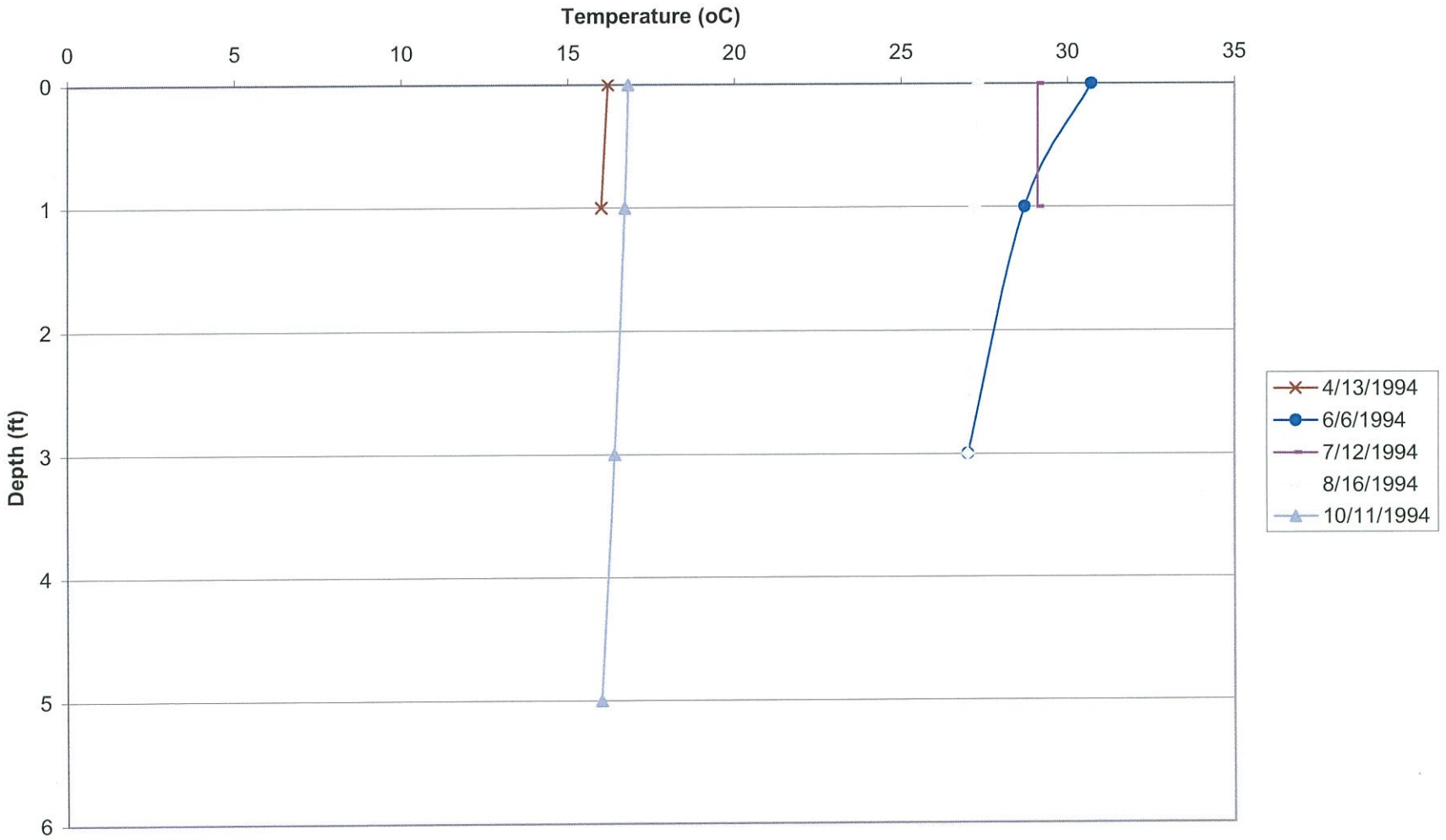
R01169

2000 Temperature Profile
Kincaid Lake (RNC-3)



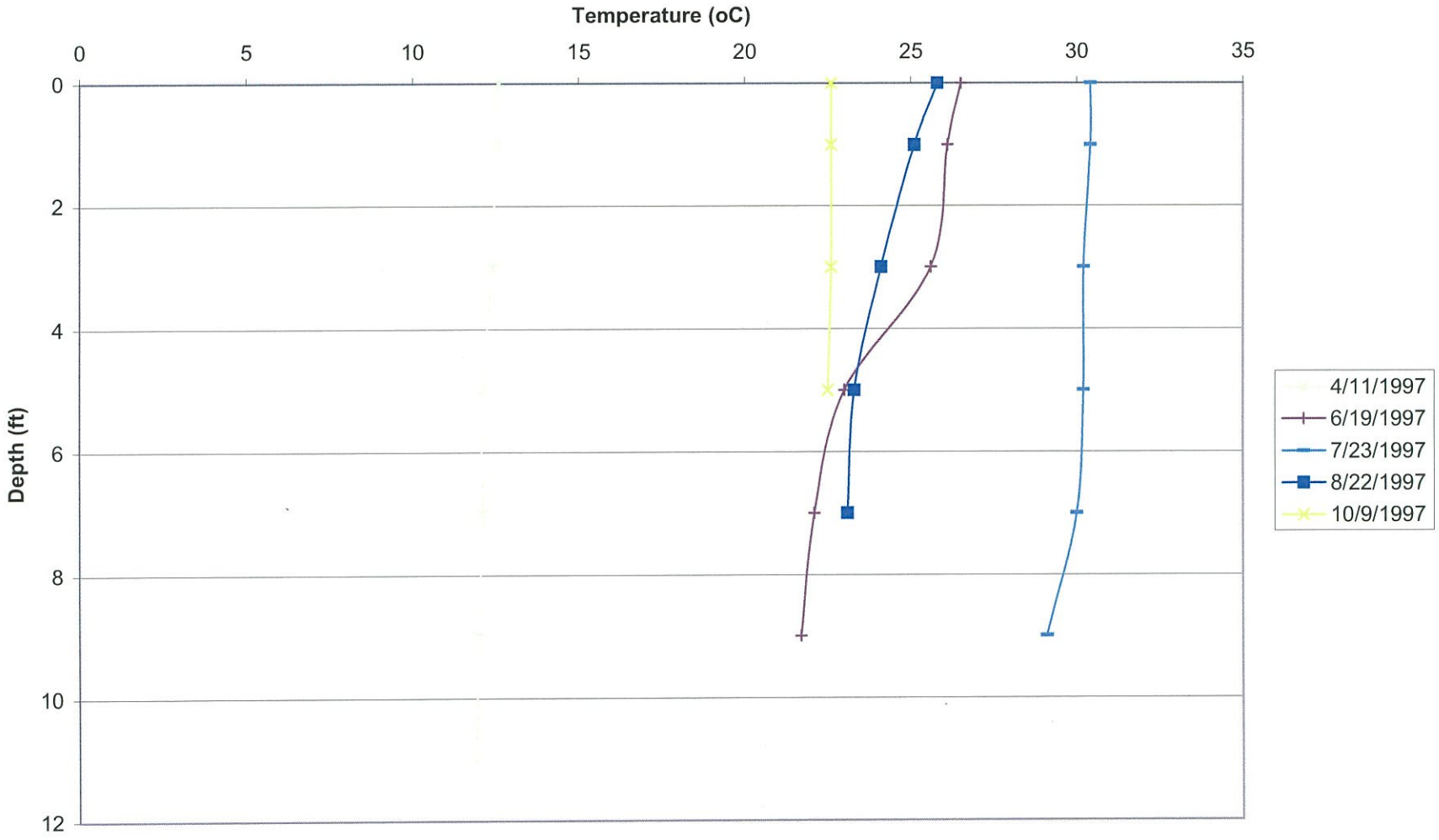
R01170

1994 Temperature Profile
Kincaid Lake (RNC-4)



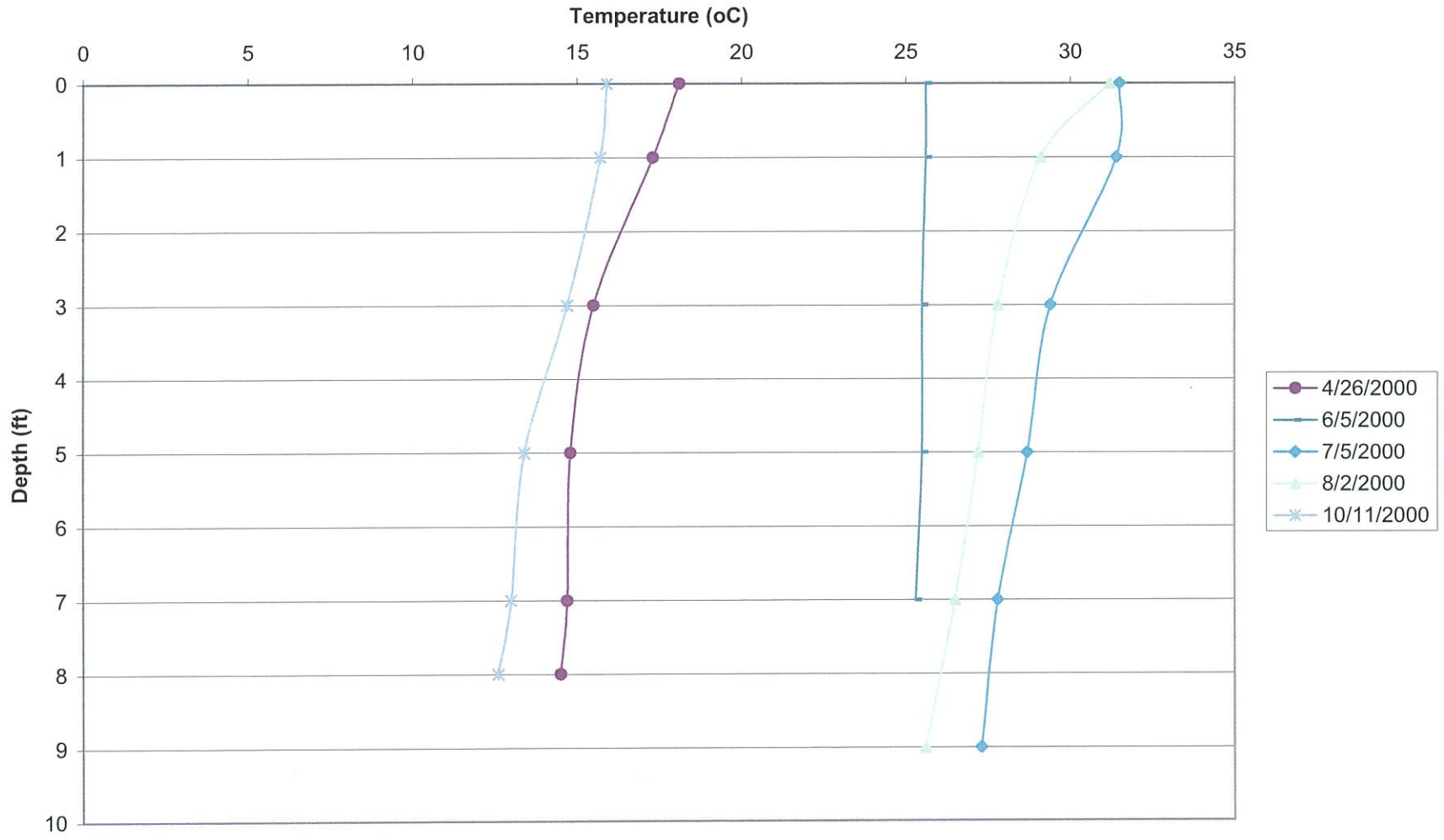
R01171

1997 Temperature Profile
Kincaid Lake (RNC-4)



R01172

2000 Temperature Profile
Kincaid Lake (RNC-4)



R01173

Appendix H
Sensitivity Analysis - BATHTUB Output Files

H.1 BATHTUB Sensitivity

This appendix provides the BATHTUB output files for the soil phosphorus sensitivity analysis. For each modeled year, the BATHTUB model was run with soil phosphorus values of 440 ppm and 660 ppm. The output concentrations from BATHTUB were not calibrated so that the raw model results could be compared.

BATHTUB Output for 1994 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 440 mg/kg

```
CASE: Kinkaid 1994 - Sed 440
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                        OBSERVED      ESTIMATED                  T STATISTICS
 VARIABLE               MEAN    CV     MEAN    CV    RATIO       1       2       3
 ------------------------------------------------------------------------------
 TOTAL P     MG/M3     135.4   .29     88.9   .48     1.52    1.44    1.56     .75
 CHL-A       MG/M3      52.1   .56     50.7   .59     1.03     .05     .08     .03
 SECCHI         M        .4   .72       .5   .67      .98    -.02    -.06    -.02
 ORGANIC N   MG/M3       .0   .00   1381.7   .47      .00     .00     .00     .00
 TP-ORTHO-P  MG/M3       .0   .00    108.0   .45      .00     .00     .00     .00
 ------------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                        OBSERVED      ESTIMATED                  T STATISTICS
 VARIABLE               MEAN    CV     MEAN    CV    RATIO       1       2       3
 ------------------------------------------------------------------------------
 TOTAL P     MG/M3      36.8   .73     49.8   .45      .74    -.41   -1.13    -.35
 CHL-A       MG/M3      24.3   .44     17.5   .65     1.39     .75     .95     .42
 SECCHI         M       1.3   .67      1.7   .66      .77    -.38    -.91    -.27
 ORGANIC N   MG/M3       .0   .00    566.7   .41      .00     .00     .00     .00
 TP-ORTHO-P  MG/M3       .0   .00     30.5   .43      .00     .00     .00     .00
 ------------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                        OBSERVED      ESTIMATED                  T STATISTICS
 VARIABLE               MEAN    CV     MEAN    CV    RATIO       1       2       3
 ------------------------------------------------------------------------------
 TOTAL P     MG/M3      22.2   .46     30.4   .45      .73    -.69   -1.17    -.49
 CHL-A       MG/M3      23.4   .44     13.0   .64     1.80    1.32    1.69     .76
 SECCHI         M       1.6   .59      2.5   .86      .64    -.76   -1.59    -.43
 ORGANIC N   MG/M3       .0   .00    460.1   .38      .00     .00     .00     .00
 TP-ORTHO-P  MG/M3       .0   .00     21.0   .54      .00     .00     .00     .00
 ------------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                        OBSERVED      ESTIMATED                  T STATISTICS
 VARIABLE               MEAN    CV     MEAN    CV    RATIO       1       2       3
 ------------------------------------------------------------------------------
 TOTAL P     MG/M3      25.2   .53     16.2   .46     1.55     .83    1.64     .63
 CHL-A       MG/M3      19.1   .52      5.9   .72     3.24    2.24    3.39    1.32
 SECCHI         M       1.9   .65      4.4  1.98      .43   -1.30   -3.01    -.40
 ORGANIC N   MG/M3       .0   .00    297.7   .38      .00     .00     .00     .00
 TP-ORTHO-P  MG/M3       .0   .00      8.3  1.65      .00     .00     .00     .00
 ------------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                        OBSERVED      ESTIMATED                  T STATISTICS
 VARIABLE               MEAN    CV     MEAN    CV    RATIO       1       2       3
 ------------------------------------------------------------------------------
 TOTAL P     MG/M3      36.7   .48     31.0   .45     1.18     .35     .63     .26
 CHL-A       MG/M3      23.6   .50     13.1   .54     1.81    1.18    1.71     .80
 SECCHI         M       1.6   .64      3.3  1.56      .49   -1.10   -2.52    -.42
 ORGANIC N   MG/M3       .0   .00    467.5   .36      .00     .00     .00     .00
 TP-ORTHO-P  MG/M3       .0   .00     23.1   .61      .00     .00     .00     .00
 ------------------------------------------------------------------------------
```

CASE: Kinkaid 1994 - Sed 440
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	FLOW (HM3/YR) CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	32.800	.000E+00	.000	.364
2	1	Subbasin 2	25.100	10.000	.000E+00	.000	.398
3	1	Subbasin 3	10.400	4.700	.000E+00	.000	.452
4	1	Subbasin 4	31.100	15.400	.000E+00	.000	.495
PRECIPITATION			9.509	10.555	.446E+01	.200	1.110
TRIBUTARY INFLOW			156.700	62.900	.000E+00	.000	.401
***TOTAL INFLOW			166.209	73.455	.446E+01	.029	.442
ADVECTIVE OUTFLOW			166.209	65.448	.102E+02	.049	.394
***TOTAL OUTFLOW			166.209	65.448	.102E+02	.049	.394
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	3899.9	67.4	.000E+00	.0	.000	118.9	43.3
2	1	Subbasin 2	600.0	10.4	.000E+00	.0	.000	60.0	23.9
3	1	Subbasin 3	198.8	3.4	.000E+00	.0	.000	42.3	19.1
4	1	Subbasin 4	802.3	13.9	.000E+00	.0	.000	52.1	25.8
PRECIPITATION			285.3	4.9	.203E+05	100.0	.500	27.0	30.0
TRIBUTARY INFLOW			5501.1	95.1	.000E+00	.0	.000	87.5	35.1
***TOTAL INFLOW			5786.3	100.0	.203E+05	100.0	.025	78.8	34.8
ADVECTIVE OUTFLOW			1062.1	18.4	.236E+06	1158.9	.457	16.2	6.4
***TOTAL OUTFLOW			1062.1	18.4	.236E+06	1158.9	.457	16.2	6.4
***RETENTION			4724.2	81.6	.249E+06	1223.5	.106	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
6.88	1.9902	36.7	.8252	1.2118	.8164

1994 – *Constant Sediment Phosphorus Concentration of 616 mg/kg*

CASE: Kinkaid 1994 - No Calibration
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	135.4	.29	105.9	.48	1.28	.84	.91	.44
CHL-A	MG/M3	52.1	.56	58.7	.57	.89	-.21	-.34	-.15
SECCHI	M	.4	.72	.4	.60	1.07	.10	.26	.08
ORGANIC N	MG/M3	.0	.00	1564.9	.46	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	122.3	.43	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.8	.73	56.2	.45	.65	-.58	-1.57	-.49
CHL-A	MG/M3	24.3	.44	18.8	.63	1.29	.58	.74	.33
SECCHI	M	1.3	.67	1.6	.60	.82	-.30	-.71	-.22
ORGANIC N	MG/M3	.0	.00	597.1	.42	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	32.9	.42	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	22.2	.46	33.1	.45	.67	-.87	-1.48	-.62
CHL-A	MG/M3	23.4	.44	14.0	.63	1.67	1.16	1.49	.67
SECCHI	M	1.6	.59	2.3	.80	.68	-.66	-1.39	-.39
ORGANIC N	MG/M3	.0	.00	482.0	.39	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	22.7	.52	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	25.2	.53	17.9	.46	1.41	.64	1.28	.49
CHL-A	MG/M3	19.1	.52	6.7	.72	2.84	1.99	3.02	1.17
SECCHI	M	1.9	.65	4.0	1.84	.47	-1.17	-2.70	-.39
ORGANIC N	MG/M3	.0	.00	316.4	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	9.8	1.47	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.7	.48	35.0	.45	1.05	.10	.17	.07
CHL-A	MG/M3	23.6	.50	14.6	.53	1.61	.95	1.39	.66
SECCHI	M	1.6	.64	3.0	1.44	.54	-.97	-2.23	-.40
ORGANIC N	MG/M3	.0	.00	503.4	.36	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	25.9	.58	.00	.00	.00	.00

CASE: Kinkaid 1994 - No Calibration
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	32.800	.000E+00	.000	.364
2	1	Subbasin 2	25.100	10.000	.000E+00	.000	.398
3	1	Subbasin 3	10.400	4.700	.000E+00	.000	.452
4	1	Subbasin 4	31.100	15.400	.000E+00	.000	.495
PRECIPITATION			9.509	10.555	.446E+01	.200	1.110
TRIBUTARY INFLOW			156.700	62.900	.000E+00	.000	.401
***TOTAL INFLOW			166.209	73.455	.446E+01	.029	.442
ADVECTIVE OUTFLOW			166.209	65.448	.102E+02	.049	.394
***TOTAL OUTFLOW			166.209	65.448	.102E+02	.049	.394
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	4798.6	67.7	.000E+00	.0	.000	146.3	53.3
2	1	Subbasin 2	700.0	9.9	.000E+00	.0	.000	70.0	27.9
3	1	Subbasin 3	198.8	2.8	.000E+00	.0	.000	42.3	19.1
4	1	Subbasin 4	1102.6	15.6	.000E+00	.0	.000	71.6	35.5
PRECIPITATION			285.3	4.0	.203E+05	100.0	.500	27.0	30.0
TRIBUTARY INFLOW			6800.1	96.0	.000E+00	.0	.000	108.1	43.4
***TOTAL INFLOW			7085.4	100.0	.203E+05	100.0	.020	96.5	42.6
ADVECTIVE OUTFLOW			1170.7	16.5	.286E+06	1405.4	.457	17.9	7.0
***TOTAL OUTFLOW			1170.7	16.5	.286E+06	1405.4	.457	17.9	7.0
***RETENTION			5914.7	83.5	.300E+06	1472.9	.093	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
6.88	1.9902	36.7	.6739	1.4839	.8348

BATHTUB Output for 1997 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 440 mg/kg

```
CASE: Kinkaid 1997 - Sed 400
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
```

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	129.6	.56	96.1	.45	1.35	.53	1.11	.41
CHL-A	MG/M3	48.9	.57	19.5	.49	2.51	1.62	2.66	1.23
SECCHI	M	.3	.34	.4	.45	.79	-.70	-.85	-.42
ORGANIC N	MG/M3	.0	.00	769.3	.25	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	83.6	.33	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	44.6	.23	47.0	.45	.95	-.23	-.19	-.10
CHL-A	MG/M3	27.5	.38	16.3	.49	1.68	1.35	1.50	.84
SECCHI	M	.9	.26	1.2	.42	.75	-1.11	-1.03	-.59
ORGANIC N	MG/M3	.0	.00	561.2	.32	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	34.9	.39	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	27.2	.26	28.6	.45	.95	-.19	-.19	-.10
CHL-A	MG/M3	19.4	.45	8.7	.53	2.22	1.79	2.31	1.16
SECCHI	M	1.1	.26	1.7	.46	.69	-1.40	-1.30	-.69
ORGANIC N	MG/M3	.0	.00	385.4	.28	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	20.6	.42	.00	.00	.00	.00

SEGMENT: 4 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	42.5	1.09	16.7	.45	2.54	.85	3.47	.79
CHL-A	MG/M3	13.2	.40	5.1	.59	2.57	2.39	2.73	1.34
SECCHI	M	1.3	.30	1.8	.44	.74	-1.03	-1.09	-.57
ORGANIC N	MG/M3	.0	.00	307.2	.24	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	15.4	.46	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	48.3	.75	31.1	.45	1.55	.59	1.64	.50
CHL-A	MG/M3	19.9	.44	9.0	.47	2.21	1.82	2.30	1.23
SECCHI	M	1.1	.29	1.5	.34	.73	-1.08	-1.11	-.70
ORGANIC N	MG/M3	.0	.00	406.4	.26	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	25.8	.34	.00	.00	.00	.00

CASE: Kinkaid 1997 - Sed 400
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	36.500	.000E+00	.000	.405
2	1	Subbasin 2	25.100	10.900	.000E+00	.000	.434
3	1	Subbasin 3	10.400	5.100	.000E+00	.000	.490
4	1	Subbasin 4	31.100	16.600	.000E+00	.000	.534
PRECIPITATION			9.509	11.886	.565E+01	.200	1.250
TRIBUTARY INFLOW			156.700	69.100	.000E+00	.000	.441
***TOTAL INFLOW			166.209	80.986	.565E+01	.029	.487
ADVECTIVE OUTFLOW			166.209	72.980	.114E+02	.046	.439
***TOTAL OUTFLOW			166.209	72.980	.114E+02	.046	.439
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	4898.3	68.2	.000E+00	.0	.000	134.2	54.4
2	1	Subbasin 2	698.7	9.7	.000E+00	.0	.000	64.1	27.8
3	1	Subbasin 3	199.9	2.8	.000E+00	.0	.000	39.2	19.2
4	1	Subbasin 4	1097.3	15.3	.000E+00	.0	.000	66.1	35.3
PRECIPITATION			285.3	4.0	.203E+05	100.0	.500	24.0	30.0
TRIBUTARY INFLOW			6894.2	96.0	.000E+00	.0	.000	99.8	44.0
***TOTAL INFLOW			7179.4	100.0	.203E+05	100.0	.020	88.7	43.2
ADVECTIVE OUTFLOW			1220.4	17.0	.307E+06	1511.3	.454	16.7	7.3
***TOTAL OUTFLOW			1220.4	17.0	.307E+06	1511.3	.454	16.7	7.3
***RETENTION			5959.0	83.0	.320E+06	1575.0	.095	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.67	1.8016	48.3	.8848	1.1303	.8300

1997 - *Constant Sediment Phosphorus Concentration of 616 mg/kg*

CASE: Kinkaid 1997 - No Calibration
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	129.6	.56	110.9	.45	1.17	.28	.58	.22
CHL-A	MG/M3	48.9	.57	21.0	.47	2.33	1.49	2.45	1.14
SECCHI	M	.3	.34	.4	.44	.80	-.66	-.81	-.41
ORGANIC N	MG/M3	.0	.00	803.8	.24	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	86.3	.31	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	44.6	.23	53.7	.45	.83	-.82	-.69	-.37
CHL-A	MG/M3	27.5	.38	18.0	.47	1.53	1.10	1.22	.70
SECCHI	M	.9	.26	1.2	.40	.79	-.93	-.86	-.51
ORGANIC N	MG/M3	.0	.00	599.0	.32	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	37.9	.38	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	27.2	.26	32.0	.45	.85	-.63	-.61	-.31
CHL-A	MG/M3	19.4	.45	9.6	.51	2.02	1.58	2.03	1.04
SECCHI	M	1.1	.26	1.6	.44	.72	-1.26	-1.18	-.64
ORGANIC N	MG/M3	.0	.00	405.3	.28	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	22.2	.40	.00	.00	.00	.00

SEGMENT: 4 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	42.5	1.09	18.5	.45	2.30	.76	3.10	.70
CHL-A	MG/M3	13.2	.40	5.7	.57	2.31	2.12	2.42	1.20
SECCHI	M	1.3	.30	1.7	.43	.76	-.94	-1.00	-.54
ORGANIC N	MG/M3	.0	.00	320.3	.25	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	16.5	.45	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	48.3	.75	35.2	.45	1.37	.42	1.18	.36
CHL-A	MG/M3	19.9	.44	9.9	.45	2.01	1.60	2.02	1.11
SECCHI	M	1.1	.29	1.5	.33	.76	-.98	-1.00	-.64
ORGANIC N	MG/M3	.0	.00	427.0	.26	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	27.4	.34	.00	.00	.00	.00

CASE: Kinkaid 1997 - No Calibration
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	36.500	.000E+00	.000	.405
2	1	Subbasin 2	25.100	10.900	.000E+00	.000	.434
3	1	Subbasin 3	10.400	5.100	.000E+00	.000	.490
4	1	Subbasin 4	31.100	16.600	.000E+00	.000	.534
PRECIPITATION			9.509	11.886	.565E+01	.200	1.250
TRIBUTARY INFLOW			156.700	69.100	.000E+00	.000	.441
***TOTAL INFLOW			166.209	80.986	.565E+01	.029	.487
ADVECTIVE OUTFLOW			166.209	72.980	.114E+02	.046	.439
***TOTAL OUTFLOW			166.209	72.980	.114E+02	.046	.439
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	5898.4	65.7	.000E+00	.0	.000	161.6	65.5
2	1	Subbasin 2	1097.6	12.2	.000E+00	.0	.000	100.7	43.7
3	1	Subbasin 3	299.9	3.3	.000E+00	.0	.000	58.8	28.8
4	1	Subbasin 4	1397.7	15.6	.000E+00	.0	.000	84.2	44.9
PRECIPITATION			285.3	3.2	.203E+05	100.0	.500	24.0	30.0
TRIBUTARY INFLOW			8693.6	96.8	.000E+00	.0	.000	125.8	55.5
***TOTAL INFLOW			8978.9	100.0	.203E+05	100.0	.016	110.9	54.0
ADVECTIVE OUTFLOW			1348.7	15.0	.375E+06	1844.8	.454	18.5	8.1
***TOTAL OUTFLOW			1348.7	15.0	.375E+06	1844.8	.454	18.5	8.1
***RETENTION			7630.2	85.0	.389E+06	1911.5	.082	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.67	1.8016	48.3	.7074	1.4135	.8498

BATHTUB Output for 2000 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 440 mg/kg

CASE: Kinkaid 2000 - Sed 440
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	54.8	.33	124.0	.45	.44	-2.46	-3.04	-1.46
CHL-A	MG/M3	38.0	.40	21.4	.35	1.78	1.44	1.66	1.08
SECCHI	M	.3	.12	.4	.21	.86	-1.26	-.55	-.63
ORGANIC N	MG/M3	.0	.00	790.8	.23	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	80.1	.23	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	21.2	.10	57.9	.45	.37	-10.36	-3.74	-2.17
CHL-A	MG/M3	16.4	.40	13.8	.44	1.18	.43	.49	.29
SECCHI	M	.9	.34	1.0	.35	.94	-.18	-.22	-.13
ORGANIC N	MG/M3	.0	.00	521.9	.27	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	36.0	.31	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	12.4	.07	35.4	.45	.35	-14.58	-3.90	-2.30
CHL-A	MG/M3	12.6	.38	11.1	.47	1.14	.33	.37	.21
SECCHI	M	1.4	.29	1.5	.35	.95	-.19	-.20	-.12
ORGANIC N	MG/M3	.0	.00	440.7	.29	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	25.1	.39	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	29.0	1.14	21.8	.45	1.33	.25	1.05	.23
CHL-A	MG/M3	18.4	1.24	8.8	.72	2.08	.59	2.12	.51
SECCHI	M	1.8	.24	3.1	1.94	.57	-2.32	-1.98	-.28
ORGANIC N	MG/M3	.0	.00	365.7	.45	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	14.0	1.39	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.4	.77	39.6	.45	.69	-.48	-1.37	-.41
CHL-A	MG/M3	18.9	.87	11.2	.53	1.69	.60	1.51	.52
SECCHI	M	1.4	.26	2.2	1.57	.65	-1.70	-1.56	-.28
ORGANIC N	MG/M3	.0	.00	443.3	.33	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	25.6	.56	.00	.00	.00	.00

CASE: Kinkaid 2000 - Sed 440
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	38.000	.000E+00	.000	.422
2	1	Subbasin 2	25.100	11.300	.000E+00	.000	.450
3	1	Subbasin 3	10.400	5.300	.000E+00	.000	.510
4	1	Subbasin 4	31.100	17.400	.000E+00	.000	.559
PRECIPITATION			9.509	12.267	.602E+01	.200	1.290
TRIBUTARY INFLOW			156.700	72.000	.000E+00	.000	.459
***TOTAL INFLOW			166.209	84.267	.602E+01	.029	.507
ADVECTIVE OUTFLOW			166.209	76.260	.118E+02	.045	.459
***TOTAL OUTFLOW			166.209	76.260	.118E+02	.045	.459
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	7311.2	64.7	.000E+00	.0	.000	192.4	81.1
2	1	Subbasin 2	1200.1	10.6	.000E+00	.0	.000	106.2	47.8
3	1	Subbasin 3	499.8	4.4	.000E+00	.0	.000	94.3	48.1
4	1	Subbasin 4	2002.7	17.7	.000E+00	.0	.000	115.1	64.4
PRECIPITATION			285.3	2.5	.203E+05	100.0	.500	23.3	30.0
TRIBUTARY INFLOW			11013.8	97.5	.000E+00	.0	.000	153.0	70.3
***TOTAL INFLOW			11299.1	100.0	.203E+05	100.0	.013	134.1	68.0
ADVECTIVE OUTFLOW			1665.9	14.7	.570E+06	2802.5	.453	21.8	10.0
***TOTAL OUTFLOW			1665.9	14.7	.570E+06	2802.5	.453	21.8	10.0
***RETENTION			9633.2	85.3	.584E+06	2870.2	.079	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
8.02	1.5738	27.4	.2907	3.4400	.8526

2000 - *Constant Sediment Phosphorus Concentration of 616 mg/kg*

CASE: Kinkaid 2000 - No Calibration
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	54.8	.33	144.4	.45	.38	-2.92	-3.60	-1.73
CHL-A	MG/M3	38.0	.40	22.7	.34	1.68	1.29	1.49	.99
SECCHI	M	.3	.12	.4	.21	.87	-1.15	-.51	-.58
ORGANIC N	MG/M3	.0	.00	820.7	.23	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	82.4	.23	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	21.2	.10	65.2	.45	.33	-11.58	-4.18	-2.43
CHL-A	MG/M3	16.4	.40	14.8	.43	1.11	.26	.30	.18
SECCHI	M	.9	.34	1.0	.34	.96	-.11	-.14	-.08
ORGANIC N	MG/M3	.0	.00	543.4	.27	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	37.7	.30	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	12.4	.07	38.8	.45	.32	-15.84	-4.24	-2.50
CHL-A	MG/M3	12.6	.38	11.9	.46	1.06	.15	.17	.10
SECCHI	M	1.4	.29	1.4	.34	.98	-.09	-.09	-.06
ORGANIC N	MG/M3	.0	.00	459.3	.29	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	26.6	.38	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	29.0	1.14	24.3	.45	1.20	.16	.66	.15
CHL-A	MG/M3	18.4	1.24	10.1	.74	1.81	.48	1.72	.41
SECCHI	M	1.8	.24	2.8	1.79	.63	-1.91	-1.63	-.25
ORGANIC N	MG/M3	.0	.00	395.9	.48	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	16.4	1.27	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.4	.77	44.6	.45	.61	-.63	-1.81	-.54
CHL-A	MG/M3	18.9	.87	12.4	.53	1.53	.49	1.22	.42
SECCHI	M	1.4	.26	2.1	1.42	.70	-1.38	-1.27	-.24
ORGANIC N	MG/M3	.0	.00	470.1	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	27.7	.56	.00	.00	.00	.00

CASE: Kinkaid 2000 - No Calibration
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	38.000	.000E+00	.000	.422
2	1	Subbasin 2	25.100	11.300	.000E+00	.000	.450
3	1	Subbasin 3	10.400	5.300	.000E+00	.000	.510
4	1	Subbasin 4	31.100	17.400	.000E+00	.000	.559
PRECIPITATION			9.509	12.267	.602E+01	.200	1.290
TRIBUTARY INFLOW			156.700	72.000	.000E+00	.000	.459
***TOTAL INFLOW			166.209	84.267	.602E+01	.029	.507
ADVECTIVE OUTFLOW			166.209	76.260	.118E+02	.045	.459
***TOTAL OUTFLOW			166.209	76.260	.118E+02	.045	.459
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	9013.6	63.9	.000E+00	.0	.000	237.2	100.0
2	1	Subbasin 2	1600.1	11.3	.000E+00	.0	.000	141.6	63.7
3	1	Subbasin 3	600.0	4.3	.000E+00	.0	.000	113.2	57.7
4	1	Subbasin 4	2603.0	18.5	.000E+00	.0	.000	149.6	83.7
PRECIPITATION			285.3	2.0	.203E+05	100.0	.500	23.3	30.0
TRIBUTARY INFLOW			13816.7	98.0	.000E+00	.0	.000	191.9	88.2
***TOTAL INFLOW			14101.9	100.0	.203E+05	100.0	.010	167.3	84.8
ADVECTIVE OUTFLOW			1850.4	13.1	.702E+06	3452.5	.453	24.3	11.1
***TOTAL OUTFLOW			1850.4	13.1	.702E+06	3452.5	.453	24.3	11.1
***RETENTION			12251.5	86.9	.717E+06	3523.1	.069	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
8.02	1.5738	27.4	.2329	4.2933	.8688

Appendix I
Reduction Analyses - BATHTUB Output Files

BATHTUB Output for 1994 Reduction Analysis

CASE: Kinkaid 1994 - Reduced

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	135.4	.29	48.9	.46	2.77	3.48	3.79	1.87
CHL-A	MG/M3	52.1	.56	18.2	.67	2.86	1.89	3.04	1.21
SECCHI	M	.4	.72	.7	1.32	.62	-.67	-1.71	-.32
ORGANIC N	MG/M3	.0	.00	641.3	.54	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	50.2	1.04	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.8	.73	21.6	.45	1.71	.73	1.99	.62
CHL-A	MG/M3	24.3	.44	13.1	.74	1.86	1.40	1.79	.72
SECCHI	M	1.3	.67	2.1	.91	.63	-.70	-1.65	-.41
ORGANIC N	MG/M3	.0	.00	466.5	.43	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	22.7	.56	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	22.2	.46	15.6	.45	1.42	.77	1.31	.55
CHL-A	MG/M3	23.4	.44	13.3	.71	1.75	1.27	1.62	.67
SECCHI	M	1.6	.59	2.4	.88	.65	-.73	-1.53	-.41
ORGANIC N	MG/M3	.0	.00	467.1	.44	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	21.5	.64	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	25.2	.53	20.2	.45	1.25	.42	.83	.32
CHL-A	MG/M3	19.1	.52	16.6	.67	1.16	.28	.42	.17
SECCHI	M	1.9	.65	2.0	.68	.93	-.10	-.24	-.07
ORGANIC N	MG/M3	.0	.00	540.5	.45	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	27.3	.60	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.7	.48	22.3	.45	1.64	1.03	1.85	.75
CHL-A	MG/M3	23.6	.50	15.6	.61	1.52	.83	1.20	.53
SECCHI	M	1.6	.64	2.0	.56	.81	-.32	-.74	-.24
ORGANIC N	MG/M3	.0	.00	524.9	.41	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	27.6	.59	.00	.00	.00	.00

CASE: Kinkaid 1994 - Reduced
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	FLOW (HM3/YR) CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	32.800	.000E+00	.000	.364
2	1	Subbasin 2	25.100	10.000	.000E+00	.000	.398
3	1	Subbasin 3	10.400	4.700	.000E+00	.000	.452
4	1	Subbasin 4	31.100	15.400	.000E+00	.000	.495
PRECIPITATION			9.509	10.555	.446E+01	.200	1.110
TRIBUTARY INFLOW			156.700	62.900	.000E+00	.000	.401
***TOTAL INFLOW			166.209	73.455	.446E+01	.029	.442
ADVECTIVE OUTFLOW			166.209	65.448	.102E+02	.049	.394
***TOTAL OUTFLOW			166.209	65.448	.102E+02	.049	.394
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	1390.7	37.8	.000E+00	.0	.000	42.4	15.4
2	1	Subbasin 2	700.0	19.0	.000E+00	.0	.000	70.0	27.9
3	1	Subbasin 3	198.8	5.4	.000E+00	.0	.000	42.3	19.1
4	1	Subbasin 4	1102.6	30.0	.000E+00	.0	.000	71.6	35.5
PRECIPITATION			285.3	7.8	.203E+05	100.0	.500	27.0	30.0
TRIBUTARY INFLOW			3392.2	92.2	.000E+00	.0	.000	53.9	21.6
***TOTAL INFLOW			3677.4	100.0	.203E+05	100.0	.039	50.1	22.1
ADVECTIVE OUTFLOW			1321.9	35.9	.358E+06	1758.8	.453	20.2	8.0
***TOTAL OUTFLOW			1321.9	35.9	.358E+06	1758.8	.453	20.2	8.0
***RETENTION			2355.6	64.1	.368E+06	1808.5	.258	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
6.88	1.9902	36.7	1.2984	.7702	.6405

BATHTUB Output for 1997 Reduction Analysis

CASE: Kinkaid 1997 - Reduced

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	129.6	.56	50.0	.45	2.59	1.68	3.54	1.32
CHL-A	MG/M3	48.9	.57	24.5	.57	2.00	1.21	2.00	.86
SECCHI	M	.3	.34	.4	.42	.82	-.57	-.69	-.36
ORGANIC N	MG/M3	.0	.00	884.5	.33	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	92.6	.33	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	44.6	.23	27.1	.45	1.65	2.20	1.86	.99
CHL-A	MG/M3	27.5	.38	18.2	.57	1.51	1.08	1.19	.60
SECCHI	M	.9	.26	1.1	.43	.79	-.91	-.84	-.47
ORGANIC N	MG/M3	.0	.00	602.8	.39	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	38.2	.46	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.2	.26	19.2	.45	1.41	1.32	1.29	.66
CHL-A	MG/M3	19.4	.45	12.0	.58	1.61	1.07	1.38	.65
SECCHI	M	1.1	.26	1.5	.42	.79	-.91	-.85	-.48
ORGANIC N	MG/M3	.0	.00	460.5	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	26.5	.46	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	42.5	1.09	33.6	.45	1.27	.22	.88	.20
CHL-A	MG/M3	13.2	.40	11.9	.48	1.11	.25	.29	.16
SECCHI	M	1.3	.30	1.4	.34	.96	-.14	-.15	-.09
ORGANIC N	MG/M3	.0	.00	462.4	.30	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	27.6	.38	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	48.3	.75	31.7	.45	1.52	.56	1.57	.48
CHL-A	MG/M3	19.9	.44	14.2	.49	1.40	.77	.98	.51
SECCHI	M	1.1	.29	1.2	.29	.90	-.38	-.39	-.27
ORGANIC N	MG/M3	.0	.00	525.3	.32	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	35.1	.38	.00	.00	.00	.00

CASE: Kinkaid 1997 - Reduced
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	36.500	.000E+00	.000	.405
2	1	Subbasin 2	25.100	10.900	.000E+00	.000	.434
3	1	Subbasin 3	10.400	5.100	.000E+00	.000	.490
4	1	Subbasin 4	31.100	16.600	.000E+00	.000	.534
PRECIPITATION			9.509	11.886	.565E+01	.200	1.250
TRIBUTARY INFLOW			156.700	69.100	.000E+00	.000	.441
***TOTAL INFLOW			166.209	80.986	.565E+01	.029	.487
ADVECTIVE OUTFLOW			166.209	72.980	.114E+02	.046	.439
***TOTAL OUTFLOW			166.209	72.980	.114E+02	.046	.439
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	1770.3	36.5	.000E+00	.0	.000	48.5	19.6
2	1	Subbasin 2	1097.6	22.6	.000E+00	.0	.000	100.7	43.7
3	1	Subbasin 3	299.9	6.2	.000E+00	.0	.000	58.8	28.8
4	1	Subbasin 4	1397.7	28.8	.000E+00	.0	.000	84.2	44.9
PRECIPITATION			285.3	5.9	.203E+05	100.0	.500	24.0	30.0
TRIBUTARY INFLOW			4565.5	94.1	.000E+00	.0	.000	66.1	29.1
***TOTAL INFLOW			4850.8	100.0	.203E+05	100.0	.029	59.9	29.2
ADVECTIVE OUTFLOW			2449.5	50.5	.123E+07	6028.8	.452	33.6	14.7
***TOTAL OUTFLOW			2449.5	50.5	.123E+07	6028.8	.452	33.6	14.7
***RETENTION			2401.2	49.5	.123E+07	6053.7	.462	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.67	1.8016	48.3	1.3095	.7637	.4950

BATHTUB Output for 2000 Reduction Analysis

CASE: Kinkaid 2000 - Reduced
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	54.8	.33	49.4	.45	1.11	.31	.38	.18
CHL-A	MG/M3	38.0	.40	24.1	.48	1.58	1.14	1.32	.73
SECCHI	M	.3	.12	.4	.22	.88	-1.04	-.46	-.50
ORGANIC N	MG/M3	.0	.00	853.1	.32	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	85.0	.28	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	21.2	.10	27.1	.45	.78	-2.54	-.92	-.53
CHL-A	MG/M3	16.4	.40	15.5	.55	1.06	.14	.16	.08
SECCHI	M	.9	.34	1.0	.36	.98	-.06	-.07	-.04
ORGANIC N	MG/M3	.0	.00	560.0	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	39.0	.39	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	12.4	.07	17.5	.45	.71	-4.75	-1.27	-.75
CHL-A	MG/M3	12.6	.38	11.4	.58	1.11	.27	.30	.15
SECCHI	M	1.4	.29	1.5	.37	.96	-.15	-.16	-.09
ORGANIC N	MG/M3	.0	.00	446.9	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	25.6	.47	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	29.0	1.14	23.5	.45	1.23	.18	.78	.17
CHL-A	MG/M3	18.4	1.24	19.1	.71	.96	-.03	-.11	-.03
SECCHI	M	1.8	.24	1.7	.76	1.03	.13	.11	.04
ORGANIC N	MG/M3	.0	.00	600.3	.48	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	32.3	.58	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.4	.77	25.6	.45	1.07	.09	.25	.08
CHL-A	MG/M3	18.9	.87	17.7	.59	1.07	.07	.18	.06
SECCHI	M	1.4	.26	1.4	.57	1.01	.04	.04	.02
ORGANIC N	MG/M3	.0	.00	592.3	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	37.2	.46	.00	.00	.00	.00

CASE: Kinkaid 2000 - Reduced
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	38.000	.000E+00	.000	.422
2	1	Subbasin 2	25.100	11.300	.000E+00	.000	.450
3	1	Subbasin 3	10.400	5.300	.000E+00	.000	.510
4	1	Subbasin 4	31.100	17.400	.000E+00	.000	.559
PRECIPITATION			9.509	12.267	.602E+01	.200	1.290
TRIBUTARY INFLOW			156.700	72.000	.000E+00	.000	.459
***TOTAL INFLOW			166.209	84.267	.602E+01	.029	.507
ADVECTIVE OUTFLOW			166.209	76.260	.118E+02	.045	.459
***TOTAL OUTFLOW			166.209	76.260	.118E+02	.045	.459
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	5407.4	51.5	.000E+00	.0	.000	142.3	60.0
2	1	Subbasin 2	1600.1	15.2	.000E+00	.0	.000	141.6	63.7
3	1	Subbasin 3	600.0	5.7	.000E+00	.0	.000	113.2	57.7
4	1	Subbasin 4	2603.0	24.8	.000E+00	.0	.000	149.6	83.7
PRECIPITATION			285.3	2.7	.203E+05	100.0	.500	23.3	30.0
TRIBUTARY INFLOW			10210.5	97.3	.000E+00	.0	.000	141.8	65.2
***TOTAL INFLOW			10495.8	100.0	.203E+05	100.0	.014	124.6	63.1
ADVECTIVE OUTFLOW			1794.7	17.1	.659E+06	3236.4	.452	23.5	10.8
***TOTAL OUTFLOW			1794.7	17.1	.659E+06	3236.4	.452	23.5	10.8
***RETENTION			8701.0	82.9	.673E+06	3305.8	.094	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
8.02	1.5738	27.4	.3129	3.1954	.8290

Appendix J
Monte Carlo Analyses

J.1 Monte Carlo Analyses

This appendix contains results of the Monte Carlo analyses for manganese and sulfates in the Big Muddy River #1 Watershed. Each analysis generates 10,000 random numbers which can be obtained electronically.

IEPA
Watershed Load Reductions
7/15/2002

Monte Carlo Simulations using @RISK 3.5

Watershed : N12 Big Muddy River #1

Manganese

Cc (Mn)	1	mg/L	- Water quality criterion
Cd (Mn)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (Mn) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Mn) 51.1% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 0.6 mg/L

LTA = mean * (1 - PR99)

LTA (Mn) 0.291 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Mn) 66.8% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 0.6 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 0.198 mg/L

IEPA
Watershed Load Reductions
7/15/2002

Monte Carlo Simulations using @RISK 3.5

Watershed : N12 Big Muddy River #1

Sulfate

Cc (Sulfate) 500 mg/L - Water quality criterion
Cd (Sulfate) #NAME? mg/L - Randomly generated pollutant source concentration base on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (Sulfate) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Sulfate) 36.2% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 246.9 mg/L

LTA = mean * (1 - PR99)

LTA (Sulfate) 157.576 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Sulfate) 58.0% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

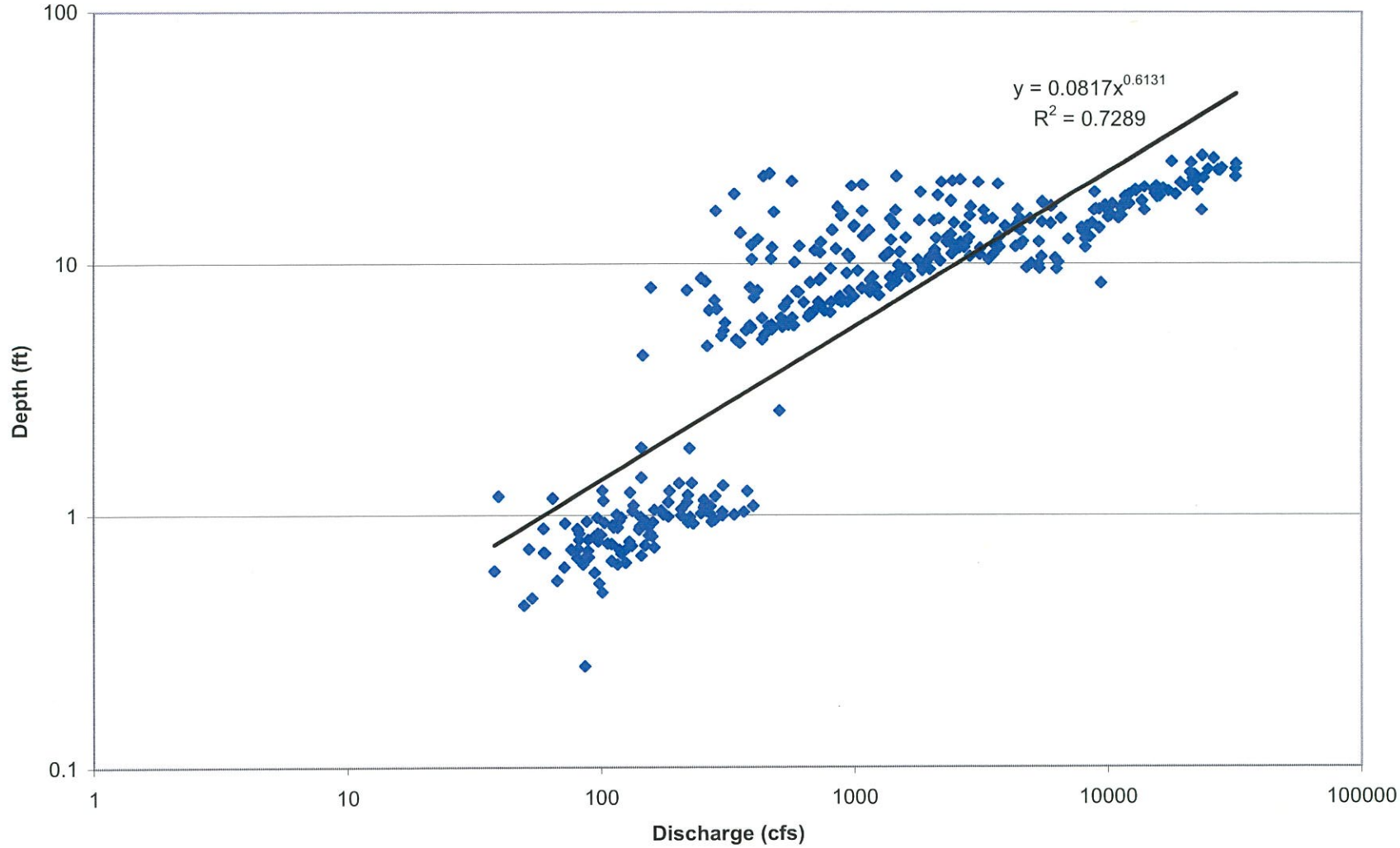
mean 246.9 mg/L

LTA = mean * (1 - PR99.9)

LTA (Sulfate) 103.660 mg/L

Appendix K
Rating Curve for Depth

Depth Rating Curve for the Big Muddy River



R01200

Appendix L
Streeter-Phelps Analyses

Big Muddy Segment N12 Watershed
Aeration Coefficient Summary

Location	Date	DO observed	BOD @ DO Observed	Ka @ DO observed	Ka at DO = 6 mg/L
N12	7/24/2000	7.9	7.3	45.4	11.05
N12	9/6/2000	4.7	7.2	3.2	11.53

Definitions

D	DO Deficit = DO at saturation minus observed DO
D_o	Initial DO deficit
k_a	Reaeration rate
k_d	BOD5 decay rate
x	Distance downstream of discharge
U	Stream velocity
L_o	Initial BOD5 at x=0
C_s	DO at saturation
C	Observed DO
H	Stream depth
T	Stream temperature
Q	Streamflow

R01202

DONE Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
0.376206	4	0.519612	45.4	0.364011	5280	1.1	7.3	8.3	7.9	8.8	25.1	2060
0.375403												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.4

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation 360 feet
DO @ Elev. 8.3 mg/L
DO Elev Factor 0.99

DO @ Temp/Elev 8.3 mg/L

N12_072400

R01203

DONE Used Q from USGS Derived Flows and H calculated from Q. Used Ka and Kd from N12 9/6/00.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
2.276206	4	0.519612	11.04779	0.364011	5280	1.1	7.3	8.3	6	8.8	25.1	2060
2.276206												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.4

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation 360 feet
DO @ Elev. 8.3 mg/L
DO Elev Factor 0.99

DO @ Temp/Elev 8.3 mg/L

R01204

DONE Using Depth and Q Determined from Habitat Survey. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
3.513029	4	1.065987	3.2	0.458047	5280	1.1	7.2	8.2	4.7	5.4	25.5	400
3.503937												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.3

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation 360 feet
DO @ Elev. 8.3 mg/L
DO Elev Factor 0.99

DO @ Temp/Elev 8.2 mg/L

N12_090600

R01205

DONE Using Depth and Q Determined from Habitat Survey. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
2.213029	4	1.065987	11.52703	0.458047	5280	1.1	7.2	8.2	6	5.4	25.5	400
2.213029												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.3

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation 360 feet
DO @ Elev. 8.3 mg/L
DO Elev Factor 0.99

DO @ Temp/Elev 8.2 mg/L

R01206

Appendix M
Error Analyses

M.1 Monte Carlo Analysis Development and Results

This appendix provides the results of the Monte-Carlo DO error analysis. The analysis was run on the range of possible values for the BOD_5 decay rate coefficient (k_d) and the reaeration rate coefficient (k_a). The Monte-Carlo program requires a distribution of k_a and k_d values. For each DO sample date, a triangle distribution was chosen to analyze the Big Muddy River segment N12 since data for this site was extremely limited.

Each DO sample date was evaluated separately using @RISK, which is a Microsoft® *Excel* Add-in for the Monte-Carlo analysis. The @RISK analysis package performed 10,000 iterations to determine the range of possible DO predictions over 10,000 combinations of randomly selected k_a and k_d values.

A triangular distribution assumes that the values of a given data set are most often at or near the mode and linearly distributed to the minimum and maximum values. The minimum is the smallest concentration of the sample data set. The maximum value is the largest sample in the sample data set. The mode is the value that is most likely to be observed in a long time series of sample data. Water quality data were not available to determine the actual k_a and k_d, so the estimated values discussed in Section 10.3 and shown in Table 10-3 were used as the mode for each sample date.

In order to define a more appropriate distribution than triangular, more data needs to be collected. In the absence of any drift, or non-random error, 10 samples can be used to define a distribution. As the data set increases, so does the ability to define an appropriate distribution, such a lognormal, normal, etc. The number of samples needed to define the true data distribution depends upon the severity of the drift.

The Monte Carlo simulation was run using 10,000 iterations with the triangular distribution. For each iteration, a DO concentration is randomly generated according to random sampling of the triangular distribution of k_a and k_d. The output of the Monte-Carlo simulation is a population of 10,000 DO concentrations that could be observed across the literature range of k_a and k_d values. Statistics were performed on the Monte-Carlo output to determine the 95^{th} and 99.9^{th} percentile confidence intervals. A confidence interval means that the stated percent of the simulated concentrations fall within the low and high concentrations of the interval.

This appendix shows the set-up for the Monte-Carlo simulation for each segment sample date, a summary of the output, and the 95^{th} and 99.9^{th} percentile confidence intervals for each sample date.

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	1.1	7.3	8.3	7.9	2060	=RiskTriang(0.01,45.4,100	=RiskTriang(0.02,0.364,3.4)

DO= =$F$3-(($B$3*EXP((-$I$3*$C$3)/($D$3*86400)))+($E$3*$J$3/($I$3-$J$3))*(EXP(-$J$3*$C$3/($D$3*86400))-EXP(-$I$3*$C$3/($D$3*86400))))

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	3.7	0.7	0.0
Maximum =	8.2	99.0	3.4
Mean =	7.6	48.7	1.3
Std Deviation =	0.6	20.6	0.8
Variance =	0.4	422.6	0.6
Skewness =	-2.2	0.1	0.6
Kurtosis =	8.4	2.4	2.4
Errors Calculated =	0.0	0.0	0.0
Mode =	7.4	39.2	2.0

95th Percent Confidence Interval
6.3 8.9

99.9th Percent Confidence Interval
5.5 9.7

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	1.0	7.2	8.2	4.7	5.38	=RiskTriang(0.01,3,100)	=RiskTriang(0.02,0.458,3.4)

DO= =$F$3-(($B$3*EXP((-$I$3*$C$3)/($D$3*86400)))+($E$3*$J$3/($I$3-$J$3))*(EXP(-$J$3*$C$3/($D$3*86400))-EXP(-$I$3*$C$3/($D$3*86400))))

Summary of Monte Carlo Results

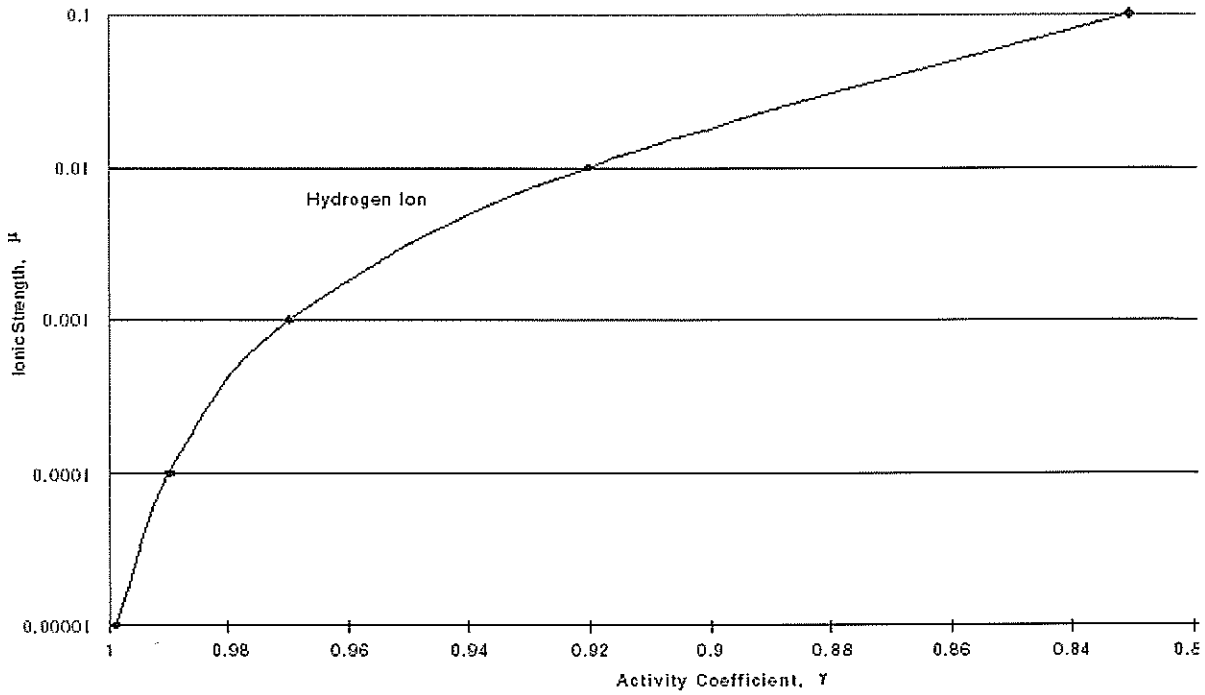
	DO	Ka	Kd
Minimum =	3.3	0.2	0.0
Maximum =	8.2	99.7	3.4
Mean =	6.9	34.4	1.3
Std Deviation =	1.1	23.3	0.7
Variance =	1.3	542.5	0.6
Skewness =	-0.9	0.6	0.5
Kurtosis =	2.7	2.4	2.4
Errors Calculated =	0.0	0.0	0.0
Mode =	6.4	44.1	0.7

95th Percent Confidence Interval
4.7 9.1

99.9th Percent Confidence Interval
3.1 10.6

Appendix N
Chart of Activity Coefficients versus Ionic Strength

Ionic Strength versus Activity Coefficient (Snoeyink 1980)



Appendix O
pH Analyses

IEPA
pH TMDL
9/12/2002

Watershed	Segment	TDS 95 percentile (mg/L)	Ionic Strength (μ)	Activity CorrectionFactor
Big Muddy River	N12	1194	0.02985	0.9

Additional Notes:
- Activity Correction factor computed from Figure 5 (KDEP 2001)
- TDS 95 percentile is computed from observed data

Watershed	Segment	Area (miles^2)	3 yr-Flow (cfs)	Max H+ Ion Loading @ pH of 6.5 (g/day)	Max H+ Ion Loading @ pH of 6.5 (lbs/day)	Actual H+ Ion Loading (g/day)	Actual H+ Ion Loading (lbs/day)	Reduction in H+ Ion Loading (lbs/day)
Big Muddy River	N12	2169	16,425.55	14,198.25	31.30	4,751.91	10.48	(20.83)

Additional Notes:
1) 3-yr flow calculated by the Log Normal Distribution
2) Max H+ concentration @ pH of 6.5 is determined by relationship in QvsLoading_g (6.5)
3) Actual H+ concentration for Big Muddy @ 3 yr flow is determined by relationship in QvsLoading_g (N12)

IEPA
pH TMDL
9/12/2002

Water Quality pH Standard = 6.5
Activity CorrectionFactor (N12) = 0.9 * based upon the TDS concentrations observed in the watershed

	N12	
Flow (cfs)	Max Ion Loading (g/day)	Max Ion Loading (lbs/day)
0	0.00	0.000
500	432.22	0.953
1000	864.45	1.906
1500	1296.67	2.859
2000	1728.89	3.811
2500	2161.12	4.764
3000	2593.34	5.717
3500	3025.56	6.670
4000	3457.78	7.623
4500	3890.01	8.576
5000	4322.23	9.529
5500	4754.45	10.482
6000	5186.68	11.434
6500	5618.90	12.387
7000	6051.12	13.340
7500	6483.35	14.293
8000	6915.57	15.246
8500	7347.79	16.199
9000	7780.02	17.152
9500	8212.24	18.105
10000	8644.46	19.057
10500	9076.68	20.010
11000	9508.91	20.963
11500	9941.13	21.916
12000	10373.35	22.869
12500	10805.58	23.822
13000	11237.80	24.775
13500	11670.02	25.728
14000	12102.25	26.680
14500	12534.47	27.633
15000	12966.69	28.586
15500	13398.92	29.539
16000	13831.14	30.492
16500	14263.36	31.445
17000	14695.58	32.398
17500	15127.81	33.351
18000	15560.03	34.303
18500	15992.25	35.256
19000	16424.48	36.209
19500	16856.70	37.162
20000	17288.92	38.115
20500	17721.15	39.068
21000	18153.37	40.021
21500	18585.59	40.974
22000	19017.82	41.926
22500	19450.04	42.879
23000	19882.26	43.832
23500	20314.48	44.785
24000	20746.71	45.738
24500	21178.93	46.691
25000	21611.15	47.644

IEPA
pH TMDL
9/12/2002

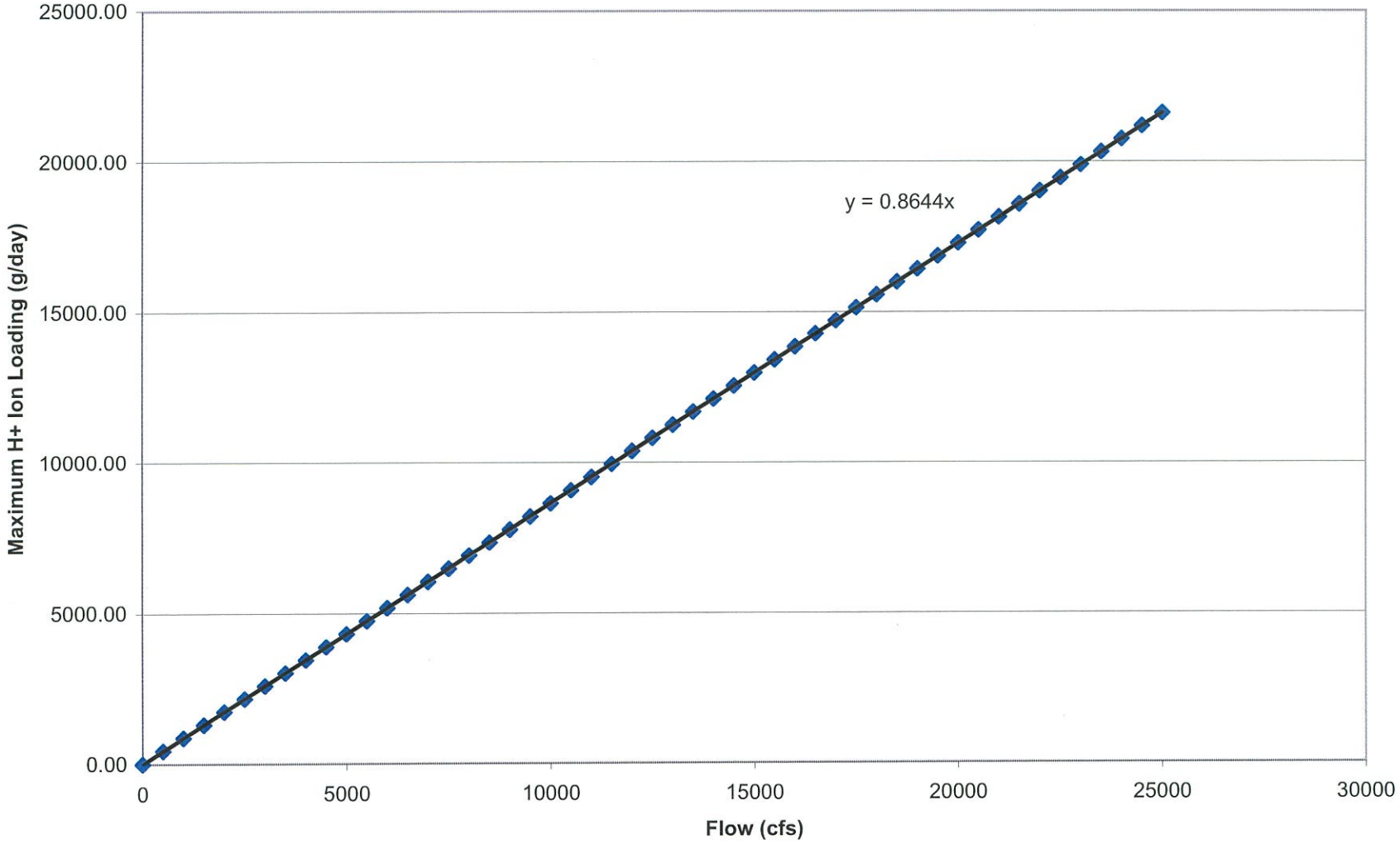
Big Muddy River (N12)

Water Quality pH Standard = 6.5
Activity Correction Factor = 0.9

Max Ion Loading (g/day)	Max Ion Loading (lbs/day)	pH (measured)	Flow (cfs)
0.081	0.000	7.600	1.858
0.09	0.000	7.600	1.858
0.368	0.001	8.300	26.386
0.361	0.001	8.300	26.386
2.27	0.005	7.500	26.386
0.361	0.001	8.300	26.386
0.111	0.000	8.600	26.386
0.111	0.000	8.600	26.386
0.72	0.002	8.000	26.386
15.111	0.033	7.000	55.600
15.111	0.033	7.000	55.600
67.27	0.148	6.900	196.551
134.21	0.296	6.600	196.551
0.45	0.001	7.500	13.112
1.79	0.004	7.300	13.112
2.25	0.005	7.200	13.112
2.25	0.005	7.200	13.112
2.25	0.005	7.200	13.112
2.25	0.005	7.200	13.112
2.25	0.005	7.200	13.112
1.79	0.004	7.300	13.112
0.28	0.001	7.500	3.285
0.56	0.001	7.200	3.285
0.56	0.001	7.200	3.285
0.16	0.000	7.600	3.541
0.63	0.005	8.200	1.508
0.63	0.000	8.200	1.508
158.81	0.350	6.400	146.740
158.81	0.350	6.400	146.740
13.14	0.029	7.100	60.850
13.14	0.029	7.1	60.850
16.54	0.036	7	60.850
13.14	0.029	7.1	60.850
13.14	0.029	7.1	60.850
26.22	0.058	6.8	60.850
26.22	0.058	6.8	60.850
16.54	0.036	7	60.850
16.54	0.036	7	60.850
2.39	0.005	7.4	22.078
2.39	0.005	7.4	22.078
1.49	0.003	7.3	10.972
1.88	0.004	7.2	10.972
0.09	0.000	7.9	2.571
0.14	0.000	7.7	2.571
0.09	0.000	7.9	2.571
0.11	0.000	7.8	2.571
0.11	0.000	7.8	2.571
0.11	0.000	7.8	2.571
0.11	0.000	7.8	2.571
0.28	0.001	6.9	0.808
0.28	0.001	6.9	0.808
0.19	0.000	7.05	0.781
0.57	0.001	7	2.687
0.57	0.001	7	2.687
9.54	0.021	6.9	27.867
7.58	0.017	7	27.867
7.58	0.017	7	27.867
7.58	0.017	7	27.867
7.58	0.017	7	27.867
7.58	0.017	7	27.867
7.58	0.017	7	27.867
7.58	0.017	7	27.867
5.93	0.013	7.2	34.598
5.93	0.013	7.2	34.598
1.38	0.003	7.3	10.164
1.38	0.003	7.3	10.164
1.66	0.022	7.44	10.164
1.29	0.003	7.33	10.164
1.42	0.003	7.29	10.164
1.42	0.003	7.29	10.164
1.18	0.003	7.1	5.479
0.43	0.001	7.1	1.979
0.43	0.001	7.1	1.979
0.66	0.000	7.7	1.164
12.40	0.027	7.4	114.565
1.56	0.003	7.6	22.886
7.52	0.017	7.7	138.663
3.77	0.008	8	138.663
5.97	0.013	7.8	138.663
7.52	0.017	7.7	138.663
9.47	0.021	7.6	138.663
7.52	0.017	7.7	138.663
1.18	0.003	8.5	138.663
3.77	0.008	8	138.663
4.75	0.010	7.9	138.663
9.47	0.021	7.6	138.663
4.75	0.010	7.9	138.663
23.78	0.052	7.2	138.663
37.69	0.083	7	138.663
18.69	0.042	7.3	138.663
4.75	0.010	7.9	138.663
18.69	0.042	7.3	138.663
0.17	0.000	7.1	0.794
1.02	0.002	7.2	5.937
1.23	0.003	7.4	11.335
0.42	0.001	7.4	3.891
12.41	0.027	6.6	18.174
169.37	0.373	6.8	393.103
17.40	0.038	6.8	40.387
1.32	0.003	7.3	9.693
8.31	0.018	7.2	48.465
9.49	0.021	6.9	27.733
4.63	0.010	6.5	5.385
0.49	0.001	7.2	2.881
2.65	0.006	6.4	2.450
0.51	0.001	7.5	5.550
2.66	0.007	7.5	34.464
9.97	0.020	7.2	52.907
17.31	0.038	7	63.677
10.17	0.022	7.1	47.118
10.22	0.023	6.7	18.647
4.82	0.011	6.4	4.456
1.10	0.002	7.3	8.077
0.18	0.000	7.3	1.306
0.44	0.001	6.1	20.194
13.61	0.030	7.3	99.891
10.21	0.023	7.2	59.504
4.18	0.009	7.4	38.637
10.26	0.024	6.5	12.529
0.10	0.000	7.3	0.754
0.05	0.000	7.4	0.512
0.35	0.001	7	1.306
4.70	0.010	6.8	6.879
5.23	0.012	6.6	7.666
1.26	0.003	7.1	5.829
0.90	0.002	7.6	13.153
9.49	0.021	6.9	27.733
4.63	0.010	6.5	5.385

Gage	Date	Time of pH Sample	pH (S.U.)	Flow (cfs)
5599500	1/9/1990	10:30	7.8	1.858
5599500	1/9/1990	10:45	7.8	1.858
5599500	2/8/1990	13:00	8.3	26.386
5599500	2/8/1990	13:30	8.3	26.386
5599500	2/8/1990	13:32	7.5	26.386
5599500	2/8/1990	13:35	8.2	26.386
5599500	2/8/1990	13:37	8.6	26.386
5599500	2/8/1990	13:38	8.6	26.386
5599500	2/8/1990	13:40	8	26.386
5599500	4/16/1990	15:00	7	55.600
5599500	4/16/1990	15:15	7	55.600
5599500	5/22/1990	10:00	6.9	196.551
5599500	5/22/1990	10:30	6.6	196.551
5599500	7/9/1990	14:00	7.9	13.112
5599500	7/9/1990	14:02	7.3	13.112
5599500	7/9/1990	14:05	7.2	13.112
5599500	7/9/1990	14:07	7.2	13.112
5599500	7/9/1990	14:10	7.2	13.112
5599500	7/9/1990	14:13	7.2	13.112
5599500	7/9/1990	14:15	7.2	13.112
5599500	7/9/1990	14:45	7.3	13.112
5599500	7/9/1990	15:00	7.3	13.112
5599500	8/21/1990	9:30	7.5	3.285
5599500	8/21/1990	9:45	7.2	3.285
5599500	8/21/1990	10:00	7.2	3.285
5599500	8/24/1990	13:30	7.6	3.541
5599500	11/13/1990	13:00	8.2	1.508
5599500	11/13/1990	13:30	8.2	1.508
5599500	1/8/1991	11:30	6.4	146.740
5599500	1/8/1991	12:00	6.4	146.740
5599500	2/12/1991	12:00	7.1	60.850
5599500	2/12/1991	12:10	7.1	60.850
5599500	2/12/1991	12:20	7	60.850
5599500	2/12/1991	12:30	7.1	60.850
5599500	2/12/1991	12:40	7.1	60.850
5599500	2/12/1991	12:50	6.8	60.850
5599500	2/12/1991	13:00	6.8	60.850
5599500	2/12/1991	13:30	7	60.850
5599500	2/12/1991	14:00	7	60.850
5599500	4/9/1991	13:00	7.4	22.078
5599500	4/9/1991	13:30	7.4	22.078
5599500	6/4/1991	10:00	7.3	10.972
5599500	6/4/1991	10:30	7.2	10.972
5599500	7/15/1991	12:30	7.9	2.571
5599500	7/15/1991	12:35	7.7	2.571
5599500	7/15/1991	12:40	7.9	2.571
5599500	7/15/1991	12:45	7.8	2.571
5599500	7/15/1991	12:50	7.8	2.571
5599500	7/15/1991	13:00	7.8	2.571
5599500	7/15/1991	13:30	7.8	2.571
5599500	8/20/1991	12:30	6.9	0.808
5599500	8/20/1991	13:00	6.9	0.808
5599500	10/15/1991	12:00	7.05	0.781
5599500	11/12/1991	12:00	7	2.687
5599500	11/12/1991	12:30	7	2.687
5599500	1/7/1992	10:15	6.9	27.867
5599500	1/7/1992	10:20	7	27.867
5599500	1/7/1992	10:25	7	27.867
5599500	1/7/1992	10:30	7	27.867
5599500	1/7/1992	10:35	7	27.867
5599500	1/7/1992	10:40	7	27.867
5599500	1/7/1992	11:00	7	27.867
5599500	1/7/1992	11:30	7	27.867
5599500	2/26/1992	11:30	7.2	34.598
5599500	2/26/1992	12:00	7.2	34.598
5599500	4/14/1992	10:30	7.3	10.164
5599500	4/14/1992	11:00	7.3	10.164
5599500	4/14/1992	11:05	7.44	10.164
5599500	4/14/1992	11:10	7.33	10.164
5599500	4/14/1992	11:15	7.29	10.164
5599500	4/14/1992	11:25	7.29	10.164
5599500	5/18/1992	11:00	7.1	5.479
5599500	7/13/1992	12:30	7.1	1.979
5599500	7/13/1992	13:00	7.1	1.979
5599500	8/17/1992	12:00	7.7	1.164
5599500	1/12/1993	7:00	7.4	114.565
5599500	2/16/1993	9:00	7.6	22.886
5599500	1/6/1994	7:00	7.7	138.663
5599500	3/2/1994	7:00	8	138.663
5599500	4/6/1994	8:00	7.8	138.663
5599500	5/23/1994	8:00	7.7	138.663
5599500	7/6/1994	12:00	7.6	138.663
5599500	8/4/1994	8:00	7.7	138.663
5599500	9/19/1994	11:00	8.5	138.663
5599500	11/1/1994	8:00	8	138.663
5599500	12/7/1994	8:00	7.9	138.663
5599500	1/30/1995	8:00	7.6	138.663
5599500	2/21/1995	8:00	7.9	138.663
5599500	4/12/1995	7:00	7.2	138.663
5599500	5/10/1995	8:00	7	138.663
5599500	6/15/1995	8:00	7.3	138.663
5599500	7/20/1995	8:00	7.9	138.663
5599500	8/22/1995	8:00	7.3	138.663
5599500	10/31/1995	8:00	7.1	0.794
5599500	12/18/1995	7:00	7.2	5.937
5599500	1/31/1996	9:00	7.4	11.335
5599500	2/29/1996	8:00	7.4	3.891
5599500	3/25/1996	8:00	6.6	18.174
5599500	5/1/1996	8:00	6.8	393.103
5599500	6/25/1996	8:00	6.8	40.387
5599500	7/31/1996	8:00	7.3	9.693
5599500	4/24/1997	8:00	7.2	48.465
N12	7/24/2000		6.9	27.733
N12	9/6/2000		6.5	5.385
N12	10/27/1997		7.2	2.881
N12	11/20/1997		6.4	2.450
N12	2/3/1998		7.5	5.550
N12	3/5/1998		7.5	34.464
N12	4/16/1998		7.2	52.907
N12	5/14/1998		7	63.677
N12	6/17/1998		7.1	47.118
N12	7/27/1998		6.7	18.647
N12	8/27/1998		6.4	4.456
N12	10/8/1998		7.3	8.077
N12	12/1/1998		7.3	1.306
N12	1/4/1999		6.1	20.194
N12	2/8/1999		7.3	99.891
N12	3/22/1999		7.2	59.504
N12	4/27/1999		7.4	38.637
N12	6/10/1999		6.5	12.529
N12	9/16/1999		7.3	0.754
N12	11/1/1999		7.4	0.512
N12	12/6/1999		7	1.306
N12	1/3/2000		6.8	6.879
N12	3/8/2000		6.6	7.666
N12	4/12/2000		7.1	5.829
N12	5/1/2000		7.6	13.153
N12	7/24/2000		6.9	27.733
N12	9/6/2000		6.5	5.385

Calculated Flow vs. Maximum H^+ Ion Loading

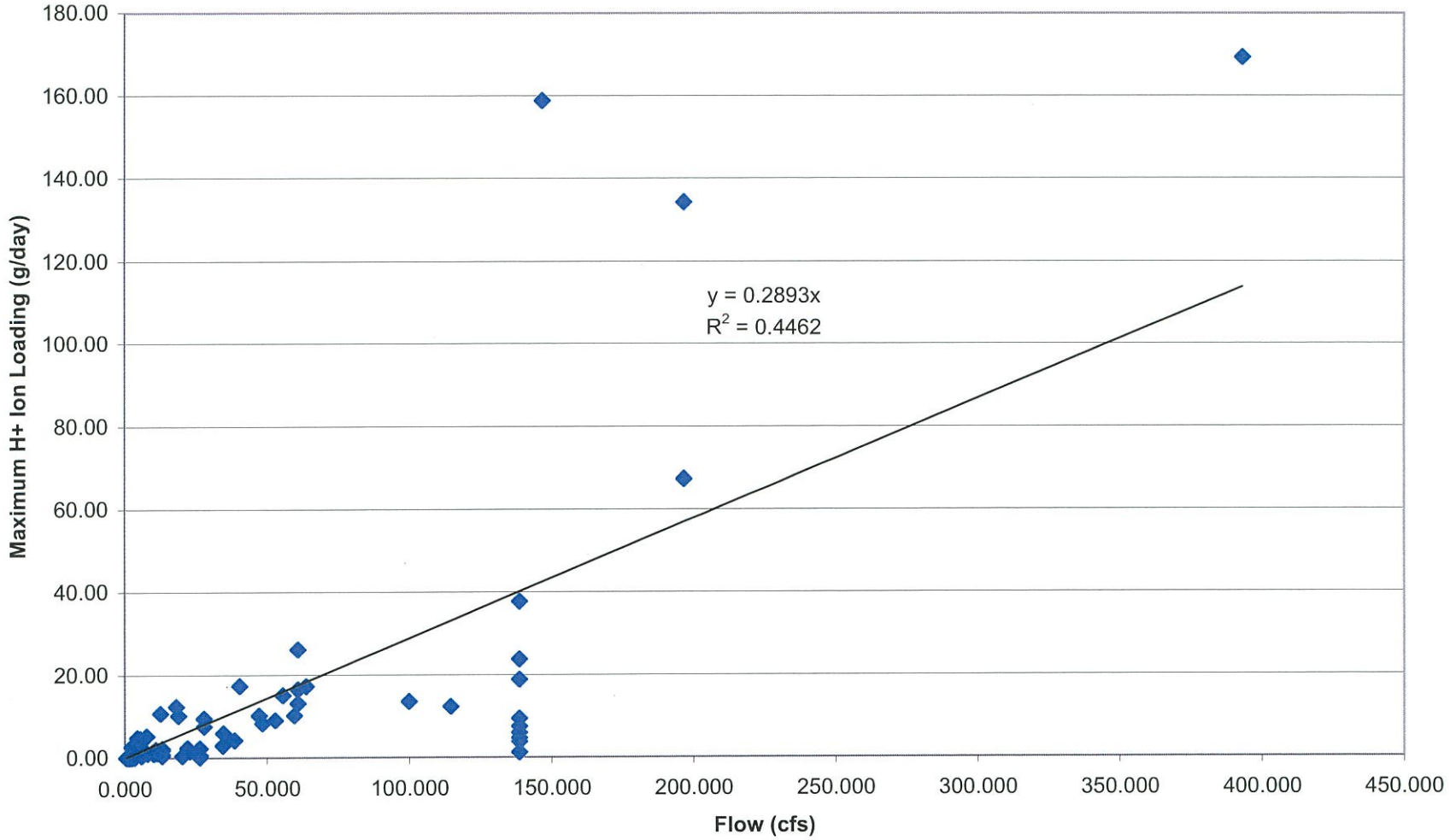


CDM

AppendixO-pHAnalyses.xls, 'QvsLoading_g (6.5)_N12'

R01217

Existing Flow vs. Maximum H^+ Ion Loading in Segment N12 of the Big Muddy River



CDM

AppendixO-pHAnalyses.xls, 'QvsLoading_g (N12)'

R01218

Appendix P
Responsiveness Summary

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Responsiveness Summary

This responsiveness summary responds to substantive questions and comments received during the public comment period from January 23, 2004 to March 29, 2004 postmarked, including those from the February 26, 2004 public meeting discussed below.

What is a TMDL?

A Total Maximum Daily Load (TMDL) is the sum of the allowable amount of a pollutant that a water body can receive from all contributing sources and still meet water quality standards or designated uses. The Big Muddy River TMDL report contains a plan detailing the actions necessary to reduce pollutant loads to the impaired water bodies and ensure compliance with applicable water quality standards. The Illinois EPA implements the TMDL program in accordance with Section 303(d) of the federal Clean Water Act and regulations thereunder.

Background

The watershed targeted for TMDL development is Big Muddy River (ILN12), which originates in Jefferson County, Illinois. The watershed encompasses an area of approximately 200 square miles. Land use in the watershed is predominately forestland followed by rural grassland and agricultural land uses. TMDLs developed for impaired water bodies in the Big Muddy River watershed include Big Muddy River segment N12 and Kinkaid Lake (RNC). In the 2002 Section 303(d) List, Big Muddy River (N12) was listed as impaired for manganese, sulfates, pH, low dissolved oxygen (DO), and total suspended solids (TSS). Kinkaid Lake was listed as impaired for pH, mercury, and siltation. The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) List. Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Therefore, TMDLs were only developed for the following: Big Muddy River (N12): manganese, sulfates, pH, and DO; Kinkaid Lake (RNC): pH. While the impairment caused by mercury is acknowledged, a TMDL will not be developed for it at this time. The Illinois EPA contracted with Camp Dresser & McKee (CDM) to prepare a TMDL report for the Big Muddy River watershed.

Public Meetings

Public meetings were held in the city of Springfield on June 5, 2001 and in the city of Murphysboro on December 12, 2001 and February 26, 2004. The Illinois EPA provided public notice for the February 26, 2004 meeting by placing display ads in the Southern Illinoisan on January 27, 2004, and the Carbondale Times and The Spokesman on January 25, 2004. This notice gave the date, time, location, and purpose of the meeting. The notice also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Approximately 50 individuals and organizations were also sent the public notice by first class mail. The draft TMDL

Report was available for review at the Murphysboro Township office and also on the Agency's web page at http://www.epa.state.il.us/water/tmdl .

The final public meeting started at 6:00 p.m. on Thursday, February 26, 2004. It was attended by approximately 36 people and concluded at 7:25 p.m. with the meeting record remaining open until midnight, March 29, 2004.

Questions and Comments

1. If Kinkaid Lake was listed only for sediment, why were nutrients addressed in the TMDL?

Response: The 2002 303(d) List shows Kinkaid Lake being impaired for pH, mercury, and siltation. As discussed in the report, mercury was not addressed in this TMDL report. Since siltation does not have a numeric water quality standard, a TMDL was not developed for it. A TMDL was developed for pH since it has a numeric water quality standard. During the analysis, an attempt was made to link pH swings to algal blooms that occur in the lake. These algal blooms are a result of increased phosphorus levels within the lake. Therefore, a reduction in phosphorus loading to the lake should help control algal blooms, which in turn should help stabilize pH levels.

2. Only three samples for pH violated the standards. Was this TMDL done just to address these few excursions?

Response: Yes. Any violation of the water quality standard can place that water body on the 303(d) List, for which TMDLs must be developed. Since numeric water quality standards exist for pH, a TMDL was developed for Kinkaid Lake.

3. Why was station RNC-4 high in phosphorus but didn't violate the pH standard? Did the phosphorus from RNC-4 get distributed throughout the rest of the lake?

Response: Phosphorus entering a lake is transported throughout the lake. RNC-4 is at the upper reaches of the reservoir. The phosphorus that was transported to other areas of the reservoir from RNC-4 could cause algal blooms and associated pH violations.

4. When will TMDLs be developed for the listed causes without standards?

Response: TMDLs are currently only conducted for listed causes for which a water quality standard exists. Pending development of appropriate water quality standards, as may be proposed by the Agency or others and adopted by the Illinois Pollution Control Board, we will continue to work with watershed planning groups and others to identify causes and treat potential sources of impairment.

5. The GWLF model assumes that all row crop runoff directly enters the lake. That assumption is not correct.

Response: GWLF does not route flow and data were not available for the tributaries to Kinkaid Lake. Therefore, calibration in these areas could not be completed. The calibration exercise was used to estimate what runoff and associated phosphorus concentrations were entering the lake. The GWLF model was selected based on the amount of data available for calibration.

6. Using the Casey Fork flow gauge for this watershed was not representative for the tributary that runs into the lake. A gauge used to be in the upper tributary years ago. That data could be used to calculate flow in Kinkaid Lake.
Response: It is best to utilize more recent flow data that occurred during the time of data collection for calibration. Use of the Casey Fork gauge was considered conservative because it has a less steep slope than the Kinkaid Lake tributaries.

7. An NRCS study performed by Roger Windhorn looked at erosion and sedimentation rates occurring in Kinkaid Lake watershed. Was that looked at during TMDL development?

Response: Yes this study was part of the Kinkaid Lake Management Plan and was evaluated during TMDL development.

8. Was runoff and erosion from the forestland within the lake watershed considered in the model?

Response: Yes, the contribution of forestland to the phosphorus load was analyzed through the GWLF model. According to the analysis, forestland contributes approximately 3,212 lbs per year, or 15 percent of the total phosphorus load entering the lake.

9. Assuming that no-till, filter strips, and dry dams are already in place, what else can a farmer do to prevent phosphorus loads in the watershed?

Response: Producers in the watershed are encouraged to use soil testing and nutrient management plans to ensure that they are not over-applying fertilizers to their fields. The Agency recommends that producers follow fertilizer recommendations found in the University of Illinois Agronomy Handbook and NRCS 590 Standard. Information pertaining to nutrient management planning and programs that provide financial incentives to develop such plans can be found in the Implementation Plan of the TMDL report.

10. A lot of highly erodable land in the watershed has been enrolled in conservation programs. About one-third of row crops currently in conservation programs have very low P tests. I don't believe the 18 percent reduction in phosphorus through nutrient management planning is achievable for this watershed. There has been a lot of conservation tillage done in the watershed in the last 20 years, so there may not be as much saving in additional conservation tillage practices.

Response: The consultants did not have access to soil test results from individual landowners. The GWLF model was set at a total phosphorus soil concentration of 660 ppm based on comparison with observed data in the BATHTUB model, as well as a sensitivity analysis to confirm that this was within the correct range. The report recognizes the high percentage of no-till being practiced in the watershed,

and encourages those not currently practicing conventional tillage to consider practicing a form of conservation tillage. In the report, the 19 percent reduction in phosphorus from conservation tillage practices is based on an average, so that reduction may or may not be reached. Likewise, the 20 percent reduction in total phosphorus from nutrient management plans is also based on an estimate. The report suggests that stakeholders use an adaptive management approach, in that the effectiveness of a BMP is estimated after it is incorporated into the watershed.

11. Why weren't any reductions recommended for internal cycling in the lake?

Response: Kinkaid Lake is very deep and is less likely to experience internal cycling than other shallower lakes in Illinois. The calibration did not indicate that phosphorus enriched sediment and cycling were causing impairments.

12. Is there a correlation between high phosphorus and low DO in the stream?

Response: There can be, although that correlation was not proved through the analysis in this report. High phosphorus loading to the stream can cause algal blooms. As the algae dies and decay, the consuming bacteria use oxygen in the water, reducing the amount of dissolved oxygen in the stream. For segment N12, we believe that low flow and stagnant conditions, as well as possible BOD loads, are causing low DO to occur in the stream. As stated in the Implementation Plan, further monitoring is required to properly identify these sources.

13. How often are samples taken for stream segment N12?

Response: The station on Segment N12 is part of the Agency's Ambient Water Quality Monitoring Network. Water chemistry samples are taken on approximately a nine-week rotating schedule, year round. This segment is also sampled by the agency every five years through the Intensive Basin Survey, in which water chemistry as well as habitat and biological parameters are assessed.

14. The report doesn't mention that county SWCDs administer the CPP program through the Illinois Department of Agriculture. Some of the practices recommended in the Implementation Plan could be funded through the CPP program as well.

Response: Thank you for your comment. This will be incorporated into the final version of this report.

15. The animal management facility mentioned in the report for Kinkaid Lake is being closed, with the land being seeded to grass, so the erosion and potential phosphorus load contribution from that site won't occur in the future.

Response: Thank you for your comment. This will be mentioned in the final version of this report.

16. At what point will the lake be delisted, or the study be completely finalized?

Response: The lake can be delisted by: 1) having a new assessment show that it is no longer impaired, 2) having an approved TMDL developed for the causes for which it is listed. The study will be finalized after it is approved by USEPA. Once approved, a final version will be printed and made available to the public.

17. At what point will a determination be made that the voluntary measures listed in the Implementation Plan become involuntary?

Response: At this time, the Agency does not foresee any of the recommended actions in the Implementation Plan becoming mandatory for the pollutants addressed in this TMDL report.

18. Would future industry or sewage plant expansion be affected by this TMDL?

Response: Any new wastewater discharge for the causes identified in this TMDL will be affected by the allocations in this report. Appropriate discharge limits for those causes will be established prior to permitting. New data will be reviewed at that time to confirm the impairment continues.

19. Has a study been done about dredging the river?

Response: To the Agency's knowledge, no study has been done for dredging this segment of the Big Muddy River.

20. Who is the contact person at the Agency for lake and stream monitoring?

Response: Mike Bundren (lake monitoring) and Dave Muir (stream monitoring) can be contacted at the Illinois EPA regional office in Marion by calling (618) 993-7200.

21. We are confused by the discussion in Section 7.1 of the basis for requiring a reduction in phosphorus to achieve the pH TMDL. Only data from stations RNC-1 and RNC-3 are presented to support the expected relationship between total phosphorus, chlorophyll-a and pH. [Note: we were not able to replicate the consultant's correlation between total phosphorus and chlorophyll-a at station RNC1. The data set for RNC-1 included in Appendix A includes two values that are not shown in figure 8-3: a chlorophyll-a value of 58.7 on 8/2/2000 (for which there is a corresponding total phosphorus value of 0.009) and a total phosphorus value of 0.654 on 10/22/90. Using those values, we calculated an r^2 of 0.03; substituting the total phosphorus median value of 0.16, results in an r^2 of 0.029. We also note that the chlorophyll-a value of 58.7 on 8/2/2000 appears to have been used in Figure 7.1 to demonstrate the expected relationship between chlorophyll-a and pH. If that value is eliminated from that analysis, the r^2 becomes 0.04.]

For most stations in the lake and for the lake as a whole (considering data from all four stations), there is no correlation (r^2,0.15) between total phosphorus and pH, chlorophyll-a and pH or total phosphorus and chlorophyll-a. Moderate correlations exist between total phosphorus and chlorophyll-a at station RNC-3 (r^2=0.46) and for the entire lake (r^2=0.37), and between chlorophyll-a and pH at station RNC-1 (r^2=0.37). For station RNC-4, which has the highest total phosphorus concentrations, but no exceedences of the pH standard, there is no correlation between any of the variables (r^2 </=0.10).

Response: The relationships presented in Section 7 were intended to confirm that there is a relationship between pH and chlorophyll-a in addition to chlorophyll-a and phosphorus. These general relationships have been established in literature, which suggest that reducing algae (chlorophyll-a) maintains pH and reducing phosphorus concentrations reduce algae (chlorophyll-a). Additional data collection for Kinkaid Lake may establish the same relationships found in literature. All the r^2 values are low, and the figures were intended to show general trends and provide examples of what has been established through literature. The relationships established in literature were used as the basis for the focus of this TMDL – control of phosphorus and thereby control of algae (chlorophyll-a) and pH.

22. We also find the discussion of loading capacity confusing. The section states that load reductions were modeled for RNC-4 because it violates the phosphorus standard (but not the pH standard), but then says that the effects of the modeled reductions are only shown for stations RNC-1 and RNC-3 because they are the only stations that violated the pH standard (RNC-1 never violates the phosphorus standard and at RNC-3 only one sample since 1994 has exceeded the standard. At both stations, the mean total phosphorus concentration is well below the standard).

Response: Phosphorus loadings in sub-basins 2, 3 and 4 were less than sub-basin 1. Therefore sub-basin 1 and its contributions to station RNC-4 were targeted for reductions. Phosphorus flows through the lake as well as settles and can cause algae growth in various parts of the lake. Since the largest loads were generated from sub-basin 1, it was the focus of the reductions to maintain pH throughout the lake.

23. The relationships provided in Figures 7-1 through 7-4 are weak, at best. At RNC-1, there is no relationship between total phosphorus and chlorophyll-a and only a moderate correlation between chlorophyll-a and pH. There is also no direct correlation between total phosphorus and pH (r^2=0.04). At RNC-3, there is only a moderate correlation between total phosphorus and chlorophyll-a and no correlation between chlorophyll-a and pH. There is also no direct correlation between total phosphorus and pH (r^2=0.0007). We also note that the predicted mean total phosphorus values after a 40 percent reduction in phosphorus loadings shown in Table 8-3 exceed the mean of the observed values at RNC-1 in 1997 and 2000 and at RNC-3 in 2000.

Response: See response to question 21.

24. In Section 9.1.2 Implementation Actions and Management Measures Summary, it is not apparent how the "Potential Percent Reductions" values in Table 9-2 were derived. For example, what is the basis for the statement in the preceding paragraph, 3rd bullet: "Nutrient management (reductions of total phosphorus in sediment by 20 percent)"? No citations to the scientific literature are provided, and no data or analysis are presented to support this statement.

Response: This was estimated by the consultant as an initial goal to target for nutrient reduction. As nutrient management plans are implemented, the effectiveness on reducing phosphorus concentrations can be further assessed against this initial target goal.

25. We were not able to find any results of modeling BMP effectiveness in Appendix C, GWLF and BATHTUB input and output files. Table 9-2 shows a potential reduction of 19% for "tillage practices" without specifying what residue levels would be required to achieve that reduction. Conservation tillage systems can result in reductions in sediment-bound phosphorus roughly proportional to the sediment load reductions. However, conservation tillage may also result in increased losses of dissolved phosphorus (McIssac et al, J. Soil and Water Conservation: 50 (4) 383-397 (1995)).

Response: The tillage practices category listed in Table 10.2 refer to conservation tillage practices, and the report has been changed to reflect that. Table 10.6 in the report suggests that it would be beneficial for all of the cropland in the watershed to have some form of conservation tillage implemented. Section 9.1.1.1 on page 9-2 of the report states "Conservation tillage is assumed to include tillage practices that preserve at least 30 percent residue cover of the soil after crops are planted." The GWLF model took into account those cropland acres in which conservation tillage practices, including no-till, have already been implemented. Although conservation tillage practices, such as no-till, can result in an increase in dissolved phosphorus runoff, the benefits gained from reductions in erosion and particulate phosphorus will decrease the loads of total phosphorus as well as sedimentation in the impaired water bodies. McIssaac et al. conclude that "[T]he fate of the dissolved P in runoff from agricultural fields is likely to depend upon the hydrologic context of each particular field in question. Dissolved P may be absorbed by vegetation or soils in buffer strips, wetlands, riparian zones, or stream banks. Whether elevated levels of dissolved P in runoff represents a problem in a watershed depends upon these processes. " If we proceed with an iterative approach to BMP installation and monitor the results, dissolved and total phosphorus loads can be better understood and treated.

26. Because no data are available on phosphorus in the streams within the watershed, it is not possible to determine whether particulate phosphorus or dissolved phosphorus is the form of phosphorus that is of greater concern.

Response: We concur with this statement and have outlined this as a future data collection need within a possible monitoring program in the Implementation Plan.

In 2003, Kinkaid Lake began a Phase I Clean Lakes Study funded through Illinois EPA. A component of this Study is to collect tributary data. Once taken and verified, these data can be analyzed to see how it can compliment or enhance the TMDL analysis.

27. We believe that it would be more helpful to producers and providers of technical assistance within the watershed to provide more readily understandable information on the changes needed to reduce phosphorus loadings. Presenting reductions in terms of soil erosion being reduced by tons per acre and targeted C factors would provide producers with a specific measurable goal rather than an indefinite "tillage practices".

Response: The required reductions in soil loss and C-factor were calculated during the analysis but not specifically stated in the text of the draft final report. These data have since been inserted into the text of the report for the convenience of producers and technical service providers.

28. Estimations of the effectiveness of management practices, such as wetlands or filter strips must account for the proportion of the total runoff in the watershed that will be transported through and effectively treated by the wetland or filter strip. For example, the only water that a filter strip can effectively treat is runoff water that moves through the strip as sheet flow. Water in a concentrated flow channel will not be treated.

Response: Section 9.1.1.2, on page 9-3 of the report states: "To maintain removal efficiency, sheet flow should be maintainted and substrate should be monitored to assess whether the wetland is operating optimally." It is true that sheet flow should be maintained in order for filter strips to properly filter pollutants. This will be reflected in the final version of the report.

29. We noted a significant disagreement between the Agency's contractors on the effectiveness of buffer strips and wetlands in removing phosphorus, and even by CDM in its discussion of BMP for nutrients in different TMDLs. The TMDL for the Charleston Side Channel Reservoir (Section 9.1.4, page 39) used the following values in its discussion of measures to achieve the necessary load reductions:

The combination of the following BMPs result in a reduction of 94.6 percent of the total phosphorus load to the lake

- 33.5 percent reduction through aeration, sediment sealing, or system flushing (90 percent of internal load)
- 20 percent reductions of external load due to cultural practices (primarily through CRP, tillage, and nutrient management practices)
- 70 percent reduction of external load due to buffer strips
- 65 percent reduction of external load due to ponds or wetlands

These values differ greatly from the values used by CDM in their discussions of implementation of the Washington County Lake TMDL (Section 10.2.3, page 10-12) and the Altamont New Reservoir TMDL (Section 9.1.3, page 9.6):

Management Measure	Altamont New Reservoir TMDL (Table 9-2)	Washington County Lake TMDL (Table 10-4)	Kinkaid Lake TMDL (Table 9-2)
Nutrient Management	17%	11%	14%
Tillage Practices	38%	30%	19%
Filter Strips*	22%	22%	14%
Wetland*	5%	40%	25%

*Literature value utilized for estimation

We note particularly the great difference in the estimates for the potential reductions from wetlands both in the two TMDLs prepared by CDM and the Charleston Side Channel Reservoir TMDL. But CDM also has taken contradictory positions on the effectiveness of wetlands in the two TMDLs we have reviewed. In the Altamont New Reservoir TMDL (Section 9.1, page 9-6), CDM states: "The lower bound of the literature value for wetlands (i.e. 5%) was used due to studies that have shown the long-term effectiveness of phosphorus removal in wetlands is negligible." But in the Washington County Lake TMDL, CDM has used a value of 40%. As quoted by CDM (Altamont New Reservoir TMDL, Section 9.1.1, page 9.2 and Washington County Lake TMDL Section 10.2.1.2, page 10.9), "Over the long term, it is generally thought that wetlands are neither sources nor sinks of phosphorus (Kovasic et al. 2000)". We believe that most of the scientific literature supports Dr. Kovacic's statement.

Response: The inconsistencies for potential percent reduction of management measures in each report prepared by CDM was done in error and will be corrected in the final published reports. The correct values for each management measure are shown below. This change does not impact the degree of implementation recommended for each watershed.

Summary of Total Phosphorus Load Reductions

Management Measure	Potential Percent Reduction
Nutrient Management	10%
Conservation Tillage Practices	11%
Filter Strips*	22%
Wetland*	5%

***Literature value utilized for estimation**

30. The only site in the watershed actually visited by the project team was the Mt. Joy boat ramp, which is in no way representative of the 38,535-acre watershed.

Response: This was the only area shown in pictures in the report. The team visited other areas of the watershed not shown in the report. The extent of the TMDL scope for the study did include field investigations.

31. The TMDL and the implementation plan are derived from a computer model and not from hands-on data collection from the watershed. While this is saving of time and money, it may not realistically reflect conditions in the watershed and may not lead to practical solutions for the impairments which exist.

Response: This TMDL was developed based on readily available data. The water quality data used in the modeling were based on data collected by Illinois EPA from Kinkaid Lake. While the amount of and types of data were lacking in some areas, the Implementation Plan suggests practices that are known to control pollutant loadings that lead to pH impairment. As the report suggests, an adaptive management approach to implementation should be taken, and future monitoring will provide more data, which local stakeholders can use for implementation decision making.

32. The Kinkaid watershed is arguably the steepest watershed in Illinois. One-third of the watershed is in excess of 15% slope and 25,000 acres are in excess of 5% slope. The highest point in the watershed is more than 400 feet above the base of the dam. The headwaters of the original creek are 254 feet higher than the base of the dam.

Response: The slope of this watershed was taken into account during the analysis. Slope length and slope steepness are factors used in the USLE equation, which is a component of the GWLF model that was used during TMDL development.

33. Stream flow into the lake was not measured, but was estimated from stream flow at Casey Fork (Mt. Vernon). One can question the similarity of the two watersheds. (p. 5-2)

Response: Flow data from the Casey Fork watershed were used in the absence of a gauge in the Kinkaid Lake watershed. The drainage area ratio method was used to estimate flows entering the lake. An explanation of this method can be found in Section 5.1.3 of the report.

34. Average monthly rainfall data were used in the model. While these data are probably accurate, there is no accounting for the rate of precipitation. In a steeply sloping watershed, three inches of rain falling over three days is entirely different from three inches over 2 hours (a heavy rain in the Kinkaid watershed is comparable to flushing a toilet).

Response: TMDLs are supposed to account for all seasonal conditions within a watershed, not specific events. Use of monthly precipitation takes into account that requirement of TMDL development.

35. How was water volume calculated for segment RNC4 (upper lake)? This appears to have a major bearing on total phosphorus entering the lake if total Phosphorus = mg Phos./L. x water volume. IEPA has not established specific boundaries for the lake segment represented by each sampling site, but has assigned a surface area to the lake

segments. When these areas were added together, it resulted in their estimate of total lake surface area being approximately 50% more than it actually is. (p. 5-15)

Response: The entire volume of the lake was calculated based on historic depth and surface area. Specific segment volumes were not calculated separately.

36. On p.5-6 and 5-7, it is stated that the correlation between pH and chlorophyll a is expected to indicate a direct relationship between the two constituents. In fact Table 5-5 (p.6) shows that segment RNC4 has some of the lowest pH values for the lake and the text indicates no individual samples with a pH impairment. Yet Table 5-7 shows segment RNC4 with chlorophyll a levels more than double those of any other portion of the lake. The actual data contradicts the hypothesis.

Response: TMDLs are supposed to account for all seasonal conditions within a watershed, not specific events. Use of monthly precipitation takes into account that requirement of TMDL development.

37. On page 5-7, it is stated that these relationships would suggest that controlling phosphorus will in turn control pH. Table 5-6 (page 5-7) shows RNC4 with by far the highest phosphorus levels for the lake, but Table 5-5 shows that segment to be in compliance for pH. In fact it is the sampling segments which are well within the standards for Phosphorus that have shown a few individual violations for pH. The actual data again disproves the hypothesis.

Response: See response to question 21.

38. The computer model assumes that all cropland is immediately adjacent to streams. That is definitely not the case in the Kinkaid watershed.

Response: See response to question 5.

39. The TMDL report states that there are no terraces in the Kinkaid Watershed. KAWP 2000 (page 11) reports more than 24,000 linear feet of terraces in the watershed (source – Jackson County Soil and Water Conservation District).

Response: This statement has been deleted from the report.

40. In 1991, 1995, and 1996, the text (page 5-6) reports a total of three individual samples slightly below the lower pH limit in the discharge below the spillway. Table 5-4 (page 5-5) reports a total of 70 samples from this location over a seven year period. In 1991, 1994, and 2000 the text reports a total of 4 individual samples testing slightly above the upper limit for pH in segments RNC1 and RNC3. Table 5-4 reports a total of 77 samples taken from these locations over an 11 year period. Do these data indicate any consistent trend toward pH violations? Is it possible to question the accuracy of the instrumentation or readings for pH?

Response: The data indicate that pH impairments are infrequent, however IEPA has determined that 1 violation in a 3 period indicates impairment. All data are shown in Appendix A

41. What is the location of the gauge at which the discharge from the lake was sampled? If it is, as we surmise, located at the Highway 149 bridge, that location is approximately one mile downstream from the spillway. That portion of the creek has it's own watershed and is, at times, actually supplied by the Big Muddy River.

Resonse: Downstream discharge was not analyzed for the Kinkaid Lake TMDL. Water quality data used for TMDL development were taken from the four water quality stations located within the lake.

42. Why does passing over the spillway cause a pH drop of 3 (9.1 in RNC 1 to 6.1 in the "discharge")?

Response: The only water quality data analyzed for Kinkaid Lake were from stations sampled within the lake. No water quality data were analyzed from water that passed over the spillway for this TMDL.

43. A 1983 erosion study of the Kinkaid watershed determined that there was almost 5 times the amount of sheet and rill erosion from cropland as was determined by the 2000 study (KAWP 2000, page 40). Some of the decrease in erosion is attributed to conversion to conservation tillage on cropland. In addition, land use changes have resulted in 1,100 acres of cropland being converted to hay or pasture lands and 2,200 acres of cropland have been enrolled into CRP and seeded to permanent grass cover.

Response: The land use coverage used in the modeling was obtained from Illinois Department of Natural Resource's Critical Trends Assessment database, and was supplemented by the National Agricultural Statistics Service's Cropland Data Layer. Cropland taken out of production would be reflected in these data. Current tillage practices were obtained from the most recent Soil Transect Survey conducted by the Illinois Department of Agriculture. These data were reviewed and verified to be applicable to the Kinkaid Lake watershed by local NRCS staff.

44. The KAWP 2000 erosion study (page 43) reports that sheet and rill erosion from cropland accounts for approximately 25% of the sediment delivered annually into Kinkaid Lake. Sheet and rill erosion from woodlands and grasslands account for 45% of the sediment delivered annually. The remaining sediment delivered annually comes from gully, stream bank and shoreline erosion.

Response: Although gully, stream bank and shoreline erosion are not accounted for in GWLF, they do contain as much phosphorus as the other sources. The source of phosphorus they do contain is accounted for in the Margin of Safety for the TMDL.

45. Sediment from woodlands, grasslands, stream banks and shoreline is not devoid of phosphorus even though none has been applied.

Response: Sediment loading and associated phosphorus loading from woodlands and grasslands was accounted for in the model. Loadings from stream banks and shoreline erosion would be accounted for in the margin of safety.

46. On page 4-5, it is stated that phosphorus is commonly released from sediment into the water when anoxic conditions exist. There is good potential in the upper lake (RNC4) for anoxic conditions to exist, especially during the warm season and especially west of Highway 151. Anoxic conditions occur all over the lake below the thermocline. How much of the soluble phosphorus in the lake comes from sediment deposited over the past 30 years?

Response: The data do not show that this portion of the lake stratifies so as to cause anoxic conditions. Further study would need to occur to determine the amount of phosphorus entering the lake via sediment.

47. The text on page 7-14 states that the model assumes internal cycling is not occurring in Kinkaid Lake. The shallow upper end, especially since significant siltation has occurred, does indeed qualify as a shallow reservoir.

Response: See response to 46.

48. Conservation tillage practices should be continued and encouraged as stated on page 9-2. Voluntary conversion of cropland into conservation programs should be continued and encouraged. Nutrient management is an economical and sensible practice and is already probably followed by most farmers.

Response: The Agency concurs with this statement, and these practices are discussed in the report's Implementation Plan.

49. KAWP 2000 page 30 reports that only 5% of the land adjacent to streams is in cropland. This refutes the assumption in the model that all cropland in the watershed is immediately adjacent to streams. 81% of land adjacent to streams is forested for a width of at least 200 feet from the stream and 14% is in grassland for a width of at least 200 feet.

Response: The model does not assume all cropland is adjacent to streams. It groups all land use within a sub-basin together and predicts loading from a given area. A detailed model which would require more extensive data than is available for the watershed would be needed to account for the spatially varying land use.

50. The implementation plan appears to assume that storm water runoff would flow slowly and evenly across the length of the filter strips. In a watershed as steep as Kinkaid, this will not be the case.

Response: Design of filter strips would have to take into account local conditions.

51. A map showing the intended location of the filter strips would be helpful. Further study may well indicate it would not be possible to filter strip 1900 feet of the two streams mentioned without tearing out existing riparian corridor (trees) or existing grasslands (some on steeply sloping land). Political considerations have been ignored. Much of those two streams are on U.S. Forest Service land. In the past they have not been eager to allow such alterations on their lands.

Response: The total potential length of filter strip installation was based on land use coverage used in the GIS analysis. Only land that is farmed to the edge of streams were considered as potential locations for filter strips. Land use currently in grassland or woodland was not considered, and the agency in no way is condoning such land being replaced by filter strips. The installation of filter strips is strictly voluntary. We encourage local stakeholders to further study filter strip placement in the watershed.

52. The text states that over the long term wetlands are not thought to have an effect on phosphorus entering the lake (page 9.3). Why then is it recommended to construct 134 acres of wetlands?

Response: The text states that there are varying results from wetlands. Consideration of wetlands would need to take this into account as well as site-specific design considerations.

53. Hedging statements such as those at the bottom of page 7-13, pointing out deficiencies in data plus lack of on-the-ground experience in the watershed, lead one to question the validity of both the TMDL and implementation procedures. There is a reasonable possibility that if the implementation plan is completely carried out, the TMDL will still not be in compliance.

Response: This TMDL was developed based on readily available data. We noted in the report where data gaps exist, and suggest additional data that could be collected to strengthen the correlations attempted in the report. The purpose of the Implementation Plan is to suggest practices that may help reduce phosphorus loads to the lake, which should help control pH. We recommend using an adaptive management approach in concert with future monitoring. Data from future monitoring-collected after some BMPs are installed-will determine whether or not the lake is fully supporting its designated uses and if and where additional BMPs are needed.

54. Since 1983 many improvements have been made in the watershed and efforts are on-going to do more. There is also a reasonable probability that if nothing is done to carry out the implementation plan, the lake will show compliance (unless, of course, we continue to use data from the last century).

Response: Land use data, cropping and tillage practices in the watershed were based on the most recent data and verified by county NRCS staff, which would reflect improvements made since 1983. Future assessments of Lake Kinkaid will be based on future data taken through the Ambient Lake Monitoring Program. These monitoring data will be assessed according to methodologies explained in the state's 305(b) Report. The lake will only show compliance when future data show that it is fully supporting all of it's designated uses.

55. On the basis of the TMDL report, it is difficult to see justification for expenditure of public and private funds to create the wetlands and filter strips recommended in the implementation plan.

Response: The report's Implementation Plan recommends that an adaptive management approach be taken. Not all of the recommended practices need to be installed all at once, but rather interested landowners can voluntarily enroll land in programs that provide financial assistance for implementing these practices. Landowners are free to install these practices regardless of whether or not a TMDL has been developed in their watershed. Filter strips and wetlands are recommended based on their ability to reduce the amount of nutrient-laden sediments from entering waterways.

56. Most local citizens perceive sedimentation and siltation to be the major problems at Kinkaid Lake. If we continue existing efforts to prevent sedimentation through erosion control and to manage siltation, the TMDL as perceived by the EPA will come into compliance.

Response: The goal of the TMDL is for Kinkaid Lake to fully support all of its designated uses. Future data assessments will be based on samples taken through the Clean Lake Study and the Ambient Lake Monitoring Program. The target for this TMDL is based on the numeric standard for pH, which can be achieved by reducing phosphorus loads to the lake. Much of this phosphorus enters the lake through sediment. By decreasing the amount of sediment entering the lake through implementation of the recommended BMPs, the phosphorus loads should decrease as well.

57. The only impairment the contractor addressed in the TMDL was pH due to four minor excursions over a ten-year period. The hypothesis used by the consultant is based on a hypothesis by Wetzel who asserts that photosynthesis and respiration are major influences on pH. That hypothesis would not work in RNC-4 because the light column is too short for chlorophyll-a due to the sediment in suspension. I would prefer data from Kinkaid Lake be applied to prove their hypothesis before making an assumption based on a previous study from another situation and location to suggest a relationship between phosphorus and chlorophyll-a to pH in Kinkaid Lake

Response: The TMDL takes into account the entire lake column not just segment RNC-4. It is likely that the algae activity that could be associated with pH impairments occur in different portions of the lake. . In fact, none of the pH excursions were measured in RNC-4-there were two each in RNC-1 and RNC-3.

58. Why did CDM not conclude the paucity of infractions from as large a number of samples should remove the impairment concern from Kinakid Lake? Is it a federal mandate that once a resource is placed on an impaired list, it cannot be found to be an insignificant impairment to warrant removal from the 303(d) List?

Response: pH is listed as a cause of impairment in lakes when at least one violation of the applicable standard for pH (<6.5 or >9.0) occurs during the monitoring year. The Clean Water Act mandates that TMDLs should be developed for waters listed on the State's 303(d) List. The only way a cause of impairment can be de-listed is if: 1. a TMDL is developed for that cause; 2. new data show the water body is no longer impaired for that cause; or 3. the cause is found to be "pollution" (e.g., flow reduction or habitat modification) and not a "pollutant" (e.g., pH).

59. During the final public meeting, the consultant was provided with a copy of "Kinkaid Lake Watershed Investigation" conducted July 11, 2000, by R. D. Windhorn, which arrived at figures for deposition of materials from the watershed to Kinkaid Lake. The BATHTUB model used the wrong assumption that all materials from crop fields and the watershed were deposited directly into Kinkaid Lake. That assumption is not scientifically sound and taints the model's findings. Perhaps Mr. Windhorn's data could be inserted into the model and the load form the watershed to the lake recalculated for a more accurate assessment.

Response: See response to 49.

60. Presently, the Kinkaid-Reed's Creek Conservancy District is in the middle of a Phase I Clean Lakes Study that should provide fresh data for a review on the validity and the necessity of this impairment at Kinkaid Lake. The new data should be reviewed to ascertain if the present condition of Kinkaid Lake warrants the Illinois EPA impairment concern.

Response: We concur with this statement. As new data are taken from the lake, through the Clean Lakes Study as well as the Agency's Ambient Lake Monitoring Program, the data will be used in future assessments to determine if the lake is supporting all of it's designated uses. If not, the most recent data will be assessed to determine causes of impairment. The Implementation Plan for this report includes a continued monitoring plan and an adaptive management approach for monitoring BMP effectiveness.

DISTRIBUTION OF RESPONSIVENESS SUMMARY

Additional copies of this responsiveness summary are available from Mark Britton, Illinois EPA Office of Community Relations, phone 217-524-7342 or email Mark.Britton@epa.state.il.us

ILLINOIS EPA CONTACTS

TMDL Inquiries	Bruce Yurdin	217-782-3362
Legal Questions	Sanjay Sofat	217-782-5544
Public Relations	Mark Britton	217-524-7342

Questions regarding the public record and access of the exhibits should be directed to Hearing Officer Sanjay Sofat, 217-782-5544.

Written requests can be mailed to:

Illinois Environmental Protection Agency
Bureau of Water, Watershed Management Section
1021 North Grand Avenue East
Post Office Box 19276
Springfield, IL 62794-9276

2445 16-B
R01240

Supplemental Water Data

SUMMIT ENVIRONMENTAL SERVICES, INC.
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Website: www.summitenviro.com

CLIENT: Mach Mining
PDL: 21407-1
SAMPLE ID: Pond 1
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.9	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	144	mg/L	10	2320 B	10/31/19 OG
Sulfate	113	mg/L	5	4500 E	10/29/19 KR
Chloride	80	mg/L	10	4500 B	10/29/19 KR
Hardness	244	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	< 5	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.372	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.195	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21407-2
SAMPLE ID: Pond 2
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT: DRY
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	*	Unit	1 - 14	4500 B	*
Acidity	*	mg/L	10	2310 B	*
Alkalinity	*	mg/L	10	2320 B	*
Sulfate	*	mg/L	5	4500 E	*
Chloride	*	mg/L	10	4500 B	*
Hardness	*	mg/L	10	2340 C	*
Total Suspended Solids	*	mg/L	5	2540 D	*
Settleable Solids	*	mL/L	0.25	2540 F	*
Cyanide	*	mg/L	0.02	335.4	*
Phenols, Total Recoverable	*	mg/L	0.01	420.4	*
Antimony	*	mg/L	0.0100	200.7	*
Arsenic	*	mg/L	0.0100	200.7	*
Beryllium	*	mg/L	0.0010	200.7	*
Cadmium, Total	*	mg/L	0.0020	200.7	*
Cadmium, Dissolved	*	mg/L	0.0020	200.7	*
Chromium	*	mg/L	0.0050	200.7	*
Copper	*	mg/L	0.0050	200.7	*
Iron, Total	*	mg/L	0.100	200.7	*
Iron, Dissolved	*	mg/L	0.100	200.7	*
Lead	*	mg/L	0.0060	200.7	*
Manganese, Total	*	mg/L	0.0100	200.7	*
Manganese, Dissolved	*	mg/L	0.0100	200.7	*
Mercury	*	mg/L	0.002	245.1	*
Nickel, Total	*	mg/L	0.0050	200.7	*
Nickel, Dissolved	*	mg/L	0.0050	200.7	*
Selenium	*	mg/L	0.0100	200.7	*
Silver	*	mg/L	0.0050	200.7	*
Thallium	*	mg/L	0.0200	200.7	*
Zinc	*	mg/L	0.0200	200.7	*

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21407-3
SAMPLE ID: Pond 3
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	10.7	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	176	mg/L	10	2320 B	10/31/19 OG
Sulfate	40	mg/L	5	4500 E	10/29/19 KR
Chloride	15	mg/L	10	4500 B	10/29/19 KR
Hardness	180	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	48	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	1.72	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.625	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21407-4
SAMPLE ID: Pond 4
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.3	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	136	mg/L	10	2320 B	10/31/19 OG
Sulfate	93	mg/L	5	4500 E	10/29/19 KR
Chloride	30	mg/L	10	4500 B	10/29/19 KR
Hardness	300	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	11	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.593	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.368	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.0203	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21407-5
SAMPLE ID: Pond 5
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.3	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	160	mg/L	10	2320 B	10/31/19 OG
Sulfate	60	mg/L	5	4500 E	10/29/19 KR
Chloride	18	mg/L	10	4500 B	10/29/19 KR
Hardness	276	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	39	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	2.48	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.736	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.0052	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.0255	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21407-6
SAMPLE ID: Pond 6
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.4	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	640	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,320	mg/L	5	4500 E	10/29/19 KR
Chloride	1,490	mg/L	10	4500 B	10/29/19 KR
Hardness	340	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	15	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.651	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.0772	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.0245	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	0.0168	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.0217	mg/L	0.0200	200.7	11/15/19 WA

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21407-7
SAMPLE ID: Pond 7
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.5	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	412	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,220	mg/L	5	4500 E	10/29/19 KR
Chloride	1,350	mg/L	10	4500 B	10/29/19 KR
Hardness	580	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	12	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	0.0089	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	0.0072	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	0.0123	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.801	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	2.05	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	1.82	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.140	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	0.113	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.227	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21407-8
SAMPLE ID: Pond 8
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	6.9	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	26	mg/L	10	2310 B	10/31/19 OG
Alkalinity	312	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,633	mg/L	5	4500 E	10/29/19 KR
Chloride	1,590	mg/L	10	4500 B	10/29/19 KR
Hardness	980	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	91	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	1.50	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	0.0114	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	0.0031	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	0.0155	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	60.3	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	4.19	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	3.61	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.222	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	0.100	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.288	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21407-9
SAMPLE ID: Pond 9
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	484	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,600	mg/L	5	4500 E	10/29/19 KR
Chloride	1,380	mg/L	10	4500 B	10/29/19 KR
Hardness	400	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	22	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.647	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.239	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.0488	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	0.0341	mg/L	0.0050	200.7	11/15/19 WA
Selenium	0.0172	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-1	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.6	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	116	mg/L	10	2320 B	10/31/19 OG
Sulfate	100	mg/L	5	4500 E	11/1/19 KR
Chloride	56	mg/L	10	4500 B	11/1/19 OG
Hardness	240	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	9	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.003	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.680	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.063	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.052	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21426-2
SAMPLE ID: Pond 2
DATE SAMPLED: 10/30/19

REPORT DATE: 11/26/19
COMMENT: Grab W2
SAMPLED BY: Client-BM
DATE RECEIVED: 10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.2	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	112	mg/L	10	2320 B	10/31/19 OG
Sulfate	350	mg/L	5	4500 E	11/1/19 KR
Chloride	52	mg/L	10	4500 B	11/1/19 OG
Hardness	304	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	7	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0009	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	0.0008	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.195	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.376	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.323	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.023	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.019	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.004	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-3	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.0	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	148	mg/L	10	2320 B	10/31/19 OG
Sulfate	46	mg/L	5	4500 E	11/1/19 KR
Chloride	< 10	mg/L	10	4500 B	11/1/19 OG
Hardness	184	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	5	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.001	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.003	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.634	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.106	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.250	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.025	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21426-4
SAMPLE ID: Pond 4
DATE SAMPLED: 10/30/19

REPORT DATE: 11/26/19
COMMENT: Grab W2
SAMPLED BY: Client-BM
DATE RECEIVED: 10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.9	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	12	mg/L	10	2310 B	10/31/19 OG
Alkalinity	156	mg/L	10	2320 B	10/31/19 OG
Sulfate	86	mg/L	5	4500 E	11/1/19 KR
Chloride	14	mg/L	10	4500 B	11/1/19 OG
Hardness	232	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	24	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.499	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.067	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.085	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.005	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.003	mg/L	0.001	3125 B	11/25/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-5	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.8	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	108	mg/L	10	2320 B	10/31/19 OG
Sulfate	180	mg/L	5	4500 E	11/1/19 KR
Chloride	32	mg/L	10	4500 B	11/1/19 OG
Hardness	284	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	43	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.002	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	1.575	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.321	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.296	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.135	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.004	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.003	mg/L	0.001	3125 B	11/25/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21426-6
REPORT DATE: 11/26/19
COMMENT: Precip/ Grab W2

SAMPLE ID: Pond 6
DATE SAMPLED: 10/28/19
SAMPLED BY: Client-BM
DATE RECEIVED: 10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.2	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	16	mg/L	10	2310 B	10/31/19 OG
Alkalinity	272	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,567	mg/L	5	4500 E	11/1/19 KR
Chloride	880	mg/L	10	4500 B	11/1/19 OG
Hardness	632	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	31	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0073	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	0.0073	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.012	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.704	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.147	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	1.749	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	1.749	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.096	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.094	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.019	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-7	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.1	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	16	mg/L	10	2310 B	10/31/19 OG
Alkalinity	392	mg/L	10	2320 B	10/31/19 OG
Sulfate	967	mg/L	5	4500 E	11/1/19 KR
Chloride	776	mg/L	10	4500 B	11/1/19 OG
Hardness	628	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	26	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.006	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.290	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.062	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.320	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.128	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.021	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.021	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.006	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-8	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.2	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	340	mg/L	10	2320 B	10/31/19 OG
Sulfate	967	mg/L	5	4500 E	11/1/19 KR
Chloride	1,516	mg/L	10	4500 B	11/1/19 OG
Hardness	672	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	25	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.007	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.391	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.103	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.417	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.197	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.023	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.021	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.009	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-9	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.3	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	320	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,333	mg/L	5	4500 E	11/1/19 KR
Chloride	834	mg/L	10	4500 B	11/1/19 OG
Hardness	524	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	27	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0005	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.009	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.001	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.267	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.351	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.224	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.033	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.026	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.022	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	0.0005	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21449-1
SAMPLE ID: Pond 2
DATE SAMPLED: 11/5/19

REPORT DATE: 11/27/19
COMMENT: Grab W3
SAMPLED BY: Client-BM
DATE RECEIVED: 11/5/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.7	Unit	1 - 14	4500 B	11/5/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	36	mg/L	10	2320 B	11/11/19 OG
Sulfate	540	mg/L	5	4500 E	11/11/19 KR
Chloride	26	mg/L	10	4500 B	11/6/19 KR
Hardness	610	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	39	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/5/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.354	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.063	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.037	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.006	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.005	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.015	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21451-1
SAMPLE ID: Pond 1
DATE SAMPLED: 11/6/19

REPORT DATE: 11/27/19
COMMENT: Grab W3
SAMPLED BY: Client-BM
DATE RECEIVED: 11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.6	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	116	mg/L	10	2320 B	11/11/19 OG
Sulfate	120	mg/L	5	4500 E	11/11/19 KR
Chloride	52	mg/L	10	4500 B	11/12/19 OG
Hardness	220	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.359	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.077	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.044	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.002	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.001	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.011	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-2	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	108	mg/L	10	2320 B	11/11/19 OG
Sulfate	60	mg/L	5	4500 E	11/11/19 KR
Chloride	< 10	mg/L	10	4500 B	11/12/19 OG
Hardness	108	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.003	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.275	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.073	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.054	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.002	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.009	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-3	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.2	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	100	mg/L	10	2320 B	11/11/19 OG
Sulfate	100	mg/L	5	4500 E	11/11/19 KR
Chloride	36	mg/L	10	4500 B	11/12/19 OG
Hardness	180	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.002	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.249	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.059	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.004	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.008	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21451-4
SAMPLE ID: Pond 5
DATE SAMPLED: 11/6/19

REPORT DATE: 11/27/19
COMMENT: Grab W3
SAMPLED BY: Client-BM
DATE RECEIVED: 11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.1	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	104	mg/L	10	2320 B	11/11/19 OG
Sulfate	145	mg/L	5	4500 E	11/11/19 KR
Chloride	34	mg/L	10	4500 B	11/12/19 OG
Hardness	188	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	35	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.002	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	1.233	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.245	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.213	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.126	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.007	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21451-5
SAMPLE ID: Pond 6
DATE SAMPLED: 11/6/19

REPORT DATE: 11/27/19
COMMENT: Grab W3
SAMPLED BY: Client-BM
DATE RECEIVED: 11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.6	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	12	mg/L	10	2310 B	11/11/19 OG
Alkalinity	176	mg/L	10	2320 B	11/11/19 OG
Sulfate	560	mg/L	5	4500 E	11/11/19 KR
Chloride	248	mg/L	10	4500 B	11/12/19 OG
Hardness	480	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	13	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0014	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	0.0014	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.004	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.002	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.520	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.112	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.438	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.390	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.025	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.024	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.009	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21451-6
SAMPLE ID: Pond 7
DATE SAMPLED: 11/6/19

REPORT DATE: 11/27/19
COMMENT: Grab W3
SAMPLED BY: Client-BM
DATE RECEIVED: 11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	32	mg/L	10	2310 B	11/11/19 OG
Alkalinity	720	mg/L	10	2320 B	11/11/19 OG
Sulfate	1,800	mg/L	5	4500 E	11/11/19 KR
Chloride	1,600	mg/L	10	4500 B	11/12/19 OG
Hardness	980	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0003	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.010	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.463	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.112	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.404	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.394	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.011	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.010	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.020	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-7	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	24	mg/L	10	2310 B	11/11/19 OG
Alkalinity	668	mg/L	10	2320 B	11/11/19 OG
Sulfate	1,867	mg/L	5	4500 E	11/11/19 KR
Chloride	1,799	mg/L	10	4500 B	11/12/19 OG
Hardness	780	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0003	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.010	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.399	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.374	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.356	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.011	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.010	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.020	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21451-8
SAMPLE ID: Pond 9
DATE SAMPLED: 11/6/19

REPORT DATE: 11/27/19
COMMENT: Grab W3
SAMPLED BY: Client-BM
DATE RECEIVED: 11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	432	mg/L	10	2320 B	11/11/19 OG
Sulfate	1,467	mg/L	5	4500 E	11/11/19 KR
Chloride	1,200	mg/L	10	4500 B	11/12/19 OG
Hardness	460	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	46	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.008	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.210	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.057	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.013	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.013	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.021	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21478-1
SAMPLE ID: Pond 1
DATE SAMPLED: 11/13/19

REPORT DATE: 12/3/19
COMMENT: Grab Wk4
SAMPLED BY: Client-BM
DATE RECEIVED: 11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.1	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	80	mg/L	10	2320 B	11/19/19 KR
Sulfate	115	mg/L	5	4500 E	11/15/19 KR
Chloride	54	mg/L	10	4500 B	11/18/19 OG
Hardness	108	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	7	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.260	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.085	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT: Mach Mining
PDL: 21478-2
SAMPLE ID: Pond 2
DATE SAMPLED: 11/13/19

REPORT DATE: 12/3/19
COMMENT: Grab Wk4
SAMPLED BY: Client-BM
DATE RECEIVED: 11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.3	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	100	mg/L	10	2320 B	11/19/19 KR
Sulfate	660	mg/L	5	4500 E	11/15/19 KR
Chloride	156	mg/L	10	4500 B	11/18/19 OG
Hardness	460	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	17	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	0.0008	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	0.0008	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.164	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.068	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.511	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	0.511	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.003	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-3	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.5	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	64	mg/L	10	2320 B	11/19/19 KR
Sulfate	63	mg/L	5	4500 E	11/15/19 KR
Chloride	12	mg/L	10	4500 B	11/18/19 OG
Hardness	104	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	5	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.473	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.209	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT: Mach Mining
PDL: 21478-4
SAMPLE ID: Pond 4
DATE SAMPLED: 11/13/19

REPORT DATE: 12/3/19
COMMENT: Grab Wk4
SAMPLED BY: Client-BM
DATE RECEIVED: 11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.9	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	88	mg/L	10	2320 B	11/19/19 KR
Sulfate	107	mg/L	5	4500 E	11/15/19 KR
Chloride	22	mg/L	10	4500 B	11/18/19 OG
Hardness	168	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	19	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.019	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.127	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.058	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-5	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.4	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	72	mg/L	10	2320 B	11/19/19 KR
Sulfate	130	mg/L	5	4500 E	11/15/19 KR
Chloride	38	mg/L	10	4500 B	11/18/19 OG
Hardness	176	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	19	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.384	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.147	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.139	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21478-6
SAMPLE ID: Pond 6
DATE SAMPLED: 11/13/19

REPORT DATE: 12/3/19
COMMENT: Grab Wk4
SAMPLED BY: Client-BM
DATE RECEIVED: 11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.1	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	172	mg/L	10	2320 B	11/19/19 KR
Sulfate	760	mg/L	5	4500 E	11/15/19 KR
Chloride	526	mg/L	10	4500 B	11/18/19 OG
Hardness	420	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	10	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	0.0007	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	0.0007	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.007	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.155	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.088	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.508	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	0.508	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.009	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT: Mach Mining
PDL: 21478-7
SAMPLE ID: Pond 7
DATE SAMPLED: 11/13/19

REPORT DATE: 12/3/19
COMMENT: Grab Wk4
SAMPLED BY: Client-BM
DATE RECEIVED: 11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	16	mg/L	10	2310 B	11/19/19 KR
Alkalinity	740	mg/L	10	2320 B	11/19/19 KR
Sulfate	1,933	mg/L	5	4500 E	11/15/19 KR
Chloride	1,849	mg/L	10	4500 B	11/18/19 OG
Hardness	1,200	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	14	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.021	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.045	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	1.156	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.943	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.597	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	0.597	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.020	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT: Mach Mining
PDL: 21478-8
SAMPLE ID: Pond 8
DATE SAMPLED: 11/13/19

REPORT DATE: 12/3/19
COMMENT: Grab Wk4
SAMPLED BY: Client-BM
DATE RECEIVED: 11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.0	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	630	mg/L	10	2320 B	11/19/19 KR
Sulfate	1,700	mg/L	5	4500 E	11/15/19 KR
Chloride	1,500	mg/L	10	4500 B	11/18/19 OG
Hardness	760	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	14	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.014	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.072	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.149	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.416	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	0.416	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.016	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-9	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	440	mg/L	10	2320 B	11/19/19 KR
Sulfate	1,500	mg/L	5	4500 E	11/15/19 KR
Chloride	1,250	mg/L	10	4500 B	11/18/19 OG
Hardness	360	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	16	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.010	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.008	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	< 0.050	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.016	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT: Mach Mining
PDL: 21505-1
SAMPLE ID: Pond 1
DATE SAMPLED: 11/20/19

REPORT DATE: 12/6/19
COMMENT: Grab W5
SAMPLED BY: Client-BM
DATE RECEIVED: 11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.9	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	68	mg/L	10	2320 B	11/22/19 KR
Sulfate	120	mg/L	5	4500 E	11/25/19 KR
Chloride	60	mg/L	10	4500 B	11/21/19 KR
Hardness	120	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	8	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.002	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.808	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.197	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.121	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.057	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.003	mg/L	0.001	3125 B	12/2/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT: Mach Mining
PDL: 21505-2
SAMPLE ID: Pond 2
DATE SAMPLED: 11/20/19

REPORT DATE: 12/6/19
COMMENT: Grab W5
SAMPLED BY: Client-BM
DATE RECEIVED: 11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.7	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	100	mg/L	10	2320 B	11/22/19 KR
Sulfate	590	mg/L	5	4500 E	11/25/19 KR
Chloride	172	mg/L	10	4500 B	11/21/19 KR
Hardness	550	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	5	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	0.0013	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	0.0013	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.002	mg/L	0.001	3125 B	12/2/19 AK
Copper	0.005	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.218	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.104	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.641	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.641	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.029	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.029	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.006	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT: Mach Mining
PDL: 21505-3
SAMPLE ID: Pond 3
DATE SAMPLED: 11/20/19

REPORT DATE: 12/6/19
COMMENT: Grab W5
SAMPLED BY: Client-BM
DATE RECEIVED: 11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	44	mg/L	10	2320 B	11/22/19 KR
Sulfate	68	mg/L	5	4500 E	11/25/19 KR
Chloride	16	mg/L	10	4500 B	11/21/19 KR
Hardness	104	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.548	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.262	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.185	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.146	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	12/2/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21505-4
SAMPLE ID: Pond 4
DATE SAMPLED: 11/20/19

REPORT DATE: 12/6/19
COMMENT: Grab W5
SAMPLED BY: Client-BM
DATE RECEIVED: 11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.3	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	68	mg/L	10	2320 B	11/22/19 KR
Sulfate	117	mg/L	5	4500 E	11/25/19 KR
Chloride	24	mg/L	10	4500 B	11/21/19 KR
Hardness	176	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	11	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.327	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.118	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.101	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.040	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.005	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.005	mg/L	0.001	3125 B	12/2/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-5	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.7	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	68	mg/L	10	2320 B	11/22/19 KR
Sulfate	135	mg/L	5	4500 E	11/25/19 KR
Chloride	38	mg/L	10	4500 B	11/21/19 KR
Hardness	172	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	20	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.001	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.754	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.241	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.226	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.131	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.003	mg/L	0.001	3125 B	12/2/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-6	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.2	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	132	mg/L	10	2320 B	11/22/19 KR
Sulfate	933	mg/L	5	4500 E	11/25/19 KR
Chloride	605	mg/L	10	4500 B	11/21/19 KR
Hardness	372	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	8	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	0.0010	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	0.0009	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.006	mg/L	0.001	3125 B	12/2/19 AK
Copper	0.012	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.302	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.071	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.675	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.629	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.032	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.028	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.016	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-7	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.7	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	556	mg/L	10	2320 B	11/22/19 KR
Sulfate	1,800	mg/L	5	4500 E	11/25/19 KR
Chloride	1,719	mg/L	10	4500 B	11/21/19 KR
Hardness	740	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	12	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.012	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.750	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.223	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.558	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.558	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.017	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.016	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.018	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT: Mach Mining
PDL: 21505-8
SAMPLE ID: Pond 8
DATE SAMPLED: 11/20/19

REPORT DATE: 12/6/19
COMMENT: Grab W5
SAMPLED BY: Client-BM
DATE RECEIVED: 11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	18	mg/L	10	2310 B	11/22/19 KR
Alkalinity	640	mg/L	10	2320 B	11/22/19 KR
Sulfate	2,000	mg/L	5	4500 E	11/25/19 KR
Chloride	1,969	mg/L	10	4500 B	11/21/19 KR
Hardness	800	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	14	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.004	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.015	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	1.919	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.366	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.569	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.566	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.014	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.012	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.024	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-9	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	480	mg/L	10	2320 B	11/22/19 KR
Sulfate	1,733	mg/L	5	4500 E	11/25/19 KR
Chloride	1,530	mg/L	10	4500 B	11/21/19 KR
Hardness	310	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	18	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	0.003	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.004	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.013	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.385	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.166	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.091	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.048	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.022	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.020	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.027	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT: Mach Mining
PDL: 21533-1
SAMPLE ID: Pond 2
DATE SAMPLED: 11/26/19

REPORT DATE: 12/11/19
COMMENT: W1 makeup
SAMPLED BY: Client-JP
DATE RECEIVED: 11/26/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.6	Unit	1 - 14	4500 B	11/26/19 OG
Acidity	< 10	mg/L	10	2310 B	12/2/19 OG
Alkalinity	120	mg/L	10	2320 B	12/2/19 OG
Sulfate	867	mg/L	5	4500 E	11/26/19 KR
Chloride	250	mg/L	10	4500 B	12/3/19 KR
Hardness	800	mg/L	10	2340 C	12/2/19 OG
Total Suspended Solids	8	mg/L	5	2540 D	12/3/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/26/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	12/10/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/5/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/5/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/5/19 AK
Cadmium, Total	0.0022	mg/L	0.0002	3125 B	12/5/19 AK
Cadmium, Dissolved	0.0017	mg/L	0.0002	3125 B	12/5/19 AK
Chromium	0.005	mg/L	0.001	3125 B	12/5/19 AK
Copper	0.013	mg/L	0.001	3125 B	12/5/19 AK
Iron, Total	0.063	mg/L	0.050	3125 B	12/5/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/5/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/5/19 AK
Manganese, Total	0.711	mg/L	0.020	3125 B	12/5/19 AK
Manganese, Dissolved	0.219	mg/L	0.020	3125 B	12/5/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.048	mg/L	0.001	3125 B	12/5/19 AK
Nickel, Dissolved	0.031	mg/L	0.001	3125 B	12/5/19 AK
Selenium	0.008	mg/L	0.002	3125 B	12/5/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/5/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/5/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/5/19 AK

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CLIENT: Mach Mining
PDL: 21550-1
SAMPLE ID: Pond 1
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	10	mg/L	10	2310 B	12/9/19 OG
Alkalinity	92	mg/L	10	2320 B	12/9/19 OG
Sulfate	82	mg/L	5	4500 E	12/9/19 OG
Chloride	34	mg/L	10	4500 B	12/6/19 KR
Hardness	100	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	29	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.004	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	1.897	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.253	mg/L	0.050	3125 B	12/10/19 AK
Lead	0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.121	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.074	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.002	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/16/19
PDL:	21550-2	**COMMENT:**	Grab W6
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/6/19	**DATE RECEIVED:**	12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.3	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	14	mg/L	10	2310 B	12/9/19 OG
Alkalinity	72	mg/L	10	2320 B	12/9/19 OG
Sulfate	640	mg/L	5	4500 E	12/9/19 OG
Chloride	175	mg/L	10	4500 B	12/6/19 KR
Hardness	608	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	9	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0039	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0038	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.004	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.421	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.149	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	1.185	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	1.185	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.074	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.074	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.016	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	0.059	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21550-3
SAMPLE ID: Pond 3
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.3	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	< 10	mg/L	10	2310 B	12/9/19 OG
Alkalinity	52	mg/L	10	2320 B	12/9/19 OG
Sulfate	41	mg/L	5	4500 E	12/9/19 OG
Chloride	< 10	mg/L	10	4500 B	12/6/19 KR
Hardness	64	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	23	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.004	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	2.247	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.324	mg/L	0.050	3125 B	12/10/19 AK
Lead	0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.123	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.103	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT: Mach Mining
PDL: 21550-4
SAMPLE ID: Pond 4
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.5	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	14	mg/L	10	2310 B	12/9/19 OG
Alkalinity	128	mg/L	10	2320 B	12/9/19 OG
Sulfate	95	mg/L	5	4500 E	12/9/19 OG
Chloride	18	mg/L	10	4500 B	12/6/19 KR
Hardness	236	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	15	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.002	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.612	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.151	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.750	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.736	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/16/19
PDL:	21550-5	**COMMENT:**	Grab W6
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/6/19	**DATE RECEIVED:**	12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.8	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	12	mg/L	10	2310 B	12/9/19 OG
Alkalinity	80	mg/L	10	2320 B	12/9/19 OG
Sulfate	90	mg/L	5	4500 E	12/9/19 OG
Chloride	20	mg/L	10	4500 B	12/6/19 KR
Hardness	148	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	30	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.003	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	1.666	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.349	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.174	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.149	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT: Mach Mining
PDL: 21550-6
SAMPLE ID: Pond 6
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.8	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	14	mg/L	10	2310 B	12/9/19 OG
Alkalinity	120	mg/L	10	2320 B	12/9/19 OG
Sulfate	780	mg/L	5	4500 E	12/9/19 OG
Chloride	610	mg/L	10	4500 B	12/6/19 KR
Hardness	550	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0065	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0060	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.006	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.364	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.128	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	1.734	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	1.603	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.106	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.103	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.022	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	0.095	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT: Mach Mining
PDL: 21550-7
SAMPLE ID: Pond 7
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.8	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	20	mg/L	10	2310 B	12/9/19 OG
Alkalinity	472	mg/L	10	2320 B	12/9/19 OG
Sulfate	1,220	mg/L	5	4500 E	12/9/19 OG
Chloride	1,150	mg/L	10	4500 B	12/6/19 KR
Hardness	680	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	12	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0009	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0009	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.014	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.909	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.538	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.776	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.776	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.023	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.021	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.020	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	0.217	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT: Mach Mining
PDL: 21550-8
SAMPLE ID: Pond 8
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.0	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	18	mg/L	10	2310 B	12/9/19 OG
Alkalinity	428	mg/L	10	2320 B	12/9/19 OG
Sulfate	940	mg/L	5	4500 E	12/9/19 OG
Chloride	1,000	mg/L	10	4500 B	12/6/19 KR
Hardness	610	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	14	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0010	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0010	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.012	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.505	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.311	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.694	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.694	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.024	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.024	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.016	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	0.185	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21550-9
SAMPLE ID: Pond 9
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	< 10	mg/L	10	2310 B	12/9/19 OG
Alkalinity	352	mg/L	10	2320 B	12/9/19 OG
Sulfate	1,000	mg/L	5	4500 E	12/9/19 OG
Chloride	1,000	mg/L	10	4500 B	12/6/19 KR
Hardness	450	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	29	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0019	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0019	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.010	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.513	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.103	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.661	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.661	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.048	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.048	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.027	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21406-1
SAMPLE ID: 417
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.4	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	644	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,220	mg/L	5	4500 E	10/29/19 KR
Chloride	1,250	mg/L	10	4500 B	10/29/19 KR
Hardness	344	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	28	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Ammonia	1.99	mg/L	0.02	4500B,F	10/29/19 KR
Total Phosphorus	0.13	mg/L	0.05	365.4	10/29/19 KR
Total Nitrogen	2.8	mg/L (as N)	1.0	351.2 / 353.2	10/29/19 KR
Total Kjeldahl Nitrogen	2.3	mg/L (as N)	0.5	351.2	10/29/19 KR
Total Nitrate-Nitrite	0.5	mg/L (as N)	0.5	353.2	10/29/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	0.01	mg/L	0.01	420.4	11/4/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/12/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/12/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/12/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/12/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/12/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/12/19 WA
Iron, Total	0.650	mg/L	0.100	200.7	11/12/19 WA
Iron, Dissolved	0.300	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/12/19 WA
Manganese, Total	0.0590	mg/L	0.0100	200.7	11/12/19 WA
Manganese, Dissolved	0.0504	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.0278	mg/L	0.0050	200.7	11/12/19 WA
Nickel, Dissolved	0.0192	mg/L	0.0050	200.7	11/15/19 WA
Selenium	0.0128	mg/L	0.0100	200.7	11/12/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/12/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/12/19 WA
Zinc	< 0.0200	mg/L	0.0200	200.7	11/12/19 WA

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21437-1	**COMMENT:**	Grab W2
SAMPLE ID:	417	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/1/19	**DATE RECEIVED:**	11/1/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.2	Unit	1 - 14	4500 B	11/1/19 KR
Acidity	< 10	mg/L	10	2310 B	11/4/19 OG
Alkalinity	596	mg/L	10	2320 B	11/4/19 OG
Sulfate	1,633	mg/L	5	4500 E	11/5/19 KR
Chloride	1,300	mg/L	10	4500 B	11/6/19 KR
Hardness	280	mg/L	10	2340 C	11/5/19 KR
Total Suspended Solids	28	mg/L	5	2540 D	11/4/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/1/19 KR
Ammonia	2.10	mg/L	0.02	4500B,F	11/4/19 KR
Total Phosphorus	0.10	mg/L	0.05	365.4	11/4/19 KR
Total Nitrogen	3.1	mg/L (as N)	1.0	351.2 / 353.2	11/4/19 KR
Total Kjeldahl Nitrogen	2.6	mg/L (as N)	0.5	351.2	11/4/19 KR
Total Nitrate-Nitrite	0.5	mg/L (as N)	0.5	353.2	11/4/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	0.005	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.004	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.011	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.012	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.153	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.054	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.043	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.015	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.013	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.019	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21457-1	**COMMENT:**	Grab W3
SAMPLE ID:	417	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/7/19	**DATE RECEIVED:**	11/7/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.4	Unit	1 - 14	4500 B	11/7/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	584	mg/L	10	2320 B	11/11/19 OG
Sulfate	1,367	mg/L	5	4500 E	11/11/19 KR
Chloride	1,350	mg/L	10	4500 B	11/12/19 OG
Hardness	260	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	32	mg/L	5	2540 D	11/12/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/7/19 KR
Ammonia	2.01	mg/L	0.02	4500B,F	11/8/19 KR
Total Phosphorus	0.07	mg/L	0.05	365.4	11/13/19 KR
Total Nitrogen	3.5	mg/L (as N)	1.0	351.2 / 353.2	11/13/19 KR
Total Kjeldahl Nitrogen	3.0	mg/L (as N)	0.5	351.2	11/13/19 KR
Total Nitrate-Nitrite	0.5	mg/L (as N)	0.5	353.2	11/13/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	0.003	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.009	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.003	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.107	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.037	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.008	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.007	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.022	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21479-1	**COMMENT:**	Grab Wk4
SAMPLE ID:	417	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.4	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	530	mg/L	10	2320 B	11/19/19 KR
Sulfate	1,567	mg/L	5	4500 E	11/15/19 KR
Chloride	1,799	mg/L	10	4500 B	11/18/19 OG
Hardness	1,000	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	21	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Ammonia	1.78	mg/L	0.02	4500B,F	11/14/19 KR
Total Phosphorus	0.06	mg/L	0.05	365.4	11/13/19 KR
Total Nitrogen	3.0	mg/L (as N)	1.0	351.2 / 353.2	11/13/19 KR
Total Kjeldahl Nitrogen	2.5	mg/L (as N)	0.5	351.2	11/13/19 KR
Total Nitrate-Nitrite	0.5	mg/L (as N)	0.5	353.2	11/13/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.014	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.025	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.399	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.019	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21506-1	**COMMENT:**	Grab W5
SAMPLE ID:	417	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	520	mg/L	10	2320 B	11/22/19 KR
Sulfate	1,833	mg/L	5	4500 E	11/25/19 KR
Chloride	1,570	mg/L	10	4500 B	11/21/19 KR
Hardness	380	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	49	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Ammonia	1.93	mg/L	0.02	4500B,F	11/27/19 KR
Total Phosphorus	< 0.05	mg/L	0.05	365.4	11/27/19 KR
Total Nitrogen	2.8	mg/L (as N)	1.0	351.2 / 353.2	11/27/19 KR
Total Kjeldahl Nitrogen	2.3	mg/L (as N)	0.5	351.2	11/27/19 KR
Total Nitrate-Nitrite	0.5	mg/L (as N)	0.5	353.2	11/27/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	0.004	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.004	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	0.0003	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.011	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	1.405	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.076	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.036	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.016	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.014	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.023	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/16/19
PDL:	21551-1	**COMMENT:**	Grab W6
SAMPLE ID:	417	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/6/19	**DATE RECEIVED:**	12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	< 10	mg/L	10	2310 B	12/9/19 OG
Alkalinity	604	mg/L	10	2320 B	12/9/19 OG
Sulfate	1,280	mg/L	5	4500 E	12/9/19 OG
Chloride	1,250	mg/L	10	4500 B	12/6/19 KR
Hardness	360	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	29	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Ammonia	1.04	mg/L	0.02	4500B,F	12/10/19 KR
Total Phosphorus	< 0.05	mg/L	0.05	365.4	12/10/19 KR
Total Nitrogen	3.0	mg/L (as N)	1.0	351.2 / 353.2	12/10/19 KR
Total Kjeldahl Nitrogen	2.5	mg/L (as N)	0.5	351.2	12/10/19 KR
Total Nitrate-Nitrite	0.5	mg/L (as N)	0.5	353.2	12/10/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	0.005	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.004	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0004	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0003	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.013	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.392	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.072	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.145	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.145	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.014	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.014	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.027	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	4.44	ηg/L	0.500	1631 E	1/13/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.783	ηg/L	0.500	1631 E	1/13/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	3.65	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.963	ηg/L	0.500	1631 E	1/13/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	3.57	ηg/L	0.500	1631 E	1/13/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/13/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.09	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.974	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.29	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.86	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-11	**COMMENT:**	
SAMPLE ID:	Field Blank	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/13/20 WA

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21579-1	**COMMENT:**	
SAMPLE ID:	Mach	**SAMPLED BY:**	Client-CS
DATE SAMPLED:	12/16/19	**DATE RECEIVED:**	12/16/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/23/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21589-1	**COMMENT:**	
SAMPLE ID:	Mach 2	**SAMPLED BY:**	Client-CS
DATE SAMPLED:	12/18/19	**DATE RECEIVED:**	12/19/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21589-2	**COMMENT:**	
SAMPLE ID:	Mach 3	**SAMPLED BY:**	Client-CS
DATE SAMPLED:	12/19/19	**DATE RECEIVED:**	12/19/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.109	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21603-2
SAMPLE ID: Pond 2
DATE SAMPLED: 12/20/19

REPORT DATE: 12/30/19
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.222	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.082	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.174	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-10	**COMMENT:**	
SAMPLE ID:	Mach 4 (417)	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT: Mach Mining
PDL: 21614-1
SAMPLE ID: Pond 1
DATE SAMPLED: 12/23/19

REPORT DATE: 1/2/20
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.139	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.250	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.123	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.107	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.114	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-10	**COMMENT:**	
SAMPLE ID:	Mach 4 (417)	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
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CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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Website: www.summitenviro.com

ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-10	**COMMENT:**	
SAMPLE ID:	Mach 6 (417)	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.362	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.573	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.126	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.179	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.200	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-10	**COMMENT:**	
SAMPLE ID:	Mach 7 (417)	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.400	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.085	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.730	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.280	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.299	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.247	mg/L	0.050	3125 B	1/17/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.595	mg/L	0.050	3125 B	1/17/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.118	mg/L	0.050	3125 B	1/17/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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Website: www.summitenviro.com

ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.265	mg/L	0.050	3125 B	1/17/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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Fax (618) 983-8208
Website: www.summitenviro.com

ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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AquAeTer

optimizing
resources | water, air, earth

MEMORANDUM

TO: **James Plumley**
CC: Clayton Cross
FROM: John Michael Corn, P.E. (TN)
DATE: January 17, 2020
JOB NO.: 192590
RE: **Updated CORMIX Model Results**

AquAeTer previously submitted a mixing zone report detailing the conceptual diffuser design for the proposed diffuser on the Big Muddy River. At that time, we utilized the data available to us from the USGS Plumfield gage for the channel geometry. An additional consideration for the diffuser design was the amount of debris carried by the River. During one of our reconnaissance trips on the stream, we could not access the current location from the USGS gage site due to a log jam. For that reason, we wanted to keep the ports as low as possible to reduce the possibilities of log strikes, both from the standpoint of reducing the risk of damage to the ports and to reduce the risk of log jams forming at the diffuser.

Prior to the Public Comment Period, Mr. Scott Thwaite of the Illinois Environmental Protection Agency (IEPA) requested that we revise the modeling to reduce bottom attachment.

MODEL RESULTS

The model results are shown in Table 1. The changes made to the model will be discussed in further detail in the section following this one. For most cases, Case 1 maximum flow being the exception, the distances required to achieve the necessary dispersion of 34.0:1 were shorter than those reported in the Mixing Zone Report. The Case 1 maximum flow scenario required approximately ten feet further downstream to meet 34:1. For all cases, the cross-sectional area of the plume(s) was(were) less than 25% of the cross-sectional area of the River.

In looking that the independent calculations, the plume from each port is expected to be stable. This means that the plumes will emanate from the port and expand outward in a bell-shaped geometry. This is important to keep in mind since CORMIX uses rectangular shapes for all model subsections after the initial jet zone.

Table 1. Model Results

SCENARIO	RIVER FLOW (cfs)	ACTIVE PORT(S)	TOTAL DISCHARGE (gpm)
Case 1, Min.	30	Port 1	102
Case 1, Max.	>=116	Port 1	396
Case 2, Min.	117	Ports 1 & 2	396
Case 2, Max.	>=233	Ports 1 & 2	793
Case 3, Min.	234	Ports 1, 2, &.3	793
Case 3, Max.	>=440	Ports 1, 2, & 3	1,499
Case 4, Min.	441	Ports 1, 2, 3, & 4	1,499
Case 4, Max.	>=906	Ports 1, 2, 3, & 4	3,085
Case 5, Min.	907	Ports 1, 2, 3, 4, & 5	3,085
Case 5, Max.	>=1,734	Ports 1, 2, 3, 4, & 5	5,905

SCENARIO	ACTIVE PORT(S)	ACUTE ZONE DISTANCE (ft)	ORIGINAL PREDICTED TOTAL MIXING ZONE DISTANCE (ft)	REVISED PREDICTED TOTAL MIXING ZONE DISTANCE (ft)
Case 1, Min.	Port 1	7.1	50	35
Case 1, Max.	Port 1	5.8	37	47
Case 2, Min.	Ports 1 & 2	4.4	36.6	36.6
Case 2, Max.	Ports 1 & 2	6.9	88	88
Case 3, Min.	Ports 1, 2, & 3	11.2	46	46
Case 3, Max.	Ports 1, 2, & 3	9.3	116	116
Case 4, Min.	Ports 1, 2, 3, & 4	13.9	176	176
Case 4, Max.	Ports 1, 2, 3, & 4	11.4	147	147
Case 5, Min.	Ports 1, 2, 3, 4, & 5	18.2		231.8
Case 5, Max.	Ports 1, 2, 3, 4, & 5	14.5		251

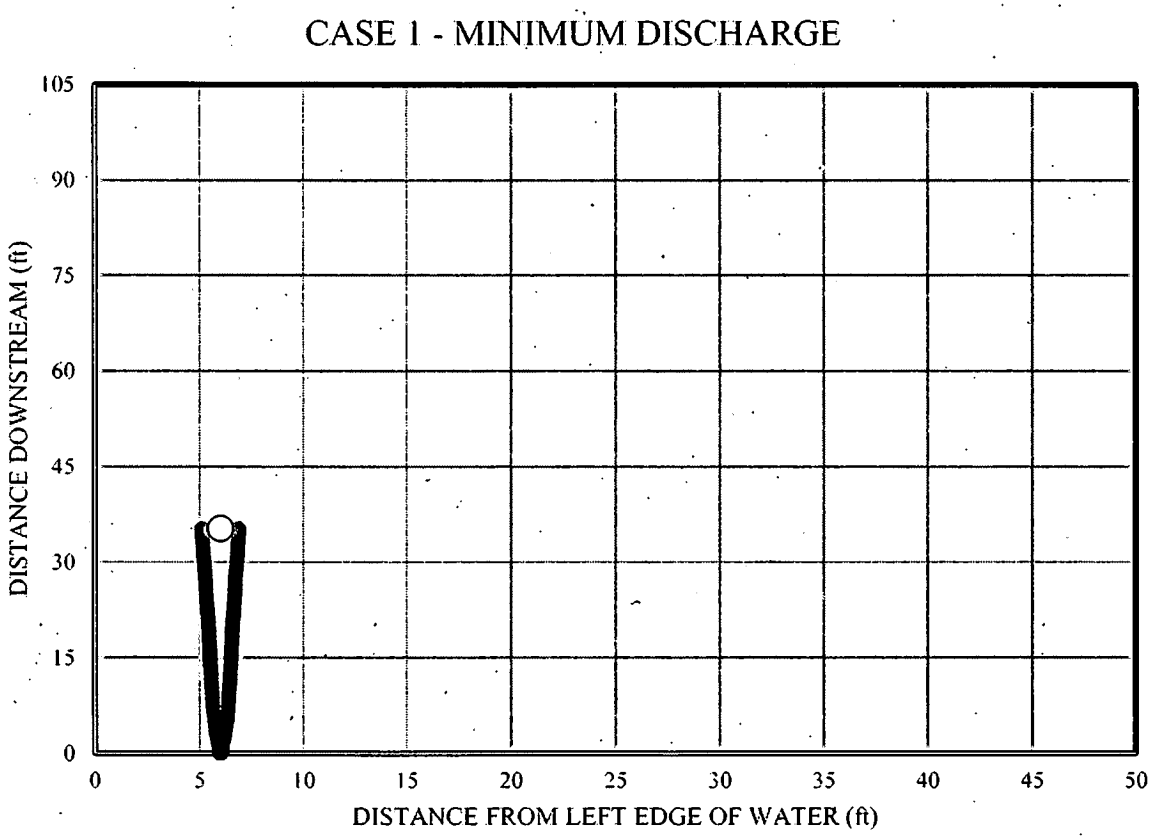
The results for each case will be discussed in more detail below, along with providing the graphics of the plan and profile views of the plume(s) for each Case.

Case 1 – 1st Port Only

Case 1 incorporates the minimum allowable flow based on the lowest projected flow for the Big Muddy River at the proposed diffuser location. Only the first port will be discharging during this condition. The discharge during this condition is 102 gallons per minute, which is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 1. The plan and profile for the maximum discharge condition under Case 1 are provided in Figure 2. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations.

Figure 1 Plan and Profile of the Model for Case 1 – Minimum Flow Condition



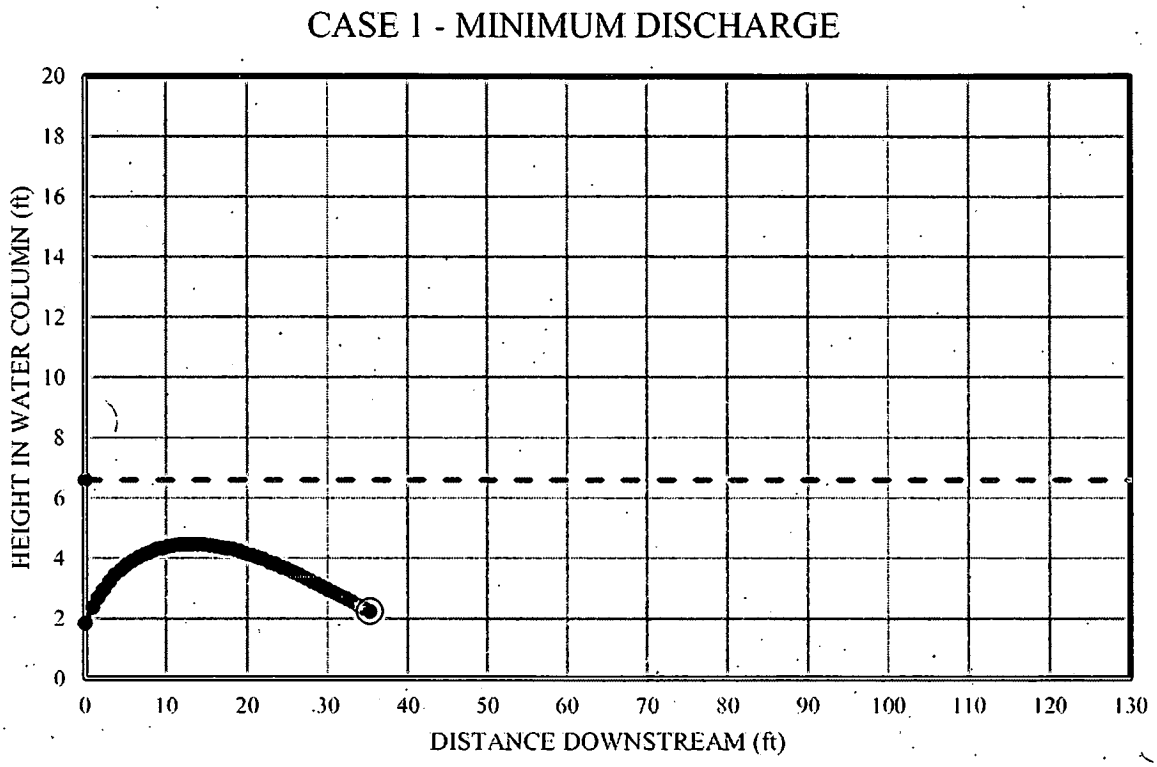
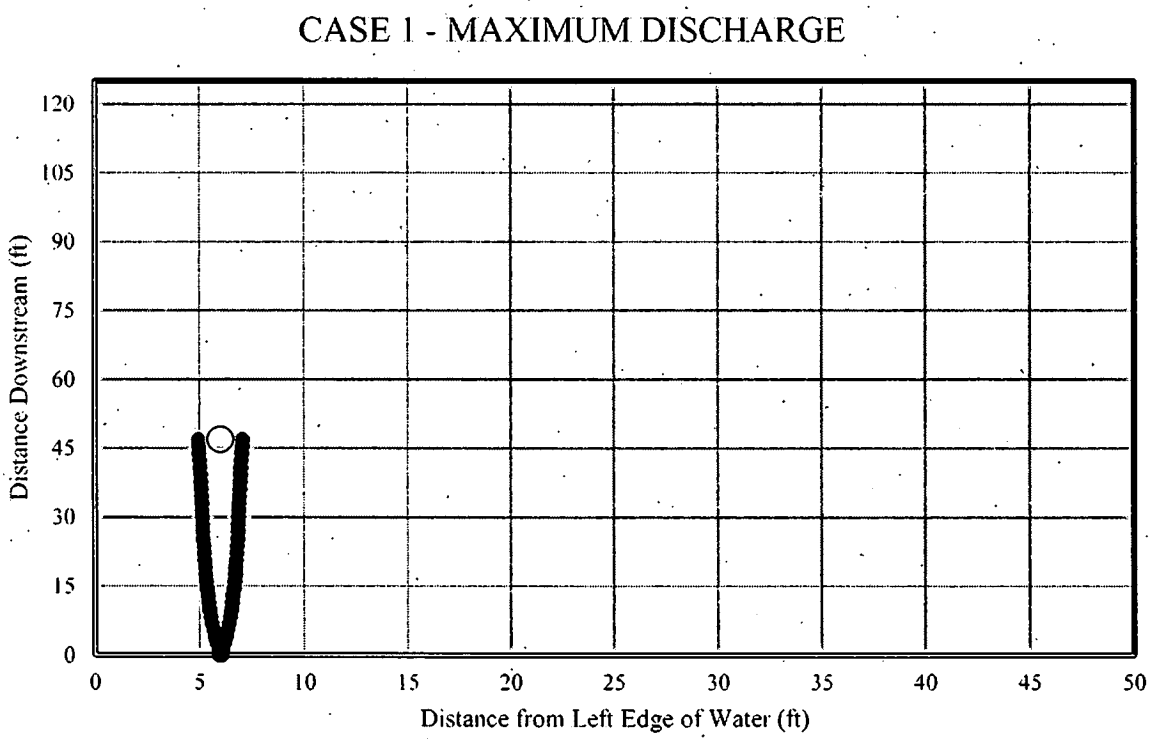
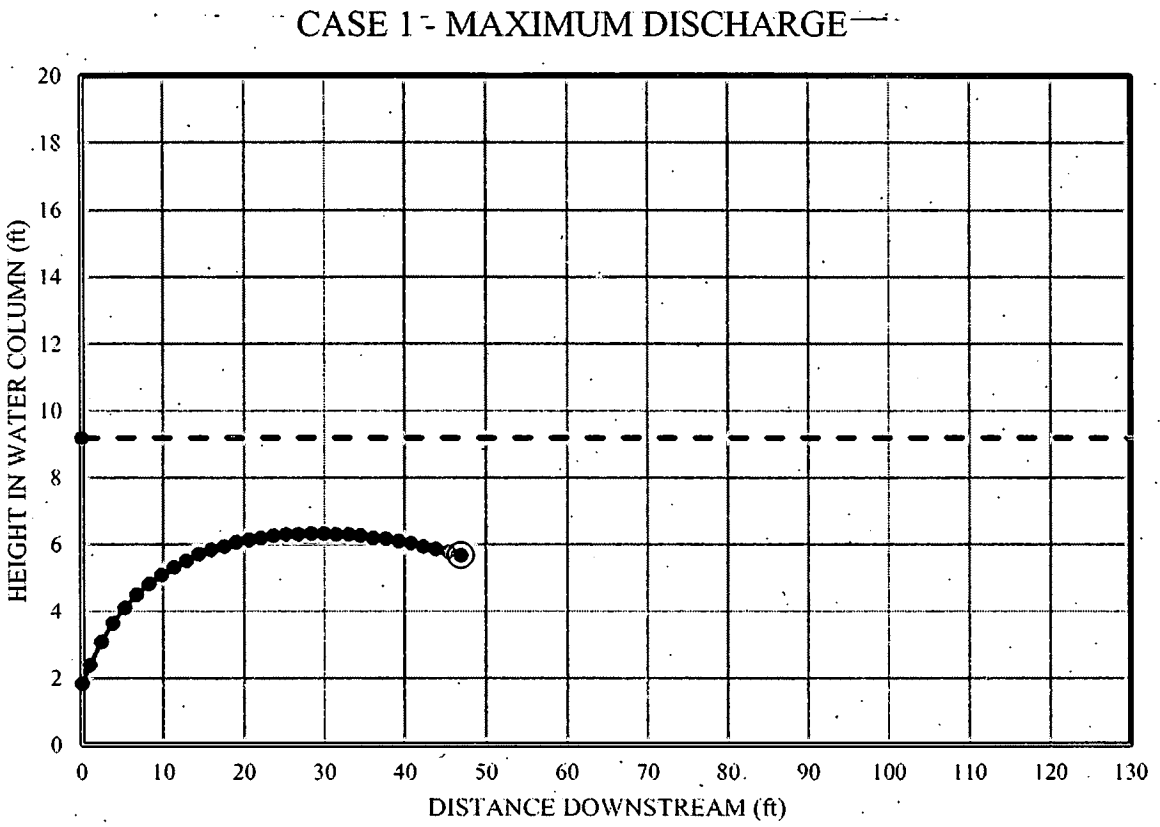


Figure 2. Plan and Profile of the Model for Case 1 – Maximum Flow Condition





These two scenarios represent the minimum and maximum flow conditions for Port 1 when only the first port is discharging. This occurs at lower River flows. The water quality criteria will be met at all flow conditions. For each of these cases, the plumes are less than 4% of the cross-sectional area.

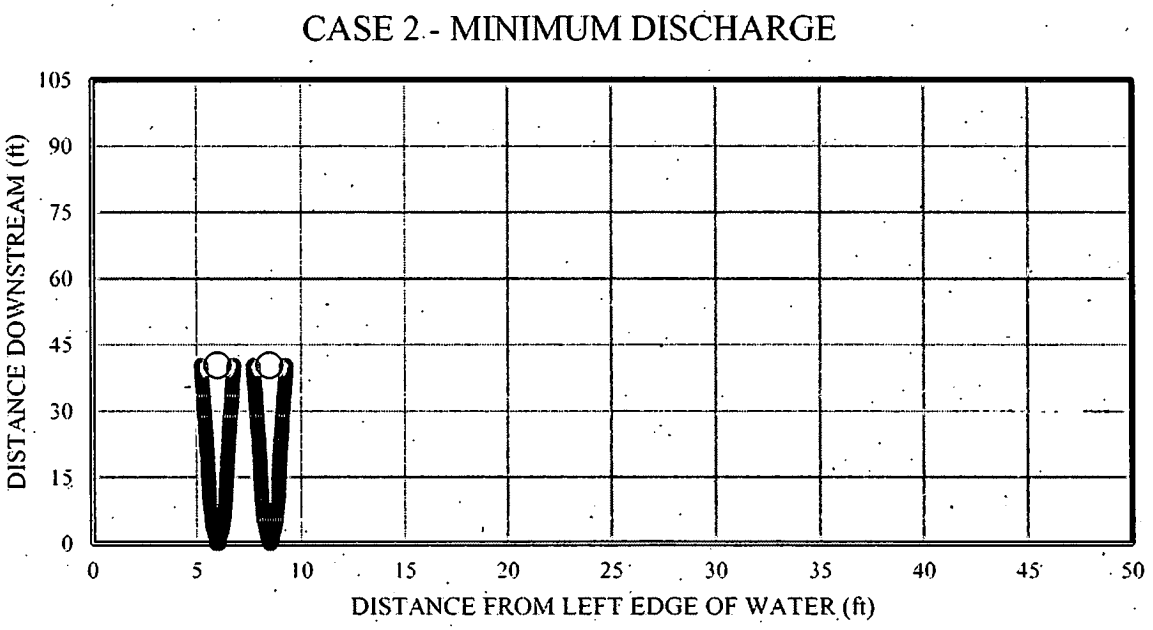
Case 2 – 1st and 2nd Ports Discharging

Case 2 begins at the maximum discharge for Case 1. Once the flow condition is met, the discharge is converted from the maximum discharge through Port 1 to equal discharges through Ports 1 and 2. In other words, the flows through Ports 1 and 2 at the Case 2 minimum flow condition are equivalent to the maximum discharge from Port 1 at Case 1. As with Case 1, the discharge during this condition is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 3. The plan and profile for the maximum discharge condition under Case 2 are provided in Figure 4. The profile picture appears as one line since the ports are equal. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations. For the minimum flow

condition, the plumes remain separate. For the maximum flow condition, the plumes merge near the point of meeting the water quality criteria.

Figure 3. Plan and Profile of the Model for Case 2 – Minimum Flow Condition



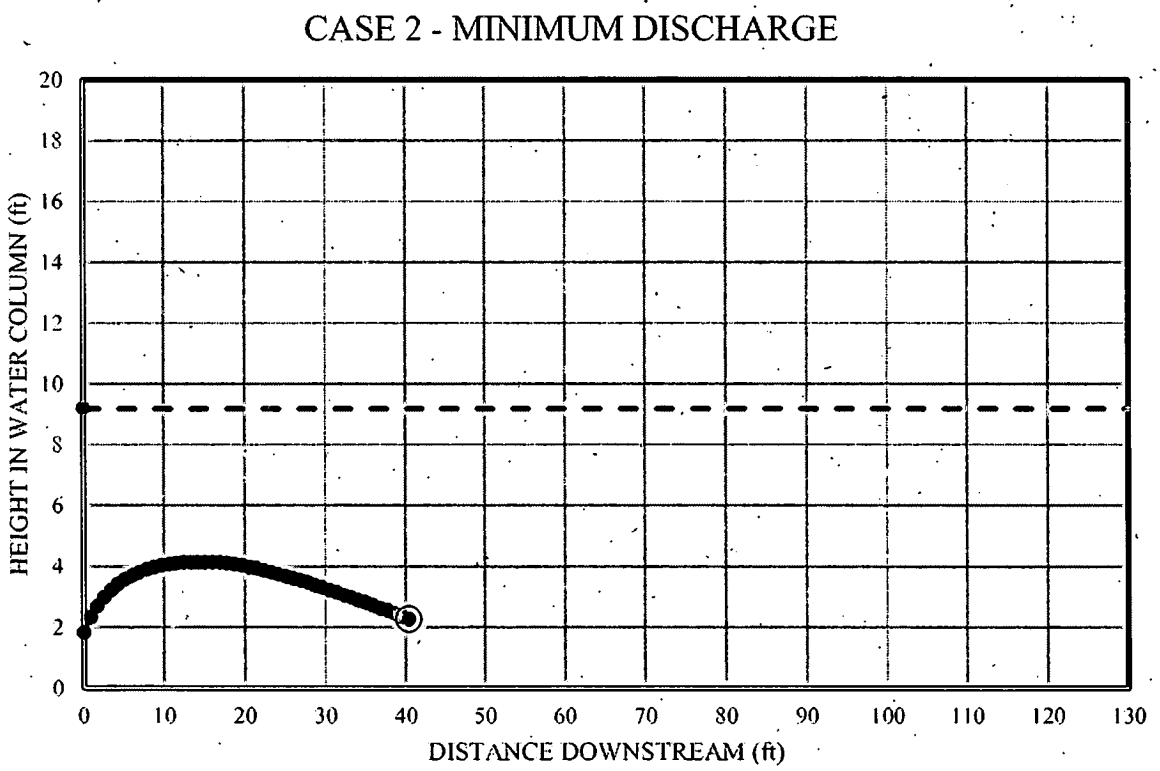
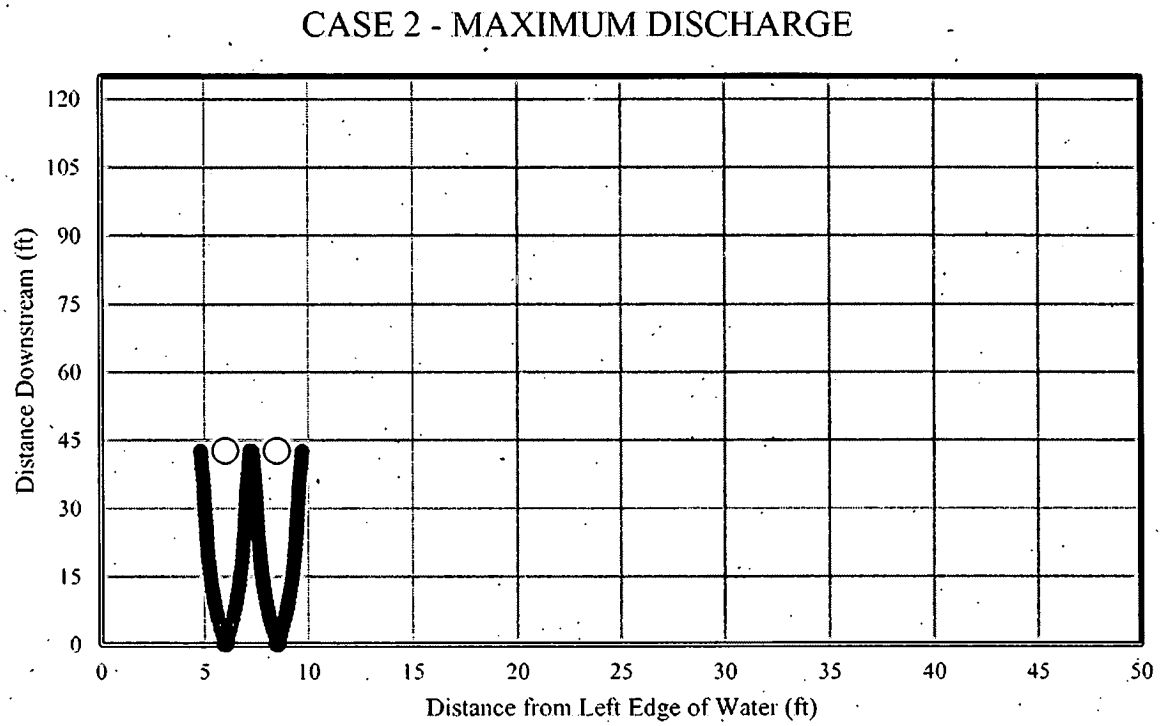
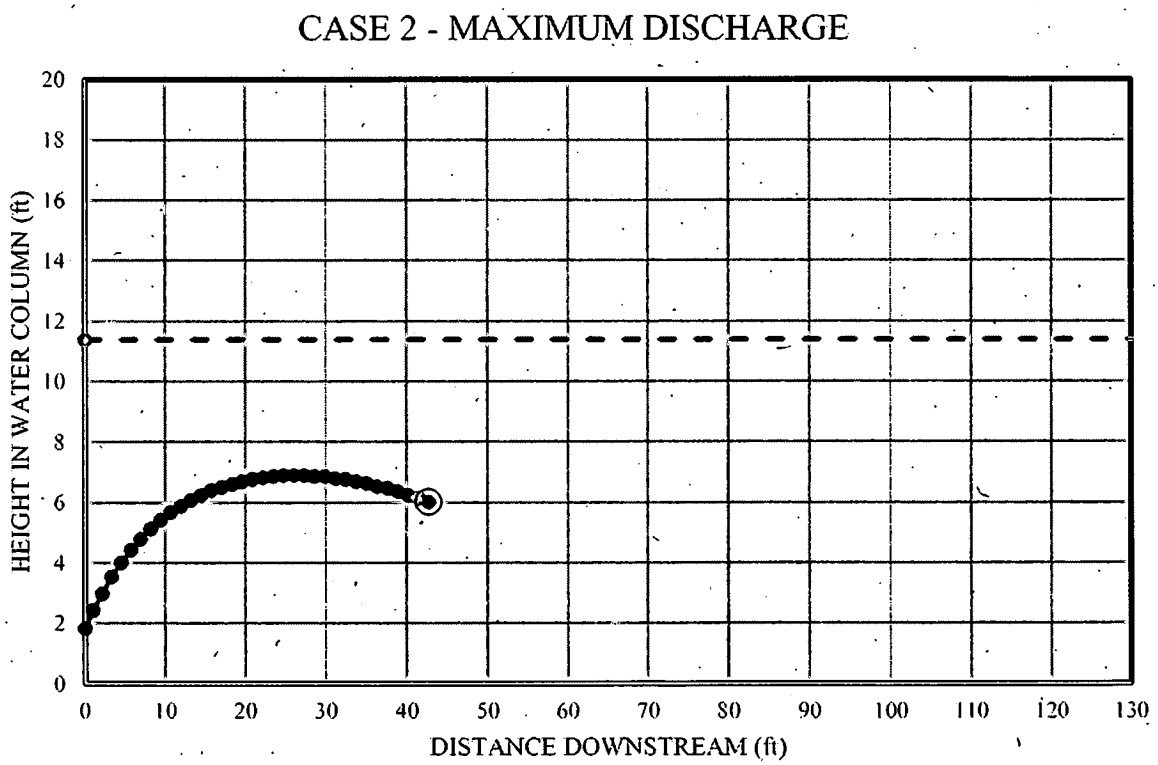


Figure 4. Plan and Profile of the Model for Case 2 – Maximum Flow Condition





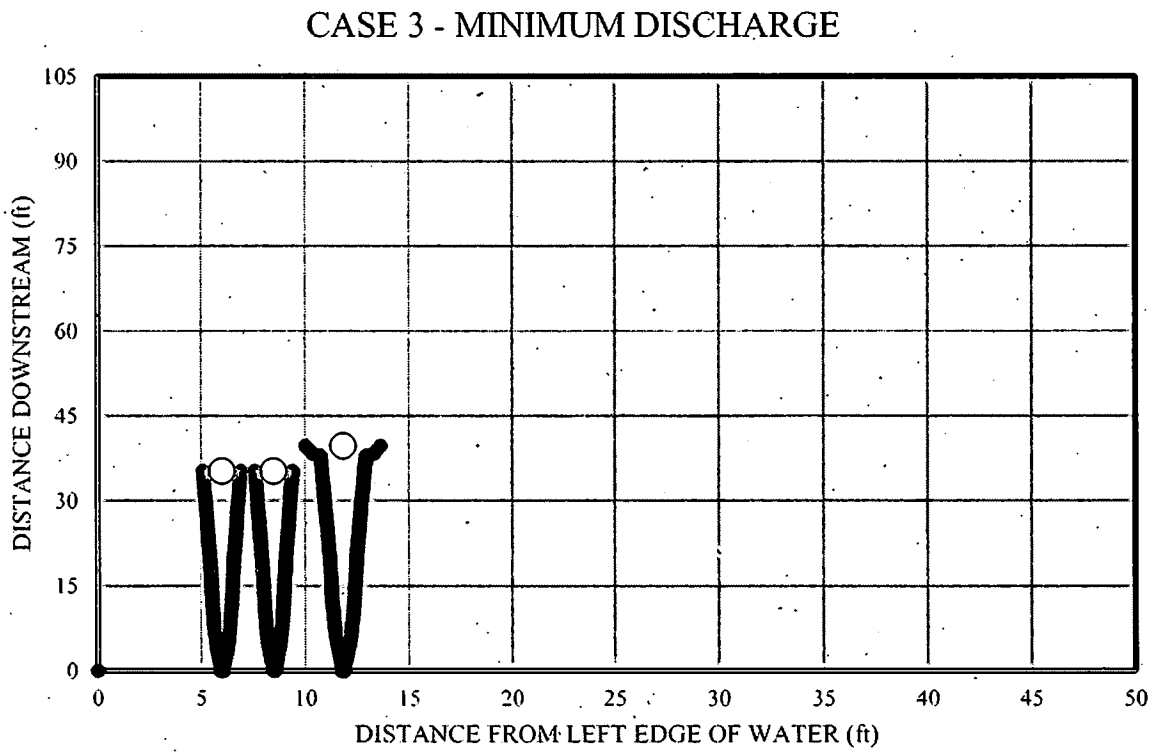
The water quality criteria will be met at all flow conditions for Case 2. For each of these scenarios, the plumes are less than 3% of the cross-sectional area. The calculation of the cross-sectional area accounts for both plumes at the point of meeting the water quality standard.

Case 3 – 1st, 2nd and 3rd Ports Discharging

Case 3 begins at the maximum discharge for Case 2. Once the flow condition is met, the discharge is converted from the maximum discharge through Ports 1 and 2 to discharges through Ports 1, 2 and 3. In other words, the flows through Ports 1, 2 and 3 at the Case 3 minimum flow condition are equivalent to the maximum discharge from Ports 1 and 2 at Case 2. As with Case 2, the discharge during this condition is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 5. The plan and profile for the maximum discharge condition under Case 3 are provided in Figure 6. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations.

Figure 5. Plan and Profile of the Model for Case 3 – Minimum Flow Condition



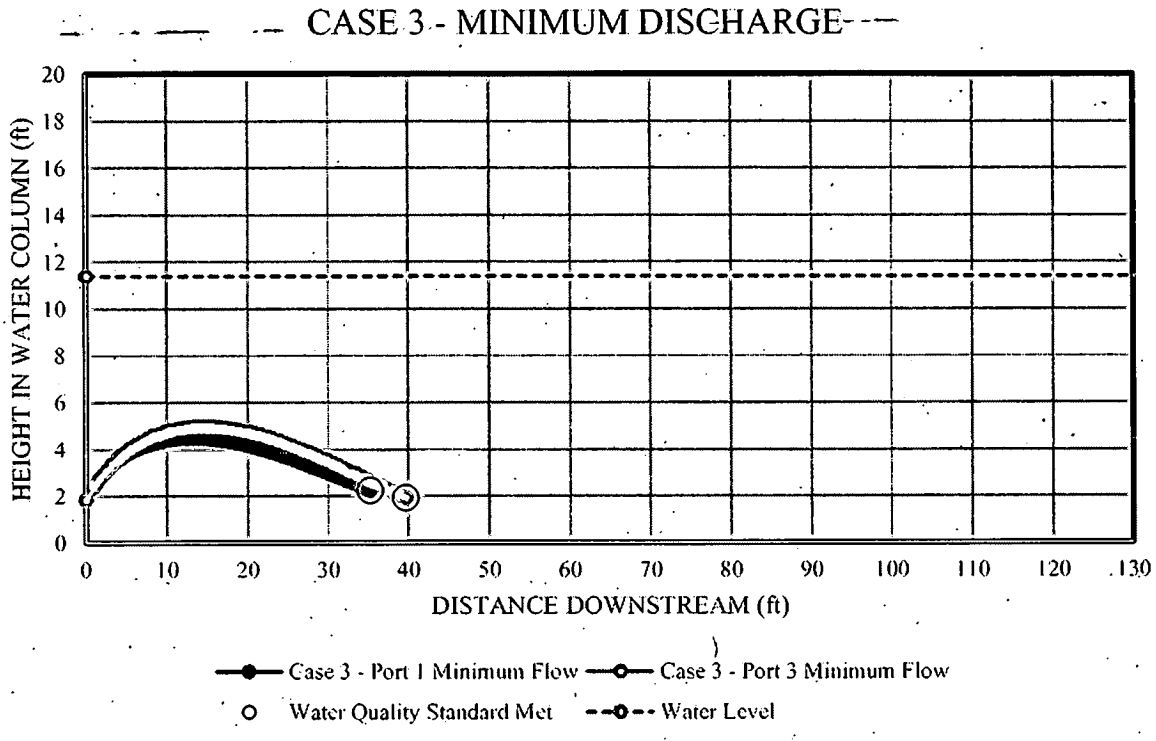
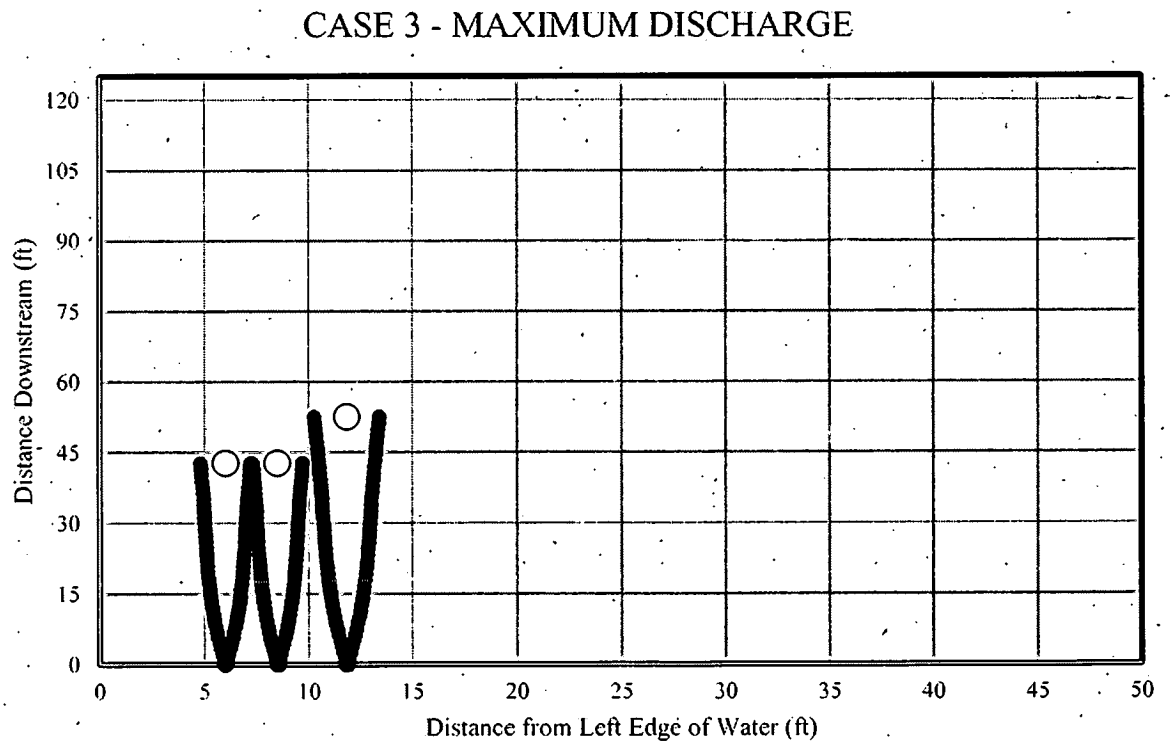
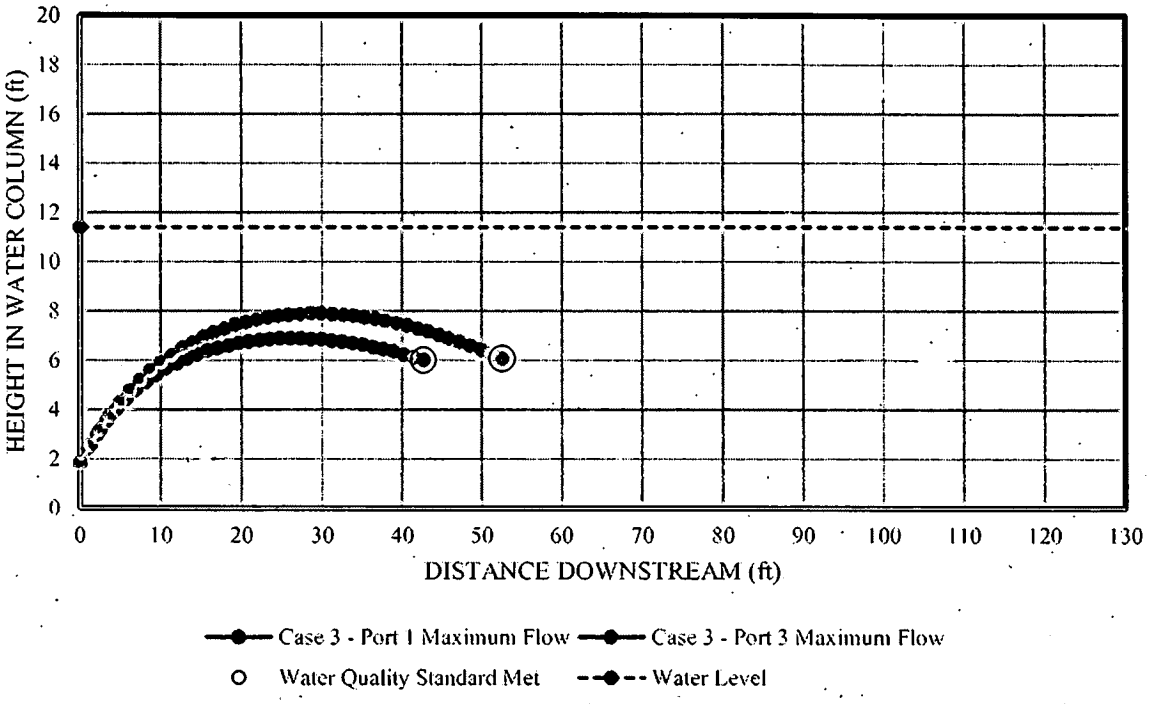


Figure 6. Plan and Profile of the Model for Case 3 – Maximum Flow Condition



CASE 3 - MAXIMUM DISCHARGE



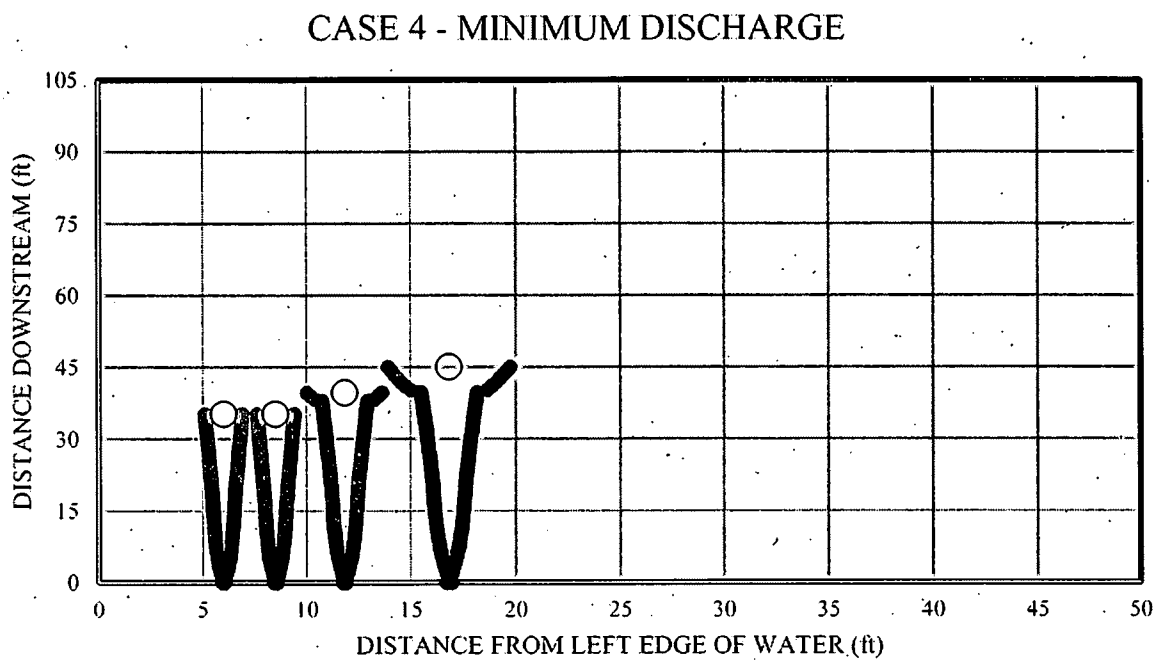
The water quality criteria will be met at all flow conditions for Case 3. For each of these scenarios, the plumes are less than 6% of the cross-sectional area. Due to the staggered and unequal flow conditions for the ports after Port 2, the water quality criteria are met at different distances downstream. Ports 1 and 2 have been predicted to have the shortest distances. For those cases in which ports 3, 4, and/or 5 are discharging, the total mixing zone for each part includes the cross-sectional areas for each port.

Case 4 – 1st, 2nd, 3rd and 4th Ports Discharging

Case 4 begins at the maximum discharge for Case 3. Once the flow condition is met, the discharge is converted from the maximum discharge through Ports 1, 2 and 3 to discharges through Ports 1, 2, 3 and 4. In other words, the flows through Ports 1, 2, 3 and 4 at the Case 4 minimum flow condition are equivalent to the maximum discharge from Ports 1, 2, and 3 at Case 3. As with the previous cases, the discharge during this condition is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 7. The plan and profile for the maximum discharge condition under Case 4 are provided in Figure 8. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations.

Figure 7. Plan and Profile of the Model for Case 4 – Minimum Flow Condition



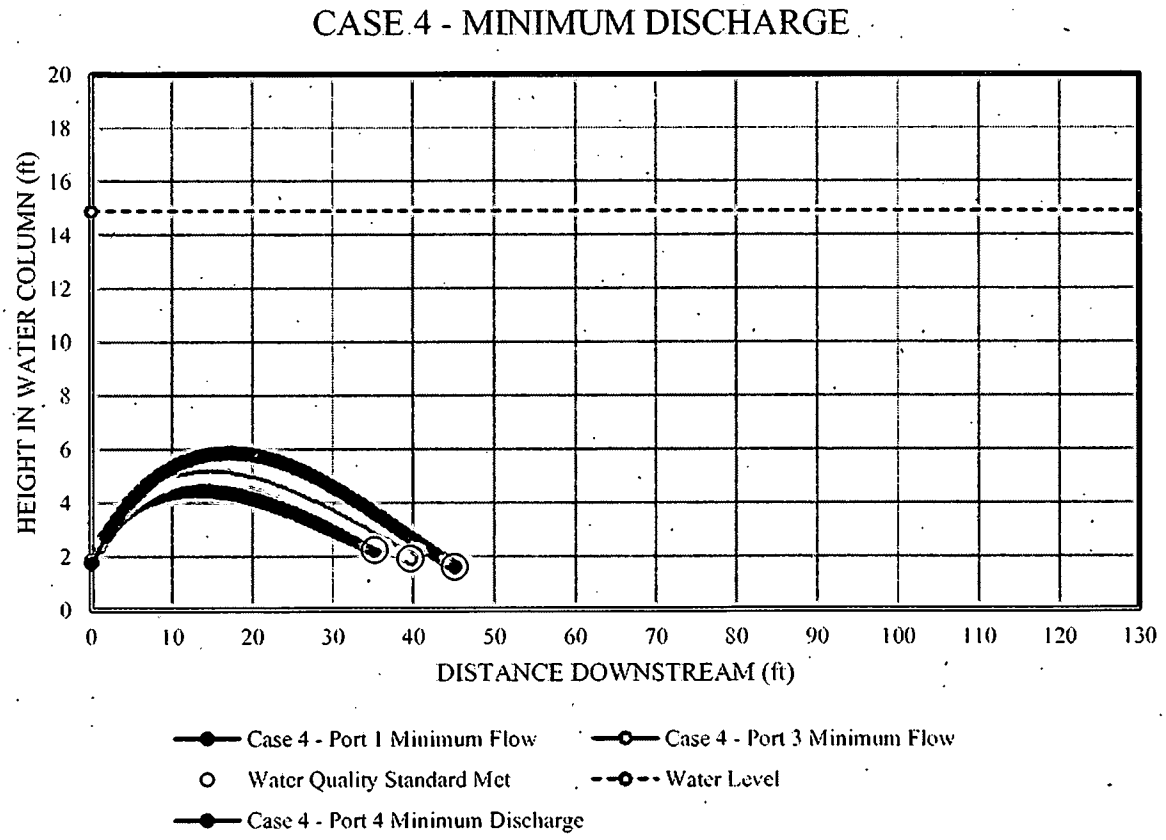
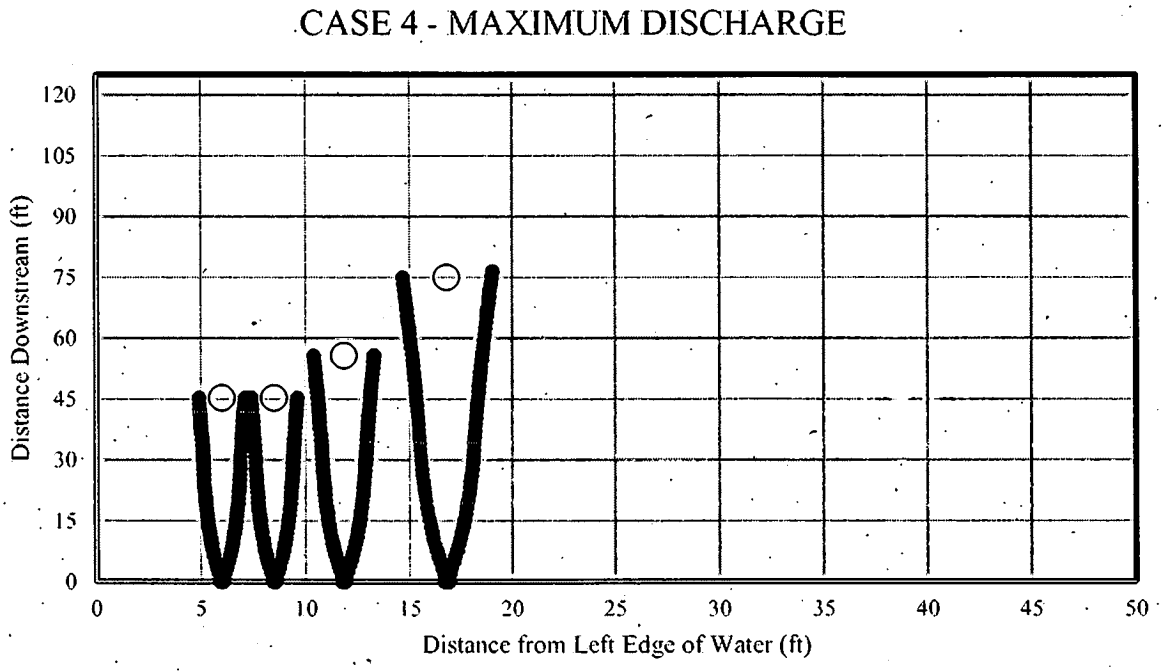
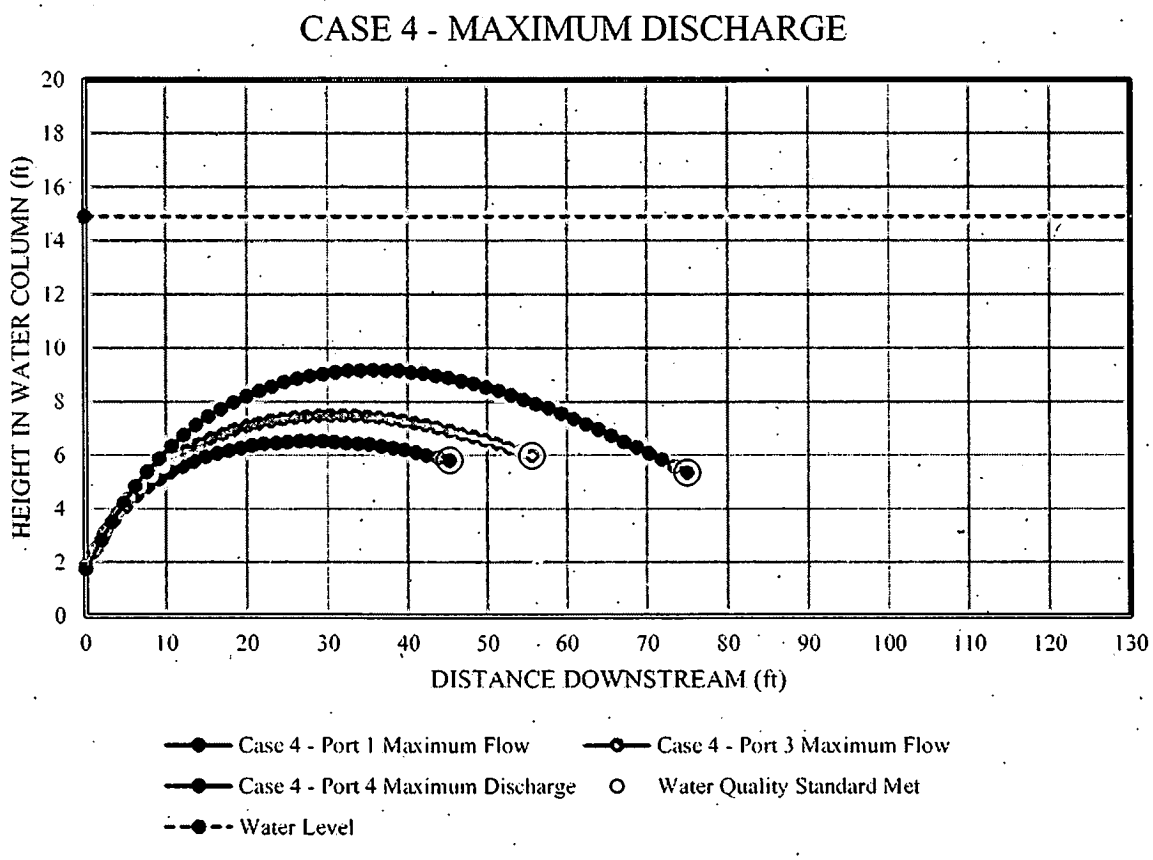


Figure 8. Plan and Profile of the Model for Case 4 – Maximum Flow Condition





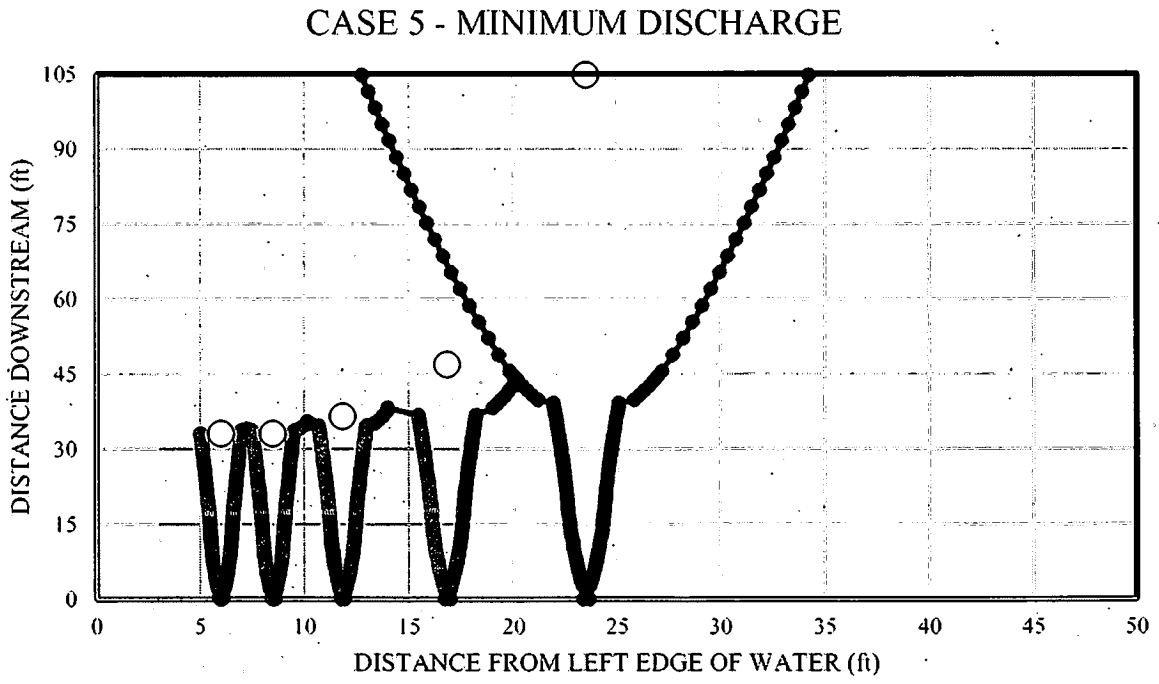
The water quality criteria will be met at all flow conditions for Case 4. For each of these scenarios, the plumes are less than 8% of the cross-sectional area. Due to the staggered and unequal flow conditions for the ports after Port 2, the water quality criteria are met at different distances downstream. Ports 1 and 2 have been predicted to have the shortest distances. For those cases in which ports 3, 4, and/or 5 are discharging, the total mixing zone for each part includes the cross-sectional areas for each port at the distance met by the respective port.

Case 5 – 1st, 2nd, 3rd, 4th and 5th Ports Discharging

Case 5 begins at the maximum discharge for Case 4. Once the flow condition is met, the discharge is converted from the maximum discharge through Ports 1, 2, 3 and 4 to discharges through Ports 1, 2, 3, 4 and 5. In other words, the flows through Ports 1, 2, 3, 4 and 5 at the Case 5 minimum flow condition are equivalent to the maximum discharge from Ports 1, 2, 3 and 4 at Case 4. As with the previous cases, the discharge during this condition is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 9. The plan and profile for the maximum discharge condition under Case 5 are provided in Figure 10. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations.

Figure 9. Plan and Profile of the Model for Case 5 – Minimum Flow Condition



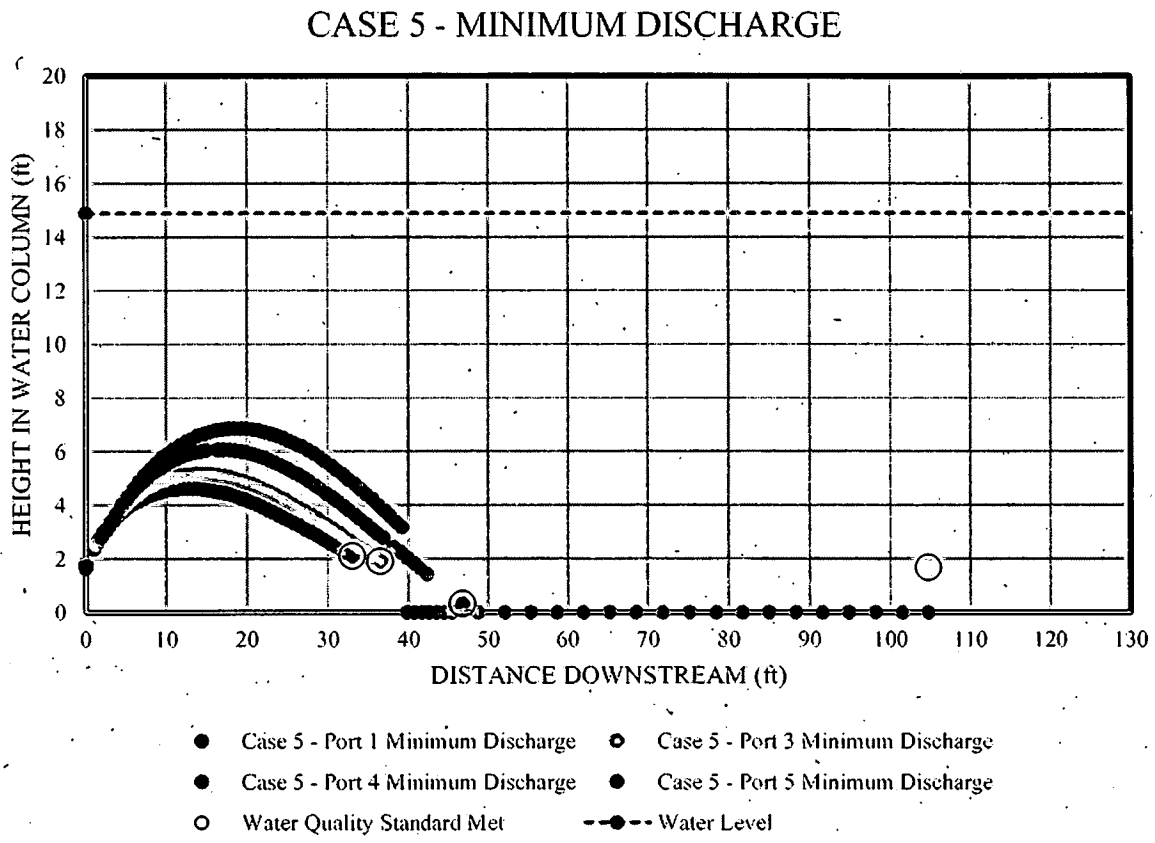
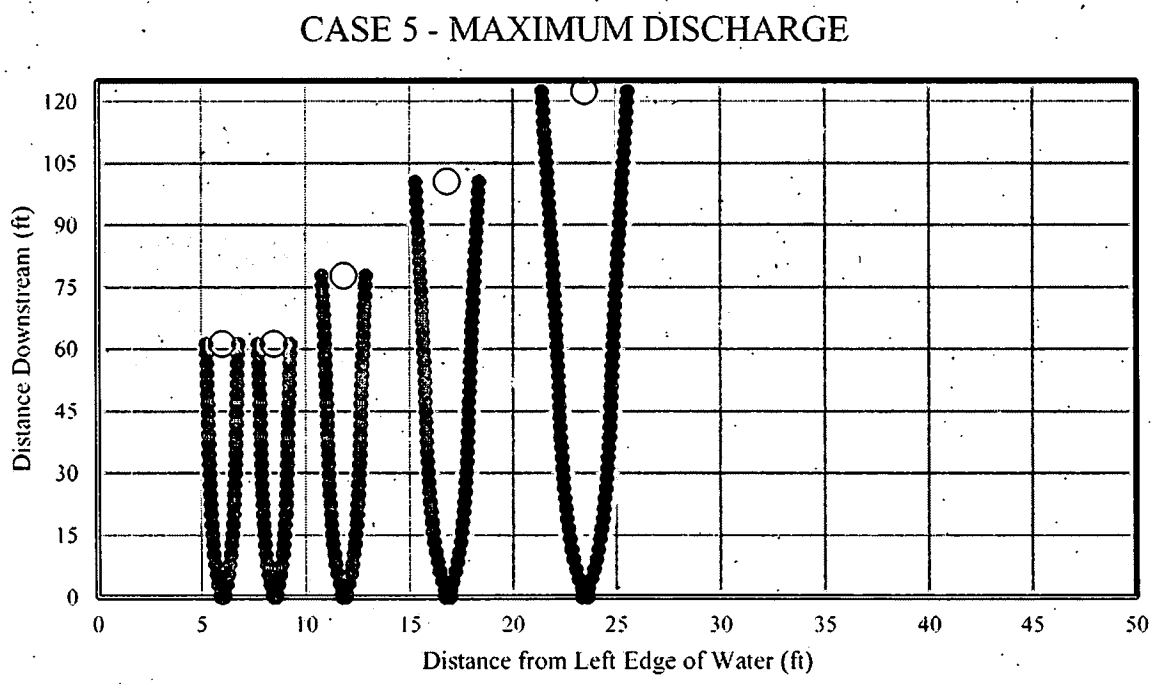
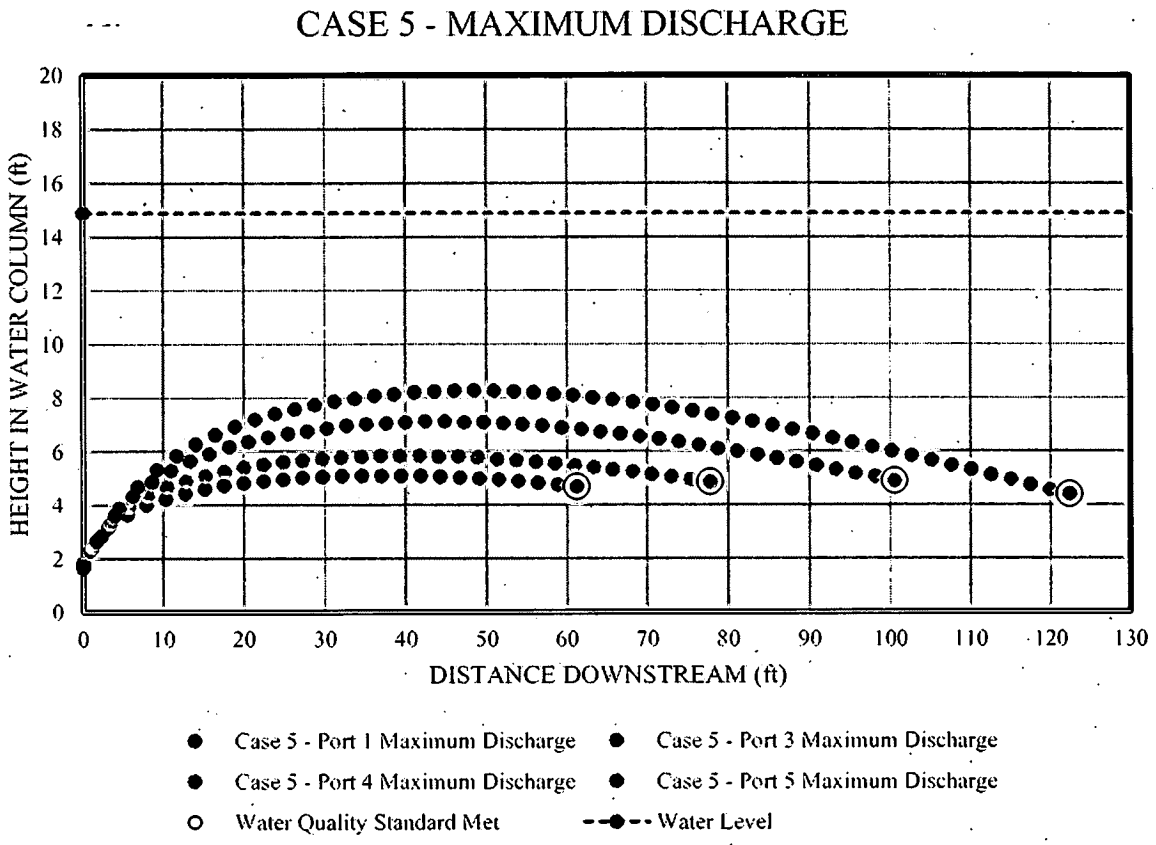


Figure 10. Plan and Profile of the Model for Case 5 – Maximum Flow Condition





The water quality criteria will be met at all flow conditions for Case 5. For each of these scenarios, the plumes are less than 8% of the cross-sectional area. Due to the staggered and unequal flow conditions for the ports after Port 2, the water quality criteria are met at different distances downstream. Ports 1 and 2 have been predicted to have the shortest distances. For those cases in which ports 3, 4, and/or 5 are discharging, the total mixing zone for each part includes the cross-sectional areas for each port at the distance met by the respective port.

It is noted that the apparent bottom interaction for Port 5 at its minimum discharge condition is an artifact of CORMIX's modules. The plume is predicted to extend higher at this point than when the centerline is projected at its maximum height.

UPDATES TO THE MODEL

As part of the project, Horner & Shifrin's design includes a transect of the proposed diffuser location. An excerpt of this transect is shown in Figure 11. The following data were derived for each of the model cases. The transect was treated as a trapezoid. For modeling purposes, CORMIX utilizes rectangular dimensions. The cross-sectional area of the trapezoid was translated to a rectangle for the model by keeping the height constant, then determining the width of the model rectangle. The dimensions for the River for the various cases are shown in Table 2.

Figure 11. Transect at Proposed Diffuser Location, Excerpt from Horner & Shifrin Design documents

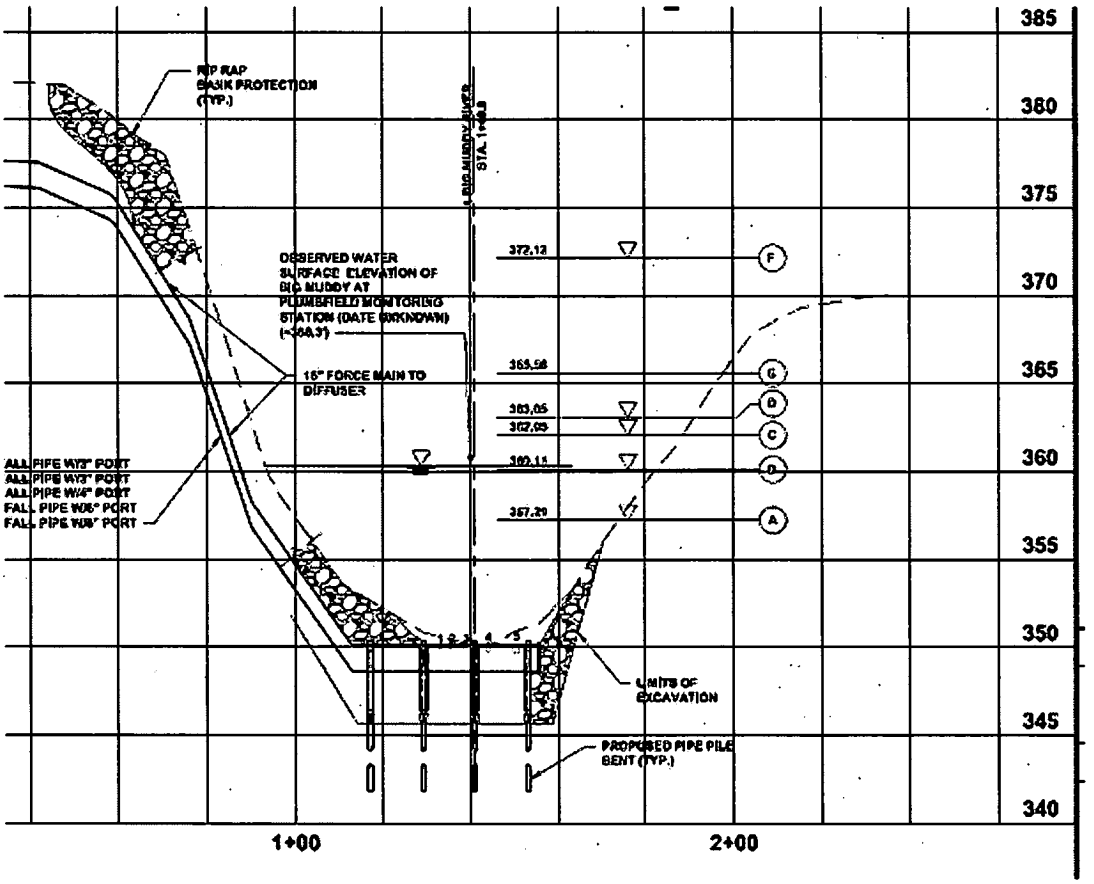


Table 2. Transect Dimensions

CASE	FLOW CONDITION	WATER COLUMN HEIGHT (ft)	AREA (ft^2)
Case 1	Minimum	6.6	376
	Maximum	9.2	605
Case 2	Minimum	9.2	605
	Maximum	11.4	807
Case 3	Minimum	11.4	807
	Maximum	12.5	903
Case 4	Minimum	12.5	903
	Maximum	14.9	1159
Case 5	Minimum	14.9	1159
	Maximum	14.9	1159

If you should have questions or comments concerning our assessment, please call us at (615) 373-8532 or by FAX at (615) 373-8512 or by e-mail at jmcorn@aquaeter.com.

MAC1-1N1.CX1

CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111

CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:
Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION
Site name/label: MACH^BIG^MUDDY^RIVER
Design case: CASE^1^-^PORT^1^NORMAL^FLOW
FILE NAME: cormix\sim\MAC1-1N1.cx1
Time of Fortran run: 01/13/20--21:45:52

ENVIRONMENT PARAMETERS (metric units)
Bounded section
BS = 17.37 AS = 34.91 QA = 10.02 ICHREG= 2
HA = 2.01 HD = 2.01
UA = .287 F = .076 USTAR = .2801E-01
UW = 2.000 UWSTAR= .2198E-02
Uniform density environment
STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)
BANK = LEFT DISTB = 8.00
D0 = .076 A0 = .005 H0 = .56
THETA = 30.00 SIGMA = .00
U0 = 2.866 Q0 = .013 = .1307E-01
RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00
C0 = .1000E+04 CUNITS= PPM
IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)
Q0 = .1307E-01 M0 = .3746E-01 J0 =-.1913E-02 SIGNJ0= -1.0
Associated length scales (meters)
LQ = .07 LM = 1.95 Lm = .67 Lb = .08
Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS
FR0 = 27.14 R = 9.98

FLOW CLASSIFICATION
11111111111111111111111111111111111111111
1 Flow class (CORMIX1) = NH4 1
1 Applicable layer depth HS = 2.01 1
11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1000E+04 CUNITS= PPM

MAC1-1N1.CX1

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1000.00  XMAX   =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
         8.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .56     1.0   .100E+04     .04

END OF MOD101: DISCHARGE MODULE
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.17  SIGMAE=      .00
  LE    =       .32  XE    =       .28  YE    =       .00  ZE    =       .72

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .56     1.0   .100E+04     .04
      .28      .00      .72     1.0   .100E+04     .04
      .48      .00      .82     1.6   .640E+03     .07
      .68      .00      .90     2.3   .433E+03     .09
      .90      .00      .98     3.1   .321E+03     .12
     1.11      .00     1.05     3.9   .256E+03     .14
     1.33      .00     1.10     4.7   .212E+03     .16
     1.55      .00     1.15     5.5   .183E+03     .18
     1.77      .00     1.19     6.2   .161E+03     .19
     2.00      .00     1.23     6.9   .144E+03     .21
     2.22      .00     1.26     7.6   .132E+03     .22
     2.44      .00     1.28     8.2   .122E+03     .23
     2.67      .00     1.31     8.8   .114E+03     .24
     2.89      .00     1.32     9.3   .107E+03     .25
     3.12      .00     1.34     9.9   .101E+03     .26
```

3.34	.00	1.35	10.3	.970E+02	.27
3.57	.00	1.36	10.7	.931E+02	.28
3.79	.00	1.36	11.1	.899E+02	.28
4.02	.00	1.36	11.5	.872E+02	.29

Maximum jet height has been reached.

4.24	.00	1.36	11.8	.848E+02	.30
4.47	.00	1.36	12.2	.823E+02	.30
4.69	.00	1.35	12.6	.796E+02	.31
4.92	.00	1.34	13.0	.769E+02	.31
5.15	.00	1.33	13.5	.742E+02	.32
5.37	.00	1.32	14.0	.715E+02	.33
5.59	.00	1.31	14.5	.689E+02	.34
5.82	.00	1.29	15.1	.662E+02	.34
6.04	.00	1.27	15.7	.637E+02	.35
6.27	.00	1.25	16.4	.611E+02	.36
6.49	.00	1.23	17.0	.588E+02	.37
6.72	.00	1.21	17.7	.564E+02	.38
6.94	.00	1.18	18.5	.542E+02	.39
7.16	.00	1.16	19.2	.521E+02	.40
7.39	.00	1.13	20.0	.500E+02	.41
7.61	.00	1.11	20.8	.480E+02	.42
7.84	.00	1.08	21.7	.461E+02	.43
8.06	.00	1.05	22.5	.444E+02	.43
8.28	.00	1.02	23.4	.427E+02	.44
8.51	.00	.99	24.3	.411E+02	.45
8.73	.00	.96	25.3	.396E+02	.46
8.95	.00	.93	26.2	.381E+02	.47
9.17	.00	.90	27.2	.368E+02	.48
9.39	.00	.87	28.2	.355E+02	.49
9.62	.00	.84	29.2	.342E+02	.50
9.84	.00	.81	30.2	.331E+02	.51
10.07	.00	.78	31.3	.319E+02	.52
10.29	.00	.74	32.4	.309E+02	.53
10.52	.00	.71	33.5	.299E+02	.54
10.74	.00	.68	34.6	.289E+02	.55
10.96	.00	.65	35.7	.280E+02	.56
11.18	.00	.62	36.8	.271E+02	.57
11.40	.00	.58	38.0	.263E+02	.58

Cumulative travel time = 22. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
11.40	.00	.58	38.0	.263E+02	.58

MAC1-1N1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.82	.00	.00	38.0	.263E+02	.00	.00	.00	.00
11.00	.00	.00	38.0	.263E+02	.76	.38	.76	.00
11.17	.00	.00	38.0	.263E+02	.90	.54	.90	.00
11.35	.00	.00	38.0	.263E+02	1.00	.66	1.00	.00
11.52	.00	.00	39.0	.256E+02	1.06	.77	1.06	.00
11.70	.00	.00	43.8	.228E+02	1.11	.86	1.11	.00
11.87	.00	.00	50.5	.198E+02	1.15	.94	1.15	.00
12.04	.00	.00	56.6	.177E+02	1.18	1.01	1.18	.00
12.22	.00	.00	60.8	.164E+02	1.20	1.08	1.20	.00
12.39	.00	.00	63.1	.159E+02	1.21	1.15	1.21	.00
12.57	.00	.00	64.5	.155E+02	1.21	1.21	1.21	.00

Cumulative travel time = 26. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
12.57	.00	.00	64.5	.155E+02	1.21	1.21	1.21	.00
13.33	.00	.00	66.1	.151E+02	1.15	1.31	1.15	.00
14.10	.00	.00	67.6	.148E+02	1.10	1.40	1.10	.00
14.86	.00	.00	69.0	.145E+02	1.05	1.49	1.05	.00
15.63	.00	.00	70.4	.142E+02	1.01	1.58	1.01	.00
16.39	.00	.00	71.8	.139E+02	.98	1.67	.98	.00
17.15	.00	.00	73.2	.137E+02	.95	1.75	.95	.00
17.92	.00	.00	74.6	.134E+02	.93	1.83	.93	.00
18.68	.00	.00	76.0	.132E+02	.91	1.91	.91	.00

19.45	.00	.00	77.5	.129E+02	.89	1.99	.89	.00
20.21	.00	.00	78.9	.127E+02	.87	2.06	.87	.00
20.98	.00	.00	80.4	.124E+02	.86	2.14	.86	.00
21.74	.00	.00	81.9	.122E+02	.84	2.21	.84	.00
22.50	.00	.00	83.5	.120E+02	.83	2.28	.83	.00
23.27	.00	.00	85.1	.117E+02	.82	2.35	.82	.00
24.03	.00	.00	86.8	.115E+02	.81	2.42	.81	.00
24.80	.00	.00	88.4	.113E+02	.81	2.49	.81	.00
25.56	.00	.00	90.2	.111E+02	.80	2.56	.80	.00
26.33	.00	.00	92.0	.109E+02	.80	2.63	.80	.00
27.09	.00	.00	93.8	.107E+02	.79	2.70	.79	.00
27.85	.00	.00	95.7	.104E+02	.79	2.76	.79	.00
28.62	.00	.00	97.6	.102E+02	.79	2.83	.79	.00
29.38	.00	.00	99.6	.100E+02	.78	2.89	.78	.00
30.15	.00	.00	101.7	.983E+01	.78	2.95	.78	.00
30.91	.00	.00	103.8	.963E+01	.78	3.02	.78	.00
31.68	.00	.00	106.0	.943E+01	.78	3.08	.78	.00
32.44	.00	.00	108.3	.924E+01	.78	3.14	.78	.00
33.20	.00	.00	110.6	.904E+01	.79	3.20	.79	.00
33.97	.00	.00	112.9	.885E+01	.79	3.26	.79	.00
34.73	.00	.00	115.4	.867E+01	.79	3.32	.79	.00
35.50	.00	.00	117.9	.848E+01	.79	3.38	.79	.00
36.26	.00	.00	120.5	.830E+01	.80	3.44	.80	.00
37.03	.00	.00	123.1	.812E+01	.80	3.50	.80	.00
37.79	.00	.00	125.8	.795E+01	.81	3.55	.81	.00
38.55	.00	.00	128.6	.778E+01	.81	3.61	.81	.00
39.32	.00	.00	131.5	.761E+01	.82	3.67	.82	.00
40.08	.00	.00	134.4	.744E+01	.82	3.73	.82	.00
40.85	.00	.00	137.4	.728E+01	.83	3.78	.83	.00
41.61	.00	.00	140.5	.712E+01	.83	3.84	.83	.00
42.38	.00	.00	143.6	.696E+01	.84	3.89	.84	.00
43.14	.00	.00	146.9	.681E+01	.85	3.95	.85	.00
43.90	.00	.00	150.2	.666E+01	.85	4.00	.85	.00
44.67	.00	.00	153.6	.651E+01	.86	4.06	.86	.00
45.43	.00	.00	157.0	.637E+01	.87	4.11	.87	.00
46.20	.00	.00	160.6	.623E+01	.88	4.16	.88	.00
46.96	.00	.00	164.2	.609E+01	.89	4.21	.89	.00
47.73	.00	.00	167.9	.596E+01	.90	4.27	.90	.00
48.49	.00	.00	171.7	.582E+01	.90	4.32	.90	.00
49.25	.00	.00	175.6	.570E+01	.91	4.37	.91	.00
50.02	.00	.00	179.5	.557E+01	.92	4.42	.92	.00
50.78	.00	.00	183.6	.545E+01	.93	4.47	.93	.00

Cumulative travel time = 159. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

MAC1-1N1.CX1

Vertical diffusivity (initial value) = .113E-01 m^2/s
Horizontal diffusivity (initial value) = .282E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
50.78	.00	.00	183.6	.545E+01	.93	4.47	.93	.00
53.64	.00	.00	193.9	.516E+01	.97	4.57	.97	.00
56.50	.00	.00	204.9	.488E+01	1.00	4.67	1.00	.00
59.35	.00	.00	216.4	.462E+01	1.03	4.76	1.03	.00
62.21	.00	.00	228.5	.438E+01	1.07	4.85	1.07	.00
65.07	.00	.00	241.2	.415E+01	1.11	4.94	1.11	.00
67.92	.00	.00	254.6	.393E+01	1.15	5.03	1.15	.00
70.78	.00	.00	268.6	.372E+01	1.20	5.12	1.20	.00
73.64	.00	.00	283.2	.353E+01	1.24	5.20	1.24	.00
76.49	.00	.00	298.5	.335E+01	1.29	5.29	1.29	.00
79.35	.00	.00	314.3	.318E+01	1.33	5.37	1.33	.00
82.21	.00	.00	330.8	.302E+01	1.38	5.45	1.38	.00
85.07	.00	.00	347.8	.288E+01	1.43	5.53	1.43	.00
87.92	.00	.00	365.4	.274E+01	1.48	5.61	1.48	.00
90.78	.00	.00	383.5	.261E+01	1.54	5.69	1.54	.00
93.64	.00	.00	402.0	.249E+01	1.59	5.76	1.59	.00
96.49	.00	.00	421.1	.237E+01	1.64	5.84	1.64	.00
99.35	.00	.00	440.6	.227E+01	1.70	5.91	1.70	.00
102.21	.00	.00	460.4	.217E+01	1.75	5.99	1.75	.00
105.06	.00	.00	480.7	.208E+01	1.81	6.06	1.81	.00
107.92	.00	.00	501.3	.199E+01	1.86	6.13	1.86	.00
110.78	.00	.00	522.2	.192E+01	1.92	6.20	1.92	.00
113.64	.00	.00	543.3	.184E+01	1.97	6.27	1.97	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

116.49	.00	.00	560.1	.179E+01	2.01	6.34	2.01	.00
119.35	.00	.00	566.2	.177E+01	2.01	6.41	2.01	.00
122.21	.00	.00	572.2	.175E+01	2.01	6.48	2.01	.00
125.06	.00	.00	578.2	.173E+01	2.01	6.55	2.01	.00
127.92	.00	.00	584.1	.171E+01	2.01	6.62	2.01	.00
130.78	.00	.00	589.9	.170E+01	2.01	6.68	2.01	.00

133.63	.00	.00	595.7	.168E+01	2.01	6.75	2.01	.00
136.49	.00	.00	601.4	.166E+01	2.01	6.81	2.01	.00
139.35	.00	.00	607.1	.165E+01	2.01	6.88	2.01	.00
142.21	.00	.00	612.7	.163E+01	2.01	6.94	2.01	.00
145.06	.00	.00	618.3	.162E+01	2.01	7.00	2.01	.00
147.92	.00	.00	623.8	.160E+01	2.01	7.07	2.01	.00
150.78	.00	.00	629.3	.159E+01	2.01	7.13	2.01	.00
153.63	.00	.00	634.7	.158E+01	2.01	7.19	2.01	.00
156.49	.00	.00	640.1	.156E+01	2.01	7.25	2.01	.00
159.35	.00	.00	645.4	.155E+01	2.01	7.31	2.01	.00
162.20	.00	.00	650.7	.154E+01	2.01	7.37	2.01	.00
165.06	.00	.00	655.9	.152E+01	2.01	7.43	2.01	.00
167.92	.00	.00	661.1	.151E+01	2.01	7.49	2.01	.00
170.77	.00	.00	666.3	.150E+01	2.01	7.55	2.01	.00
173.63	.00	.00	671.4	.149E+01	2.01	7.61	2.01	.00
176.49	.00	.00	676.5	.148E+01	2.01	7.66	2.01	.00
179.35	.00	.00	681.5	.147E+01	2.01	7.72	2.01	.00
182.20	.00	.00	686.6	.146E+01	2.01	7.78	2.01	.00
185.06	.00	.00	691.5	.145E+01	2.01	7.83	2.01	.00
187.92	.00	.00	696.5	.144E+01	2.01	7.89	2.01	.00
190.77	.00	.00	701.4	.143E+01	2.01	7.94	2.01	.00
193.63	.00	.00	706.2	.142E+01	2.01	8.00	2.01	.00

Cumulative travel time = 656. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
193.63	8.00	.00	706.2	.142E+01	2.01	16.00	2.01	.00
209.76	8.00	.00	713.1	.140E+01	2.01	16.15	2.01	.00
225.89	8.00	.00	719.8	.139E+01	2.01	16.31	2.01	.00
242.01	8.00	.00	726.5	.138E+01	2.01	16.46	2.01	.00
258.14	8.00	.00	733.1	.136E+01	2.01	16.61	2.01	.00
274.27	8.00	.00	739.7	.135E+01	2.01	16.76	2.01	.00
290.39	8.00	.00	746.2	.134E+01	2.01	16.91	2.01	.00
306.52	8.00	.00	752.7	.133E+01	2.01	17.05	2.01	.00
322.65	8.00	.00	759.1	.132E+01	2.01	17.20	2.01	.00
338.78	8.00	.00	765.4	.131E+01	2.01	17.34	2.01	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 342.14 m.

354.90	8.00	.00	771.7	.130E+01	2.01	17.37	2.01	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

371.03	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
387.16	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
403.29	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
419.41	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00

435.54	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
451.67	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
467.80	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
483.92	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
500.05	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
516.18	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
532.31	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
548.43	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
564.56	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
580.69	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
596.82	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
612.94	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
629.07	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
645.20	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
661.32	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
677.45	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
693.58	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
709.71	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
725.83	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
741.96	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
758.09	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
774.22	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
790.34	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
806.47	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
822.60	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
838.73	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
854.85	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
870.98	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
887.11	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
903.24	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
919.36	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
935.49	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
951.62	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
967.74	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
983.87	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
1000.00	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00

Cumulative travel time = 3462. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

11111111111111111111111111111111111111111111111111111111111111111111111111111

MAC1-1X1.CX1

CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111111

CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:
Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION
Site name/label: MACH^BIG^MUDDY^RIVER
Design case: CASE^1^-^PORT^1^MAXIMUM^FLOW
FILE NAME: cormix\sim\MAC1-1X1.cx1
Time of Fortran run: 01/13/20--21:41:13

ENVIRONMENT PARAMETERS (metric units)
Bounded section
BS = 20.06 AS = 56.17 QA = 22.24 ICHREG= 2
HA = 2.80 HD = 2.80
UA = .396 F = .068 USTAR = .3656E-01
UW = 2.000 UWSTAR= .2198E-02
Uniform density environment
STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)
BANK = LEFT DISTB = 10.00
D0 = .076 A0 = .005 H0 = .56
THETA = 30.00 SIGMA = .00
U0 = 5.487 Q0 = .025 = .2502E-01
RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00
C0 = .1000E+04 CUNITS= PPM
IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)
Q0 = .2502E-01 M0 = .1373E+00 J0 =-.3662E-02 SIGNJ0= -1.0
Associated length scales (meters)
LQ = .07 LM = 3.73 Lm = .94 Lb = .06
Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS
FR0 = 51.96 R = 13.85

FLOW CLASSIFICATION
1111111111111111111111111111111111111111
1 Flow class (CORMIX1) = NH4 1
1 Applicable layer depth HS = 2.80 1
1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1000E+04 CUNITS= PPM

MAC1-1X1.CX1

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1000.00  XMAX   =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        10.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .56     1.0  .100E+04     .04

END OF MOD101: DISCHARGE MODULE
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:              THETAE=     28.68  SIGMAE=       .00
  LE    =       .34  XE    =       .29  YE    =       .00  ZE    =       .73

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .56     1.0  .100E+04     .04
      .29      .00      .73     1.0  .100E+04     .04
      .71      .00      .94     2.3  .434E+03     .09
     1.15      .00     1.11     3.9  .255E+03     .15
     1.60      .00     1.25     5.7  .176E+03     .19
     2.05      .00     1.37     7.4  .135E+03     .24
     2.52      .00     1.47     9.1  .110E+03     .28
     2.98      .00     1.55    10.7  .932E+02     .31
     3.45      .00     1.62    12.3  .813E+02     .34
     3.92      .00     1.68    13.8  .727E+02     .36
     4.39      .00     1.74    15.1  .660E+02     .39
     4.86      .00     1.78    16.4  .609E+02     .41
     5.33      .00     1.81    17.6  .567E+02     .43
     5.80      .00     1.85    18.8  .533E+02     .44
     6.28      .00     1.87    19.8  .505E+02     .46
```

6.74	.00	1.89	20.8	.482E+02	.47
7.22	.00	1.91	21.7	.462E+02	.48
7.69	.00	1.92	22.5	.445E+02	.50
8.17	.00	1.92	23.2	.431E+02	.51
8.63	.00	1.93	23.9	.419E+02	.51

Maximum jet height has been reached.

9.11	.00	1.93	24.5	.408E+02	.52
9.58	.00	1.92	25.2	.397E+02	.53
10.06	.00	1.92	25.9	.386E+02	.54
10.52	.00	1.91	26.7	.375E+02	.55
11.00	.00	1.89	27.5	.363E+02	.56
11.47	.00	1.88	28.4	.352E+02	.57
11.95	.00	1.86	29.4	.340E+02	.58
12.41	.00	1.84	30.4	.329E+02	.59
12.89	.00	1.81	31.5	.318E+02	.60
13.36	.00	1.79	32.6	.307E+02	.62
13.83	.00	1.76	33.8	.296E+02	.63
14.30	.00	1.73	35.0	.286E+02	.64
14.78	.00	1.70	36.3	.276E+02	.66
15.24	.00	1.67	37.6	.266E+02	.67
15.72	.00	1.63	38.9	.257E+02	.68
16.18	.00	1.60	40.3	.248E+02	.70
16.66	.00	1.56	41.8	.239E+02	.71
17.13	.00	1.52	43.2	.231E+02	.72
17.60	.00	1.48	44.8	.223E+02	.74
18.07	.00	1.44	46.3	.216E+02	.75
18.54	.00	1.40	47.9	.209E+02	.77
19.01	.00	1.36	49.5	.202E+02	.78
19.49	.00	1.32	51.2	.195E+02	.80
19.95	.00	1.28	52.9	.189E+02	.81
20.43	.00	1.23	54.6	.183E+02	.82
20.89	.00	1.19	56.3	.178E+02	.84
21.37	.00	1.15	58.1	.172E+02	.85
21.83	.00	1.10	59.9	.167E+02	.87
22.31	.00	1.06	61.7	.162E+02	.88
22.77	.00	1.01	63.6	.157E+02	.90
23.25	.00	.97	65.5	.153E+02	.91
23.72	.00	.93	67.3	.149E+02	.92

Cumulative travel time = 37. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
23.72	.00	.93	67.3	.149E+02	.92

MAC1-1X1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
22.79	.00	.00	67.3	.149E+02	.00	.00	.00	.00
23.07	.00	.00	67.3	.149E+02	1.20	.60	1.20	.00
23.35	.00	.00	67.3	.149E+02	1.42	.85	1.42	.00
23.62	.00	.00	67.3	.149E+02	1.56	1.04	1.56	.00
23.90	.00	.00	69.2	.145E+02	1.67	1.20	1.67	.00
24.18	.00	.00	77.8	.129E+02	1.74	1.34	1.74	.00
24.46	.00	.00	89.6	.112E+02	1.80	1.47	1.80	.00
24.73	.00	.00	100.4	.996E+01	1.85	1.59	1.85	.00
25.01	.00	.00	107.8	.927E+01	1.88	1.70	1.88	.00
25.29	.00	.00	111.9	.894E+01	1.90	1.80	1.90	.00
25.56	.00	.00	114.5	.874E+01	1.90	1.90	1.90	.00

Cumulative travel time = 41. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
25.56	.00	.00	114.5	.874E+01	1.90	1.90	1.90	.00
26.01	.00	.00	115.4	.867E+01	1.88	1.94	1.88	.00
26.46	.00	.00	116.3	.860E+01	1.86	1.98	1.86	.00
26.90	.00	.00	117.2	.853E+01	1.83	2.02	1.83	.00
27.35	.00	.00	118.1	.847E+01	1.82	2.06	1.82	.00
27.80	.00	.00	119.0	.840E+01	1.80	2.09	1.80	.00
28.24	.00	.00	119.9	.834E+01	1.78	2.13	1.78	.00
28.69	.00	.00	120.8	.828E+01	1.76	2.17	1.76	.00
29.13	.00	.00	121.8	.821E+01	1.75	2.20	1.75	.00

29.58	.00	.00	122.7	.815E+01	1.73	2.24	1.73	.00
30.03	.00	.00	123.6	.809E+01	1.72	2.28	1.72	.00
30.47	.00	.00	124.6	.803E+01	1.70	2.31	1.70	.00
30.92	.00	.00	125.5	.797E+01	1.69	2.35	1.69	.00
31.36	.00	.00	126.5	.791E+01	1.68	2.38	1.68	.00
31.81	.00	.00	127.4	.785E+01	1.67	2.42	1.67	.00
32.26	.00	.00	128.4	.779E+01	1.65	2.45	1.65	.00
32.70	.00	.00	129.4	.773E+01	1.64	2.49	1.64	.00
33.15	.00	.00	130.4	.767E+01	1.63	2.52	1.63	.00
33.59	.00	.00	131.3	.761E+01	1.62	2.55	1.62	.00
34.04	.00	.00	132.4	.756E+01	1.62	2.59	1.62	.00
34.49	.00	.00	133.4	.750E+01	1.61	2.62	1.61	.00
34.93	.00	.00	134.4	.744E+01	1.60	2.65	1.60	.00
35.38	.00	.00	135.4	.738E+01	1.59	2.69	1.59	.00
35.82	.00	.00	136.5	.733E+01	1.58	2.72	1.58	.00
36.27	.00	.00	137.5	.727E+01	1.58	2.75	1.58	.00
36.72	.00	.00	138.6	.721E+01	1.57	2.79	1.57	.00
37.16	.00	.00	139.7	.716E+01	1.57	2.82	1.57	.00
37.61	.00	.00	140.8	.710E+01	1.56	2.85	1.56	.00
38.06	.00	.00	141.9	.705E+01	1.56	2.88	1.56	.00
38.50	.00	.00	143.0	.699E+01	1.55	2.91	1.55	.00
38.95	.00	.00	144.1	.694E+01	1.55	2.95	1.55	.00
39.39	.00	.00	145.3	.688E+01	1.54	2.98	1.54	.00
39.84	.00	.00	146.4	.683E+01	1.54	3.01	1.54	.00
40.29	.00	.00	147.6	.677E+01	1.53	3.04	1.53	.00
40.73	.00	.00	148.8	.672E+01	1.53	3.07	1.53	.00
41.18	.00	.00	150.0	.667E+01	1.53	3.10	1.53	.00
41.62	.00	.00	151.2	.661E+01	1.53	3.13	1.53	.00
42.07	.00	.00	152.4	.656E+01	1.52	3.16	1.52	.00
42.52	.00	.00	153.7	.651E+01	1.52	3.19	1.52	.00
42.96	.00	.00	154.9	.645E+01	1.52	3.22	1.52	.00
43.41	.00	.00	156.2	.640E+01	1.52	3.25	1.52	.00
43.85	.00	.00	157.5	.635E+01	1.52	3.28	1.52	.00
44.30	.00	.00	158.8	.630E+01	1.51	3.31	1.51	.00
44.75	.00	.00	160.1	.625E+01	1.51	3.34	1.51	.00
45.19	.00	.00	161.4	.619E+01	1.51	3.37	1.51	.00
45.64	.00	.00	162.8	.614E+01	1.51	3.40	1.51	.00
46.09	.00	.00	164.1	.609E+01	1.51	3.43	1.51	.00
46.53	.00	.00	165.5	.604E+01	1.51	3.46	1.51	.00
46.98	.00	.00	166.9	.599E+01	1.51	3.49	1.51	.00
47.42	.00	.00	168.3	.594E+01	1.51	3.52	1.51	.00
47.87	.00	.00	169.8	.589E+01	1.51	3.55	1.51	.00

Cumulative travel time = 98. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

MAC1-1X1.CX1

Vertical diffusivity (initial value) = .205E-01 m^2/s
Horizontal diffusivity (initial value) = .512E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
47.87	.00	.00	169.8	.589E+01	1.51	3.55	1.51	.00
52.18	.00	.00	187.4	.534E+01	1.56	3.78	1.56	.00
56.49	.00	.00	205.8	.486E+01	1.62	4.01	1.62	.00
60.80	.00	.00	224.9	.445E+01	1.68	4.22	1.68	.00
65.10	.00	.00	244.8	.409E+01	1.75	4.42	1.75	.00
69.41	.00	.00	265.6	.377E+01	1.82	4.62	1.82	.00
73.72	.00	.00	287.3	.348E+01	1.89	4.80	1.89	.00
78.03	.00	.00	309.9	.323E+01	1.97	4.98	1.97	.00
82.34	.00	.00	333.3	.300E+01	2.04	5.15	2.04	.00
86.65	.00	.00	357.7	.280E+01	2.12	5.32	2.12	.00
90.96	.00	.00	382.8	.261E+01	2.21	5.48	2.21	.00
95.26	.00	.00	408.7	.245E+01	2.29	5.64	2.29	.00
99.57	.00	.00	435.3	.230E+01	2.37	5.79	2.37	.00
103.88	.00	.00	462.5	.216E+01	2.46	5.94	2.46	.00
108.19	.00	.00	490.4	.204E+01	2.55	6.09	2.55	.00
112.50	.00	.00	518.8	.193E+01	2.63	6.23	2.63	.00
116.81	.00	.00	547.8	.183E+01	2.72	6.37	2.72	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

121.12	.00	.00	576.4	.173E+01	2.80	6.50	2.80	.00
125.42	.00	.00	588.2	.170E+01	2.80	6.64	2.80	.00
129.73	.00	.00	599.8	.167E+01	2.80	6.77	2.80	.00
134.04	.00	.00	611.1	.164E+01	2.80	6.90	2.80	.00
138.35	.00	.00	622.3	.161E+01	2.80	7.02	2.80	.00
142.66	.00	.00	633.2	.158E+01	2.80	7.14	2.80	.00
146.97	.00	.00	644.0	.155E+01	2.80	7.27	2.80	.00
151.28	.00	.00	654.5	.153E+01	2.80	7.39	2.80	.00
155.58	.00	.00	664.9	.150E+01	2.80	7.50	2.80	.00
159.89	.00	.00	675.2	.148E+01	2.80	7.62	2.80	.00
164.20	.00	.00	685.3	.146E+01	2.80	7.73	2.80	.00
168.51	.00	.00	695.2	.144E+01	2.80	7.84	2.80	.00

MAC1-1X1.CX1

172.82	.00	.00	705.1	.142E+01	2.80	7.95	2.80	.00
177.13	.00	.00	714.7	.140E+01	2.80	8.06	2.80	.00
181.43	.00	.00	724.3	.138E+01	2.80	8.17	2.80	.00
185.74	.00	.00	733.7	.136E+01	2.80	8.28	2.80	.00
190.05	.00	.00	743.0	.135E+01	2.80	8.38	2.80	.00
194.36	.00	.00	752.2	.133E+01	2.80	8.49	2.80	.00
198.67	.00	.00	761.3	.131E+01	2.80	8.59	2.80	.00
202.98	.00	.00	770.2	.130E+01	2.80	8.69	2.80	.00
207.29	.00	.00	779.1	.128E+01	2.80	8.79	2.80	.00
211.59	.00	.00	787.9	.127E+01	2.80	8.89	2.80	.00
215.90	.00	.00	796.5	.126E+01	2.80	8.99	2.80	.00
220.21	.00	.00	805.1	.124E+01	2.80	9.08	2.80	.00
224.52	.00	.00	813.6	.123E+01	2.80	9.18	2.80	.00
228.83	.00	.00	822.0	.122E+01	2.80	9.27	2.80	.00
233.14	.00	.00	830.3	.120E+01	2.80	9.37	2.80	.00
237.45	.00	.00	838.5	.119E+01	2.80	9.46	2.80	.00
241.75	.00	.00	846.7	.118E+01	2.80	9.55	2.80	.00
246.06	.00	.00	854.7	.117E+01	2.80	9.64	2.80	.00
250.37	.00	.00	862.7	.116E+01	2.80	9.73	2.80	.00
254.68	.00	.00	870.7	.115E+01	2.80	9.82	2.80	.00
258.99	.00	.00	878.5	.114E+01	2.80	9.91	2.80	.00
263.30	.00	.00	886.3	.113E+01	2.80	10.00	2.80	.00

Cumulative travel time = 641. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
263.30	10.00	.00	886.3	.113E+01	2.80	20.00	2.80	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 269.22 m.

278.03	10.00	.00	892.9	.112E+01	2.80	20.06	2.80	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

292.77	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
307.50	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
322.23	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
336.97	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
351.70	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
366.44	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
381.17	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
395.90	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
410.64	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
425.37	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
440.11	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
454.84	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
469.57	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00

MAC1-1X1.CX1

484.31	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
499.04	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
513.78	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
528.51	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
543.24	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
557.98	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
572.71	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
587.45	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
602.18	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
616.91	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
631.65	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
646.38	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
661.12	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
675.85	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
690.59	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
705.32	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
720.05	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
734.79	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
749.52	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
764.26	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
778.99	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
793.72	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
808.46	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
823.19	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
837.93	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
852.66	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
867.39	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
882.13	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
896.86	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
911.60	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
926.33	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
941.06	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
955.80	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
970.53	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
985.27	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
1000.00	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00

Cumulative travel time = 2499. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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MAC2-1N1.CX1

CORMIX1 PREDICTION FILE:
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CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:
Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION
Site name/label: MACH^BIG^MUDDY^RIVER
Design case: CASE^2^-^PORT^1^NORMAL^FLOW
FILE NAME: cormix\sim\MAC2-1N1.cx1
Time of Fortran run: 01/13/20--21:36:05

ENVIRONMENT PARAMETERS (metric units)
Bounded section
BS = 20.06 AS = 56.17 QA = 22.24 ICHREG= 2
HA = 2.80 HD = 2.80
UA = .396 F = .068 USTAR = .3656E-01
UW = 2.000 UWSTAR= .2198E-02
Uniform density environment
STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)
BANK = LEFT DISTB = 10.00
D0 = .076 A0 = .005 H0 = .56
THETA = 30.00 SIGMA = .00
U0 = 2.866 Q0 = .013 = .1307E-01
RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00
C0 = .2000E+01 CUNITS= PPM
IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)
Q0 = .1307E-01 M0 = .3746E-01 J0 =-.1913E-02 SIGNJ0= -1.0
Associated length scales (meters)
LQ = .07 LM = 1.95 Lm = .49 Lb = .03
Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS
FR0 = 27.14 R = 7.23

FLOW CLASSIFICATION
1111111111111111111111111111111111111111
1 Flow class (CORMIX1) = NH4 1
1 Applicable layer depth HS = 2.80 1
1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .2000E+01 CUNITS= PPM

MAC2-1N1.CX1

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1000.00  XMAX   =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        10.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .56      1.0  .200E+01     .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:              THETAE=     27.47  SIGMAE=       .00
  LE    =       .30  XE    =        .26  YE    =        .00  ZE    =       .71

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .56      1.0  .200E+01     .04
      .26      .00      .71      1.0  .200E+01     .04
      .51      .00      .82      1.8  .112E+01     .07
      .77      .00      .91      2.8  .719E+00     .10
     1.04      .00      .98      3.8  .527E+00     .13
     1.30      .00     1.04      4.8  .420E+00     .15
     1.58      .00     1.09      5.7  .352E+00     .17
     1.85      .00     1.13      6.5  .306E+00     .18
     2.12      .00     1.16      7.3  .272E+00     .20
     2.40      .00     1.19      8.1  .248E+00     .21
     2.67      .00     1.21      8.8  .228E+00     .22
     2.95      .00     1.23      9.4  .213E+00     .23
     3.23      .00     1.24      9.9  .201E+00     .24
     3.50      .00     1.25     10.4  .191E+00     .24
     3.78      .00     1.26     10.9  .183E+00     .25
```

4.05	.00	1.26	11.3	.177E+00	.26
4.33	.00	1.26	11.7	.171E+00	.26

Maximum jet height has been reached.

4.60	.00	1.26	12.0	.166E+00	.27
4.88	.00	1.26	12.4	.161E+00	.27
5.16	.00	1.26	12.8	.156E+00	.28
5.43	.00	1.25	13.3	.150E+00	.28
5.71	.00	1.24	13.8	.145E+00	.29
5.99	.00	1.23	14.4	.139E+00	.29
6.26	.00	1.21	14.9	.134E+00	.30
6.54	.00	1.20	15.6	.128E+00	.31
6.81	.00	1.18	16.2	.123E+00	.32
7.09	.00	1.16	16.9	.118E+00	.32
7.36	.00	1.14	17.6	.113E+00	.33
7.64	.00	1.12	18.4	.109E+00	.34
7.91	.00	1.10	19.2	.104E+00	.35
8.19	.00	1.08	20.0	.100E+00	.36
8.46	.00	1.06	20.8	.960E-01	.36
8.74	.00	1.03	21.7	.922E-01	.37
9.01	.00	1.01	22.6	.886E-01	.38
9.29	.00	.98	23.5	.851E-01	.39
9.56	.00	.96	24.4	.818E-01	.40
9.84	.00	.93	25.4	.788E-01	.41
10.11	.00	.91	26.4	.758E-01	.41
10.39	.00	.88	27.4	.731E-01	.42
10.66	.00	.86	28.4	.705E-01	.43
10.94	.00	.83	29.4	.680E-01	.44
11.21	.00	.80	30.5	.656E-01	.45
11.49	.00	.78	31.5	.634E-01	.46
11.76	.00	.75	32.6	.613E-01	.47
12.04	.00	.72	33.7	.593E-01	.47
12.31	.00	.69	34.9	.574E-01	.48
12.58	.00	.67	36.0	.556E-01	.49
12.86	.00	.64	37.1	.539E-01	.50
13.13	.00	.61	38.3	.522E-01	.51
13.41	.00	.59	39.5	.507E-01	.52
13.68	.00	.56	40.6	.492E-01	.52
13.96	.00	.53	41.8	.478E-01	.53

Cumulative travel time = 23. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
13.96	.00	.53	41.8	.478E-01	.53

MAC2-1N1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
13.42	.00	.00	41.8	.478E-01	.00	.00	.00	.00
13.58	.00	.00	41.8	.478E-01	.68	.34	.68	.00
13.74	.00	.00	41.8	.478E-01	.81	.48	.81	.00
13.90	.00	.00	41.8	.478E-01	.89	.59	.89	.00
14.06	.00	.00	43.0	.465E-01	.95	.69	.95	.00
14.22	.00	.00	48.3	.414E-01	.99	.77	.99	.00
14.38	.00	.00	55.7	.359E-01	1.03	.84	1.03	.00
14.54	.00	.00	62.4	.321E-01	1.05	.91	1.05	.00
14.70	.00	.00	67.0	.299E-01	1.07	.97	1.07	.00
14.86	.00	.00	69.5	.288E-01	1.08	1.03	1.08	.00
15.02	.00	.00	71.1	.281E-01	1.08	1.08	1.08	.00

Cumulative travel time = 26. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
15.02	.00	.00	71.1	.281E-01	1.08	1.08	1.08	.00
15.22	.00	.00	71.5	.280E-01	1.07	1.10	1.07	.00
15.42	.00	.00	72.0	.278E-01	1.06	1.12	1.06	.00
15.61	.00	.00	72.4	.276E-01	1.06	1.13	1.06	.00
15.81	.00	.00	72.9	.274E-01	1.05	1.15	1.05	.00
16.01	.00	.00	73.3	.273E-01	1.04	1.16	1.04	.00
16.21	.00	.00	73.8	.271E-01	1.03	1.18	1.03	.00
16.40	.00	.00	74.2	.270E-01	1.02	1.20	1.02	.00
16.60	.00	.00	74.7	.268E-01	1.02	1.21	1.02	.00

16.80	.00	.00	75.1	.266E-01	1.01	1.23	1.01	.00
17.00	.00	.00	75.6	.265E-01	1.00	1.24	1.00	.00
17.20	.00	.00	76.0	.263E-01	1.00	1.26	1.00	.00
17.39	.00	.00	76.5	.262E-01	.99	1.27	.99	.00
17.59	.00	.00	76.9	.260E-01	.98	1.29	.98	.00
17.79	.00	.00	77.4	.258E-01	.98	1.31	.98	.00
17.99	.00	.00	77.9	.257E-01	.97	1.32	.97	.00
18.18	.00	.00	78.3	.255E-01	.97	1.34	.97	.00
18.38	.00	.00	78.8	.254E-01	.96	1.35	.96	.00
18.58	.00	.00	79.3	.252E-01	.96	1.37	.96	.00
18.78	.00	.00	79.8	.251E-01	.95	1.38	.95	.00
18.98	.00	.00	80.2	.249E-01	.95	1.39	.95	.00
19.17	.00	.00	80.7	.248E-01	.95	1.41	.95	.00
19.37	.00	.00	81.2	.246E-01	.94	1.42	.94	.00
19.57	.00	.00	81.7	.245E-01	.94	1.44	.94	.00
19.77	.00	.00	82.2	.243E-01	.93	1.45	.93	.00
19.96	.00	.00	82.7	.242E-01	.93	1.47	.93	.00
20.16	.00	.00	83.2	.240E-01	.93	1.48	.93	.00
20.36	.00	.00	83.7	.239E-01	.92	1.50	.92	.00
20.56	.00	.00	84.3	.237E-01	.92	1.51	.92	.00
20.76	.00	.00	84.8	.236E-01	.92	1.52	.92	.00
20.95	.00	.00	85.3	.234E-01	.92	1.54	.92	.00
21.15	.00	.00	85.8	.233E-01	.91	1.55	.91	.00
21.35	.00	.00	86.4	.232E-01	.91	1.57	.91	.00
21.55	.00	.00	86.9	.230E-01	.91	1.58	.91	.00
21.74	.00	.00	87.4	.229E-01	.91	1.59	.91	.00
21.94	.00	.00	88.0	.227E-01	.90	1.61	.90	.00
22.14	.00	.00	88.6	.226E-01	.90	1.62	.90	.00
22.34	.00	.00	89.1	.224E-01	.90	1.63	.90	.00
22.53	.00	.00	89.7	.223E-01	.90	1.65	.90	.00
22.73	.00	.00	90.2	.222E-01	.90	1.66	.90	.00
22.93	.00	.00	90.8	.220E-01	.89	1.67	.89	.00
23.13	.00	.00	91.4	.219E-01	.89	1.69	.89	.00
23.33	.00	.00	92.0	.217E-01	.89	1.70	.89	.00
23.52	.00	.00	92.6	.216E-01	.89	1.71	.89	.00
23.72	.00	.00	93.2	.215E-01	.89	1.73	.89	.00
23.92	.00	.00	93.8	.213E-01	.89	1.74	.89	.00
24.12	.00	.00	94.4	.212E-01	.89	1.75	.89	.00
24.31	.00	.00	95.0	.211E-01	.89	1.77	.89	.00
24.51	.00	.00	95.6	.209E-01	.89	1.78	.89	.00
24.71	.00	.00	96.2	.208E-01	.89	1.79	.89	.00
24.91	.00	.00	96.9	.206E-01	.88	1.81	.88	.00

Cumulative travel time = 51. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

MAC2-1N1.CX1

Vertical diffusivity (initial value) = .205E-01 m^2/s
Horizontal diffusivity (initial value) = .512E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
24.91	.00	.00	96.9	.206E-01	.88	1.81	.88	.00
29.67	.00	.00	126.8	.158E-01	.92	2.28	.92	.00
34.44	.00	.00	155.7	.128E-01	.96	2.67	.96	.00
39.20	.00	.00	185.6	.108E-01	1.02	3.01	1.02	.00
43.97	.00	.00	217.6	.919E-02	1.08	3.32	1.08	.00
48.73	.00	.00	252.5	.792E-02	1.16	3.60	1.16	.00
53.50	.00	.00	291.0	.687E-02	1.25	3.86	1.25	.00
58.26	.00	.00	333.2	.600E-02	1.34	4.10	1.34	.00
63.03	.00	.00	379.2	.527E-02	1.45	4.33	1.45	.00
67.79	.00	.00	428.8	.466E-02	1.56	4.55	1.56	.00
72.56	.00	.00	481.9	.415E-02	1.67	4.75	1.67	.00
77.32	.00	.00	537.9	.372E-02	1.79	4.95	1.79	.00
82.09	.00	.00	596.6	.335E-02	1.91	5.15	1.91	.00
86.85	.00	.00	657.6	.304E-02	2.04	5.33	2.04	.00
91.62	.00	.00	720.4	.278E-02	2.16	5.51	2.16	.00
96.38	.00	.00	784.7	.255E-02	2.28	5.68	2.28	.00
101.15	.00	.00	850.4	.235E-02	2.40	5.85	2.40	.00
105.91	.00	.00	917.2	.218E-02	2.52	6.01	2.52	.00
110.68	.00	.00	984.9	.203E-02	2.63	6.17	2.63	.00
115.44	.00	.00	1053.4	.190E-02	2.75	6.33	2.75	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

120.21	.00	.00	1099.1	.182E-02	2.80	6.48	2.80	.00
124.97	.00	.00	1124.2	.178E-02	2.80	6.63	2.80	.00
129.74	.00	.00	1148.7	.174E-02	2.80	6.77	2.80	.00
134.50	.00	.00	1172.7	.171E-02	2.80	6.91	2.80	.00
139.27	.00	.00	1196.2	.167E-02	2.80	7.05	2.80	.00
144.03	.00	.00	1219.3	.164E-02	2.80	7.19	2.80	.00
148.80	.00	.00	1241.9	.161E-02	2.80	7.32	2.80	.00
153.56	.00	.00	1264.1	.158E-02	2.80	7.45	2.80	.00
158.33	.00	.00	1286.0	.156E-02	2.80	7.58	2.80	.00

163.09	.00	.00	1307.4	.153E-02	2.80	7.71	2.80	.00
167.86	.00	.00	1328.6	.151E-02	2.80	7.83	2.80	.00
172.62	.00	.00	1349.4	.148E-02	2.80	7.95	2.80	.00
177.39	.00	.00	1369.9	.146E-02	2.80	8.07	2.80	.00
182.15	.00	.00	1390.1	.144E-02	2.80	8.19	2.80	.00
186.92	.00	.00	1409.9	.142E-02	2.80	8.31	2.80	.00
191.68	.00	.00	1429.6	.140E-02	2.80	8.42	2.80	.00
196.45	.00	.00	1448.9	.138E-02	2.80	8.54	2.80	.00
201.21	.00	.00	1468.0	.136E-02	2.80	8.65	2.80	.00
205.98	.00	.00	1486.9	.135E-02	2.80	8.76	2.80	.00
210.74	.00	.00	1505.5	.133E-02	2.80	8.87	2.80	.00
215.51	.00	.00	1523.9	.131E-02	2.80	8.98	2.80	.00
220.27	.00	.00	1542.0	.130E-02	2.80	9.09	2.80	.00
225.04	.00	.00	1560.0	.128E-02	2.80	9.19	2.80	.00
229.80	.00	.00	1577.8	.127E-02	2.80	9.30	2.80	.00
234.57	.00	.00	1595.3	.125E-02	2.80	9.40	2.80	.00
239.33	.00	.00	1612.7	.124E-02	2.80	9.50	2.80	.00
244.10	.00	.00	1629.9	.123E-02	2.80	9.61	2.80	.00
248.86	.00	.00	1646.9	.121E-02	2.80	9.71	2.80	.00
253.63	.00	.00	1663.7	.120E-02	2.80	9.80	2.80	.00
258.39	.00	.00	1680.3	.119E-02	2.80	9.90	2.80	.00
263.16	.00	.00	1696.8	.118E-02	2.80	10.00	2.80	.00

Cumulative travel time = 652. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
263.16	10.00	.00	1696.8	.118E-02	2.80	20.00	2.80	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 269.07 m.

277.89	10.00	.00	1709.5	.117E-02	2.80	20.06	2.80	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

292.63	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
307.37	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
322.10	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
336.84	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
351.58	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
366.31	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
381.05	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
395.79	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
410.52	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
425.26	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
440.00	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
454.73	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
469.47	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00

MAC2-1N1.CX1

484.21	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
498.95	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
513.68	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
528.42	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
543.16	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
557.89	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
572.63	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
587.37	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
602.10	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
616.84	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
631.58	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
646.31	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
661.05	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
675.79	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
690.52	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
705.26	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
720.00	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
734.74	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
749.47	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
764.21	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
778.95	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
793.68	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
808.42	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
823.16	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
837.89	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
852.63	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
867.37	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
882.10	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
896.84	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
911.58	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
926.31	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
941.05	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
955.79	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
970.53	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
985.26	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
1000.00	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00

Cumulative travel time = 2512. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File
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MAC2-1X1.CX1

CORMIX1 PREDICTION FILE:
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CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:
Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION
Site name/label: MACH^BIG^MUDDY^RIVER
Design case: CASE^2^-^PORT^1^MAXIMUM^FLOW
FILE NAME: cormix\sim\MAC2-1X1.cx1
Time of Fortran run: 01/13/20--20:50:38

ENVIRONMENT PARAMETERS (metric units)
Bounded section
BS = 20.06 AS = 69.61 QA = 19.98 ICHREG= 2
HA = 3.47 HD = 3.47
UA = .287 F = .064 USTAR = .2557E-01
UW = 2.000 UWSTAR= .2198E-02
Uniform density environment
STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)
BANK = LEFT DISTB = 10.00
D0 = .076 A0 = .005 H0 = .56
THETA = 30.00 SIGMA = .00
U0 = 5.487 Q0 = .025 = .2502E-01
RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00
C0 = .1013E+04 CUNITS= PPM
IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)
Q0 = .2502E-01 M0 = .1373E+00 J0 =-.3662E-02 SIGNJ0= -1.0
Associated length scales (meters)
LQ = .07 LM = 3.73 Lm = 1.29 Lb = .15
Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS
FR0 = 51.96 R = 19.11

FLOW CLASSIFICATION
11111111111111111111111111111111111111
1 Flow class (CORMIX1) = NH4 1
1 Applicable layer depth HS = 3.47 1
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MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1013E+04 CUNITS= PPM

MAC2-1X1.CX1

```
 NTOX  =  0
 NSTD  =  0
 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        10.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

      X        Y        Z        S        C        B
     .00      .00      .56      1.0  .101E+04     .04

END OF MOD101: DISCHARGE MODULE
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     29.04  SIGMAE=       .00
  LE    =       .35  XE    =       .30  YE    =       .00  ZE    =       .74

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

      X        Y        Z        S        C        B
     .00      .00      .56      1.0  .101E+04     .04
     .30      .00      .74      1.0  .101E+04     .04
     .65      .00      .91      2.0  .510E+03     .08
    1.00      .00     1.08      3.2  .315E+03     .13
    1.37      .00     1.22      4.6  .222E+03     .17
    1.74      .00     1.35      5.9  .171E+03     .22
    2.11      .00     1.46      7.3  .138E+03     .25
    2.49      .00     1.56      8.8  .116E+03     .29
    2.87      .00     1.65     10.1  .100E+03     .32
    3.25      .00     1.73     11.4  .885E+02     .35
    3.65      .00     1.79     12.8  .794E+02     .38
    4.03      .00     1.85     14.0  .724E+02     .41
    4.41      .00     1.90     15.2  .669E+02     .43
    4.81      .00     1.95     16.3  .622E+02     .45
    5.20      .00     1.98     17.3  .584E+02     .47
```

5.60	.00	2.01	18.4	.552E+02	.49
5.98	.00	2.04	19.3	.526E+02	.51
6.37	.00	2.06	20.1	.503E+02	.52
6.77	.00	2.08	21.0	.484E+02	.53
7.16	.00	2.09	21.7	.467E+02	.55
7.54	.00	2.10	22.4	.453E+02	.56
7.94	.00	2.10	23.0	.441E+02	.57

Maximum jet height has been reached.

8.33	.00	2.10	23.6	.430E+02	.58
8.72	.00	2.09	24.2	.418E+02	.59
9.12	.00	2.09	24.9	.406E+02	.60
9.51	.00	2.07	25.7	.395E+02	.61
9.89	.00	2.06	26.5	.383E+02	.62
10.29	.00	2.04	27.4	.371E+02	.63
10.68	.00	2.02	28.3	.359E+02	.64
11.08	.00	1.99	29.2	.347E+02	.66
11.46	.00	1.97	30.2	.335E+02	.67
11.85	.00	1.94	31.3	.324E+02	.69
12.25	.00	1.90	32.4	.312E+02	.70
12.64	.00	1.87	33.6	.302E+02	.71
13.02	.00	1.83	34.8	.291E+02	.73
13.42	.00	1.79	36.1	.281E+02	.75
13.80	.00	1.75	37.4	.271E+02	.76
14.19	.00	1.71	38.7	.262E+02	.78
14.59	.00	1.67	40.1	.253E+02	.79
14.97	.00	1.62	41.5	.244E+02	.81
15.37	.00	1.57	43.0	.236E+02	.83
15.75	.00	1.53	44.5	.228E+02	.84
16.14	.00	1.48	46.0	.220E+02	.86
16.54	.00	1.43	47.6	.213E+02	.88
16.92	.00	1.38	49.2	.206E+02	.89
17.30	.00	1.33	50.9	.199E+02	.91
17.70	.00	1.28	52.6	.193E+02	.93
18.08	.00	1.23	54.3	.187E+02	.94
18.47	.00	1.17	56.0	.181E+02	.96
18.86	.00	1.12	57.8	.175E+02	.98
19.25	.00	1.07	59.6	.170E+02	.99
19.63	.00	1.01	61.4	.165E+02	1.01

Cumulative travel time = 35. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
19.63	.00	1.01	61.4	.165E+02	1.01

MAC2-1X1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
18.62	.00	.00	61.4	.165E+02	.00	.00	.00	.00
18.92	.00	.00	61.4	.165E+02	1.34	.67	1.34	.00
19.23	.00	.00	61.4	.165E+02	1.59	.95	1.59	.00
19.53	.00	.00	61.4	.165E+02	1.75	1.17	1.75	.00
19.83	.00	.00	63.1	.161E+02	1.87	1.35	1.87	.00
20.14	.00	.00	70.9	.143E+02	1.96	1.51	1.96	.00
20.44	.00	.00	81.7	.124E+02	2.02	1.65	2.02	.00
20.74	.00	.00	91.6	.111E+02	2.07	1.78	2.07	.00
21.05	.00	.00	98.4	.103E+02	2.11	1.91	2.11	.00
21.35	.00	.00	102.0	.993E+01	2.13	2.02	2.13	.00
21.66	.00	.00	104.4	.971E+01	2.13	2.13	2.13	.00

Cumulative travel time = 42. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
21.66	.00	.00	104.4	.971E+01	2.13	2.13	2.13	.00
23.59	.00	.00	107.9	.939E+01	1.97	2.39	1.97	.00
25.53	.00	.00	111.1	.912E+01	1.84	2.63	1.84	.00
27.47	.00	.00	114.1	.888E+01	1.74	2.86	1.74	.00
29.40	.00	.00	117.1	.865E+01	1.66	3.08	1.66	.00
31.34	.00	.00	120.1	.844E+01	1.59	3.29	1.59	.00
33.28	.00	.00	123.0	.824E+01	1.53	3.50	1.53	.00
35.22	.00	.00	125.9	.805E+01	1.48	3.70	1.48	.00
37.15	.00	.00	128.9	.786E+01	1.44	3.89	1.44	.00

39.09	.00	.00	132.0	.768E+01	1.41	4.08	1.41	.00
41.03	.00	.00	135.1	.750E+01	1.38	4.27	1.38	.00
42.96	.00	.00	138.3	.733E+01	1.35	4.45	1.35	.00
44.90	.00	.00	141.6	.716E+01	1.33	4.63	1.33	.00
46.84	.00	.00	145.0	.699E+01	1.32	4.81	1.32	.00
48.78	.00	.00	148.5	.682E+01	1.30	4.98	1.30	.00
50.71	.00	.00	152.2	.666E+01	1.29	5.15	1.29	.00
52.65	.00	.00	156.0	.650E+01	1.28	5.31	1.28	.00
54.59	.00	.00	159.9	.634E+01	1.27	5.48	1.27	.00
56.53	.00	.00	163.9	.618E+01	1.27	5.64	1.27	.00
58.46	.00	.00	168.1	.603E+01	1.26	5.80	1.26	.00
60.40	.00	.00	172.5	.587E+01	1.26	5.95	1.26	.00
62.34	.00	.00	177.0	.572E+01	1.26	6.11	1.26	.00
64.27	.00	.00	181.7	.558E+01	1.27	6.26	1.27	.00
66.21	.00	.00	186.6	.543E+01	1.27	6.41	1.27	.00
68.15	.00	.00	191.6	.529E+01	1.27	6.56	1.27	.00
70.09	.00	.00	196.8	.515E+01	1.28	6.71	1.28	.00
72.02	.00	.00	202.1	.501E+01	1.29	6.85	1.29	.00
73.96	.00	.00	207.7	.488E+01	1.29	7.00	1.29	.00
75.90	.00	.00	213.4	.475E+01	1.30	7.14	1.30	.00
77.84	.00	.00	219.3	.462E+01	1.31	7.28	1.31	.00
79.77	.00	.00	225.5	.449E+01	1.32	7.42	1.32	.00
81.71	.00	.00	231.8	.437E+01	1.34	7.56	1.34	.00
83.65	.00	.00	238.3	.425E+01	1.35	7.70	1.35	.00
85.58	.00	.00	245.0	.414E+01	1.36	7.84	1.36	.00
87.52	.00	.00	251.9	.402E+01	1.38	7.97	1.38	.00
89.46	.00	.00	259.0	.391E+01	1.39	8.11	1.39	.00
91.40	.00	.00	266.3	.381E+01	1.41	8.24	1.41	.00
93.33	.00	.00	273.8	.370E+01	1.43	8.37	1.43	.00
95.27	.00	.00	281.5	.360E+01	1.44	8.50	1.44	.00
97.21	.00	.00	289.4	.350E+01	1.46	8.63	1.46	.00
99.15	.00	.00	297.6	.341E+01	1.48	8.76	1.48	.00
101.08	.00	.00	306.0	.331E+01	1.50	8.89	1.50	.00
103.02	.00	.00	314.5	.322E+01	1.52	9.02	1.52	.00
104.96	.00	.00	323.4	.313E+01	1.54	9.14	1.54	.00
106.89	.00	.00	332.4	.305E+01	1.56	9.27	1.56	.00
108.83	.00	.00	341.6	.297E+01	1.59	9.39	1.59	.00
110.77	.00	.00	351.1	.289E+01	1.61	9.51	1.61	.00
112.71	.00	.00	360.8	.281E+01	1.63	9.64	1.63	.00
114.64	.00	.00	370.8	.273E+01	1.66	9.76	1.66	.00
116.58	.00	.00	380.9	.266E+01	1.68	9.88	1.68	.00
118.52	.00	.00	391.3	.259E+01	1.71	10.00	1.71	.00

Cumulative travel time = 379. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

MAC2-1X1.CX1

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
118.52	10.00	.00	391.3	.259E+01	1.71	20.00	1.71	.00
118.54	10.00	.00	391.4	.259E+01	1.71	20.00	1.71	.00
118.56	10.00	.00	391.5	.259E+01	1.71	20.00	1.71	.00
118.58	10.00	.00	391.6	.259E+01	1.71	20.00	1.71	.00
118.60	10.00	.00	391.7	.259E+01	1.71	20.00	1.71	.00
118.61	10.00	.00	391.8	.259E+01	1.71	20.01	1.71	.00
118.63	10.00	.00	391.9	.259E+01	1.71	20.01	1.71	.00
118.65	10.00	.00	392.0	.258E+01	1.71	20.01	1.71	.00
118.67	10.00	.00	392.1	.258E+01	1.71	20.01	1.71	.00
118.69	10.00	.00	392.2	.258E+01	1.71	20.01	1.71	.00
118.71	10.00	.00	392.3	.258E+01	1.71	20.01	1.71	.00
118.73	10.00	.00	392.4	.258E+01	1.71	20.01	1.71	.00
118.75	10.00	.00	392.5	.258E+01	1.71	20.01	1.71	.00
118.77	10.00	.00	392.6	.258E+01	1.71	20.02	1.71	.00
118.79	10.00	.00	392.7	.258E+01	1.71	20.02	1.71	.00
118.81	10.00	.00	392.8	.258E+01	1.71	20.02	1.71	.00
118.83	10.00	.00	392.9	.258E+01	1.71	20.02	1.71	.00
118.85	10.00	.00	393.0	.258E+01	1.71	20.02	1.71	.00
118.87	10.00	.00	393.1	.258E+01	1.71	20.02	1.71	.00
118.89	10.00	.00	393.2	.258E+01	1.71	20.02	1.71	.00
118.91	10.00	.00	393.3	.258E+01	1.71	20.02	1.71	.00
118.93	10.00	.00	393.4	.258E+01	1.71	20.03	1.71	.00
118.95	10.00	.00	393.5	.258E+01	1.71	20.03	1.71	.00
118.97	10.00	.00	393.6	.257E+01	1.71	20.03	1.71	.00
118.98	10.00	.00	393.7	.257E+01	1.71	20.03	1.71	.00
119.00	10.00	.00	393.8	.257E+01	1.71	20.03	1.71	.00
119.02	10.00	.00	393.9	.257E+01	1.71	20.03	1.71	.00
119.04	10.00	.00	394.0	.257E+01	1.71	20.03	1.71	.00
119.06	10.00	.00	394.1	.257E+01	1.71	20.03	1.71	.00
119.08	10.00	.00	394.2	.257E+01	1.72	20.03	1.72	.00
119.10	10.00	.00	394.3	.257E+01	1.72	20.04	1.72	.00
119.12	10.00	.00	394.4	.257E+01	1.72	20.04	1.72	.00
119.14	10.00	.00	394.5	.257E+01	1.72	20.04	1.72	.00
119.16	10.00	.00	394.6	.257E+01	1.72	20.04	1.72	.00
119.18	10.00	.00	394.7	.257E+01	1.72	20.04	1.72	.00
119.20	10.00	.00	394.8	.257E+01	1.72	20.04	1.72	.00
119.22	10.00	.00	394.9	.257E+01	1.72	20.04	1.72	.00
119.24	10.00	.00	395.0	.257E+01	1.72	20.04	1.72	.00
119.26	10.00	.00	395.1	.256E+01	1.72	20.05	1.72	.00
119.28	10.00	.00	395.2	.256E+01	1.72	20.05	1.72	.00
119.30	10.00	.00	395.3	.256E+01	1.72	20.05	1.72	.00
119.32	10.00	.00	395.4	.256E+01	1.72	20.05	1.72	.00
119.34	10.00	.00	395.5	.256E+01	1.72	20.05	1.72	.00
119.35	10.00	.00	395.6	.256E+01	1.72	20.05	1.72	.00
119.37	10.00	.00	395.7	.256E+01	1.72	20.05	1.72	.00
119.39	10.00	.00	395.8	.256E+01	1.72	20.05	1.72	.00

119.41	10.00	.00	395.9	.256E+01	1.72	20.06	1.72	.00
119.43	10.00	.00	396.0	.256E+01	1.72	20.06	1.72	.00
119.45	10.00	.00	396.1	.256E+01	1.72	20.06	1.72	.00
119.47	10.00	.00	396.2	.256E+01	1.72	20.06	1.72	.00
119.49	10.00	.00	396.3	.256E+01	1.72	20.06	1.72	.00

Cumulative travel time = 383. sec
Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .178E-01 m^2/s
Horizontal diffusivity (initial value) = .444E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
119.49	10.00	.00	396.3	.256E+01	1.72	20.06	1.72	.00
137.10	10.00	.00	440.4	.230E+01	1.91	20.06	1.91	.00
154.71	10.00	.00	488.8	.207E+01	2.12	20.06	2.12	.00
172.32	10.00	.00	541.0	.187E+01	2.35	20.06	2.35	.00
189.93	10.00	.00	596.4	.170E+01	2.59	20.06	2.59	.00
207.54	10.00	.00	654.1	.155E+01	2.84	20.06	2.84	.00
225.15	10.00	.00	713.5	.142E+01	3.10	20.06	3.10	.00
242.76	10.00	.00	773.8	.131E+01	3.36	20.06	3.36	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

260.37	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

277.98	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
295.59	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
313.20	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
330.81	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
348.42	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00

366.03	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
383.64	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
401.25	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
418.86	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
436.47	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
454.08	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
471.69	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
489.30	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
506.91	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
524.53	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
542.14	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
559.75	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
577.36	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
594.97	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
612.58	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
630.19	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
647.80	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
665.41	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
683.02	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
700.63	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
718.24	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
735.85	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
753.46	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
771.07	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
788.68	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
806.29	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
823.90	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
841.51	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
859.12	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
876.73	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
894.34	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
911.95	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
929.56	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
947.17	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
964.78	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
982.39	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
1000.00	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00

Cumulative travel time = 3447. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

11111111111111111111111111111111111111111111111111111111111111111111111111111111

MAC3-1N1.CX1

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CORMIX1 PRESICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         Mach^Big^Muddy^River
 Design case:             CASE^3^-^PORT^1^NORMAL^FLOW
 FILE NAME:               cormix\sim\MAC3-1N1.cx1
 Time of Fortran run:     01/13/20--19:49:39

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     21.58  AS    =     74.88  QA    =     21.49  ICHREG= 2
 HA    =      3.47  HD    =      3.47
 UA    =       .287 F     =       .064 USTAR = .2557E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     10.70
 D0    =       .076 A0    =       .005 H0    =       .56
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .013       = .1307E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .1307E-01  M0    = .3746E-01  J0    =-.1913E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .07  LM    =      1.95  Lm    =       .67  Lb    =       .08
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     27.14  R     =      9.98

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     3.47  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
```

MAC3-1N1.CX1

NTOX = 0
NSTD = 0
REGMZ = 0
XINT = 1000.00 XMAX = 1000.00

X-Y-Z COORDINATE SYSTEM:
ORIGIN is located at the bottom and below the center of the port:
10.70 m from the LEFT bank/shore.
X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module

BEGIN MOD101: DISCHARGE MODULE

X	Y	Z	S	C	B
.00	.00	.56	1.0	.100E+04	.04

END OF MOD101: DISCHARGE MODULE

BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

Jet/plume transition motion in strong crossflow.

Zone of flow establishment: THETAE= 28.17 SIGMAE= .00
LE = .32 XE = .28 YE = .00 ZE = .72

Profile definitions:
B = Gaussian 1/e (37%) half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	B
.00	.00	.56	1.0	.100E+04	.04
.28	.00	.72	1.0	.100E+04	.04
.48	.00	.82	1.6	.640E+03	.07
.68	.00	.90	2.3	.433E+03	.09
.90	.00	.98	3.1	.321E+03	.12
1.11	.00	1.05	3.9	.256E+03	.14
1.33	.00	1.10	4.7	.212E+03	.16
1.55	.00	1.15	5.5	.183E+03	.18
1.77	.00	1.19	6.2	.161E+03	.19
2.00	.00	1.23	6.9	.144E+03	.21
2.22	.00	1.26	7.6	.132E+03	.22
2.44	.00	1.28	8.2	.122E+03	.23
2.67	.00	1.31	8.8	.114E+03	.24
2.89	.00	1.32	9.3	.107E+03	.25
3.12	.00	1.34	9.9	.101E+03	.26

3.34	.00	1.35	10.3	.970E+02	.27
3.57	.00	1.36	10.7	.931E+02	.28
3.79	.00	1.36	11.1	.899E+02	.28
4.02	.00	1.36	11.5	.872E+02	.29

Maximum jet height has been reached.

4.24	.00	1.36	11.8	.848E+02	.30
4.47	.00	1.36	12.2	.823E+02	.30
4.69	.00	1.35	12.6	.796E+02	.31
4.92	.00	1.34	13.0	.769E+02	.31
5.15	.00	1.33	13.5	.742E+02	.32
5.37	.00	1.32	14.0	.715E+02	.33
5.59	.00	1.31	14.5	.689E+02	.34
5.82	.00	1.29	15.1	.662E+02	.34
6.04	.00	1.27	15.7	.637E+02	.35
6.27	.00	1.25	16.4	.611E+02	.36
6.49	.00	1.23	17.0	.588E+02	.37
6.72	.00	1.21	17.7	.564E+02	.38
6.94	.00	1.18	18.5	.542E+02	.39
7.16	.00	1.16	19.2	.521E+02	.40
7.39	.00	1.13	20.0	.500E+02	.41
7.61	.00	1.11	20.8	.480E+02	.42
7.84	.00	1.08	21.7	.461E+02	.43
8.06	.00	1.05	22.5	.444E+02	.43
8.28	.00	1.02	23.4	.427E+02	.44
8.51	.00	.99	24.3	.411E+02	.45
8.73	.00	.96	25.3	.396E+02	.46
8.95	.00	.93	26.2	.381E+02	.47
9.17	.00	.90	27.2	.368E+02	.48
9.39	.00	.87	28.2	.355E+02	.49
9.62	.00	.84	29.2	.342E+02	.50
9.84	.00	.81	30.2	.331E+02	.51
10.07	.00	.78	31.3	.319E+02	.52
10.29	.00	.74	32.4	.309E+02	.53
10.52	.00	.71	33.5	.299E+02	.54
10.74	.00	.68	34.6	.289E+02	.55
10.96	.00	.65	35.7	.280E+02	.56
11.18	.00	.62	36.8	.271E+02	.57
11.40	.00	.58	38.0	.263E+02	.58

Cumulative travel time = 22. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
11.40	.00	.58	38.0	.263E+02	.58

MAC3-1N1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.82	.00	.00	38.0	.263E+02	.00	.00	.00	.00
11.00	.00	.00	38.0	.263E+02	.76	.38	.76	.00
11.17	.00	.00	38.0	.263E+02	.90	.54	.90	.00
11.35	.00	.00	38.0	.263E+02	1.00	.66	1.00	.00
11.52	.00	.00	39.0	.256E+02	1.06	.77	1.06	.00
11.70	.00	.00	43.8	.228E+02	1.11	.86	1.11	.00
11.87	.00	.00	50.5	.198E+02	1.15	.94	1.15	.00
12.04	.00	.00	56.6	.177E+02	1.18	1.01	1.18	.00
12.22	.00	.00	60.8	.164E+02	1.20	1.08	1.20	.00
12.39	.00	.00	63.1	.159E+02	1.21	1.15	1.21	.00
12.57	.00	.00	64.5	.155E+02	1.21	1.21	1.21	.00

Cumulative travel time = 26. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
12.57	.00	.00	64.5	.155E+02	1.21	1.21	1.21	.00
13.56	.00	.00	66.4	.151E+02	1.13	1.34	1.13	.00
14.56	.00	.00	68.2	.147E+02	1.07	1.46	1.07	.00
15.55	.00	.00	69.9	.143E+02	1.01	1.57	1.01	.00
16.55	.00	.00	71.6	.140E+02	.97	1.68	.97	.00
17.54	.00	.00	73.3	.137E+02	.93	1.79	.93	.00
18.53	.00	.00	74.9	.134E+02	.90	1.89	.90	.00
19.53	.00	.00	76.6	.131E+02	.87	1.99	.87	.00
20.52	.00	.00	78.2	.128E+02	.85	2.09	.85	.00

21.52	.00	.00	79.9	.125E+02	.83	2.19	.83	.00
22.51	.00	.00	81.7	.122E+02	.81	2.28	.81	.00
23.51	.00	.00	83.4	.120E+02	.80	2.38	.80	.00
24.50	.00	.00	85.2	.117E+02	.79	2.47	.79	.00
25.49	.00	.00	87.1	.115E+02	.78	2.56	.78	.00
26.49	.00	.00	89.1	.112E+02	.77	2.64	.77	.00
27.48	.00	.00	91.0	.110E+02	.76	2.73	.76	.00
28.48	.00	.00	93.1	.107E+02	.75	2.82	.75	.00
29.47	.00	.00	95.2	.105E+02	.75	2.90	.75	.00
30.46	.00	.00	97.4	.103E+02	.74	2.98	.74	.00
31.46	.00	.00	99.7	.100E+02	.74	3.06	.74	.00
32.45	.00	.00	102.0	.980E+01	.74	3.14	.74	.00
33.45	.00	.00	104.5	.957E+01	.74	3.22	.74	.00
34.44	.00	.00	107.0	.935E+01	.74	3.30	.74	.00
35.44	.00	.00	109.5	.913E+01	.74	3.38	.74	.00
36.43	.00	.00	112.2	.891E+01	.74	3.45	.74	.00
37.42	.00	.00	115.0	.870E+01	.74	3.53	.74	.00
38.42	.00	.00	117.8	.849E+01	.74	3.60	.74	.00
39.41	.00	.00	120.8	.828E+01	.75	3.68	.75	.00
40.41	.00	.00	123.8	.808E+01	.75	3.75	.75	.00
41.40	.00	.00	126.9	.788E+01	.76	3.82	.76	.00
42.40	.00	.00	130.1	.769E+01	.76	3.89	.76	.00
43.39	.00	.00	133.4	.749E+01	.77	3.97	.77	.00
44.38	.00	.00	136.8	.731E+01	.77	4.04	.77	.00
45.38	.00	.00	140.4	.712E+01	.78	4.11	.78	.00
46.37	.00	.00	144.0	.695E+01	.78	4.18	.78	.00
47.37	.00	.00	147.7	.677E+01	.79	4.24	.79	.00
48.36	.00	.00	151.5	.660E+01	.80	4.31	.80	.00
49.35	.00	.00	155.4	.643E+01	.81	4.38	.81	.00
50.35	.00	.00	159.4	.627E+01	.82	4.45	.82	.00
51.34	.00	.00	163.6	.611E+01	.83	4.51	.83	.00
52.34	.00	.00	167.8	.596E+01	.83	4.58	.83	.00
53.33	.00	.00	172.2	.581E+01	.84	4.65	.84	.00
54.33	.00	.00	176.6	.566E+01	.85	4.71	.85	.00
55.32	.00	.00	181.2	.552E+01	.86	4.78	.86	.00
56.31	.00	.00	185.9	.538E+01	.87	4.84	.87	.00
57.31	.00	.00	190.6	.525E+01	.89	4.90	.89	.00
58.30	.00	.00	195.5	.511E+01	.90	4.97	.90	.00
59.30	.00	.00	200.6	.499E+01	.91	5.03	.91	.00
60.29	.00	.00	205.7	.486E+01	.92	5.09	.92	.00
61.29	.00	.00	211.0	.474E+01	.93	5.16	.93	.00
62.28	.00	.00	216.3	.462E+01	.94	5.22	.94	.00

Cumulative travel time = 199. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

MAC3-1N1.CX1

Vertical diffusivity (initial value) = .178E-01 m^2/s
Horizontal diffusivity (initial value) = .444E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
62.28	.00	.00	216.3	.462E+01	.94	5.22	.94	.00
65.87	.00	.00	227.1	.440E+01	.96	5.38	.96	.00
69.47	.00	.00	238.3	.420E+01	.98	5.54	.98	.00
73.06	.00	.00	249.8	.400E+01	1.00	5.70	1.00	.00
76.66	.00	.00	261.7	.382E+01	1.02	5.85	1.02	.00
80.25	.00	.00	274.1	.365E+01	1.04	6.00	1.04	.00
83.84	.00	.00	286.9	.348E+01	1.06	6.14	1.06	.00
87.44	.00	.00	300.4	.333E+01	1.09	6.28	1.09	.00
91.03	.00	.00	314.4	.318E+01	1.12	6.42	1.12	.00
94.63	.00	.00	329.1	.304E+01	1.14	6.55	1.14	.00
98.22	.00	.00	344.5	.290E+01	1.17	6.68	1.17	.00
101.81	.00	.00	360.6	.277E+01	1.20	6.81	1.20	.00
105.41	.00	.00	377.5	.265E+01	1.24	6.94	1.24	.00
109.00	.00	.00	395.2	.253E+01	1.27	7.06	1.27	.00
112.60	.00	.00	413.8	.242E+01	1.31	7.19	1.31	.00
116.19	.00	.00	433.4	.231E+01	1.35	7.31	1.35	.00
119.78	.00	.00	453.9	.220E+01	1.39	7.43	1.39	.00
123.38	.00	.00	475.4	.210E+01	1.44	7.54	1.44	.00
126.97	.00	.00	498.0	.201E+01	1.48	7.66	1.48	.00
130.57	.00	.00	521.6	.192E+01	1.53	7.77	1.53	.00
134.16	.00	.00	546.4	.183E+01	1.58	7.88	1.58	.00
137.75	.00	.00	572.2	.175E+01	1.63	7.99	1.63	.00
141.35	.00	.00	599.2	.167E+01	1.68	8.10	1.68	.00
144.94	.00	.00	627.3	.159E+01	1.74	8.21	1.74	.00
148.54	.00	.00	656.5	.152E+01	1.80	8.31	1.80	.00
152.13	.00	.00	686.9	.146E+01	1.86	8.42	1.86	.00
155.72	.00	.00	718.3	.139E+01	1.92	8.52	1.92	.00
159.32	.00	.00	750.8	.133E+01	1.98	8.62	1.98	.00
162.91	.00	.00	784.4	.127E+01	2.05	8.72	2.05	.00
166.51	.00	.00	819.0	.122E+01	2.11	8.82	2.11	.00
170.10	.00	.00	854.5	.117E+01	2.18	8.92	2.18	.00
173.69	.00	.00	891.0	.112E+01	2.25	9.02	2.25	.00

177.29	.00	.00	928.3	.108E+01	2.32	9.11	2.32	.00
180.88	.00	.00	966.5	.103E+01	2.39	9.21	2.39	.00
184.48	.00	.00	1005.5	.995E+00	2.46	9.30	2.46	.00
188.07	.00	.00	1045.2	.957E+00	2.53	9.40	2.53	.00
191.66	.00	.00	1085.6	.921E+00	2.60	9.49	2.60	.00
195.26	.00	.00	1126.6	.888E+00	2.68	9.58	2.68	.00
198.85	.00	.00	1168.2	.856E+00	2.75	9.67	2.75	.00
202.45	.00	.00	1210.3	.826E+00	2.82	9.76	2.82	.00
206.04	.00	.00	1253.0	.798E+00	2.90	9.85	2.90	.00
209.63	.00	.00	1296.2	.772E+00	2.97	9.94	2.97	.00
213.23	.00	.00	1339.7	.746E+00	3.04	10.03	3.04	.00
216.82	.00	.00	1383.7	.723E+00	3.12	10.11	3.12	.00
220.42	.00	.00	1428.0	.700E+00	3.19	10.20	3.19	.00
224.01	.00	.00	1472.7	.679E+00	3.26	10.28	3.26	.00
227.60	.00	.00	1517.7	.659E+00	3.33	10.37	3.33	.00
231.20	.00	.00	1562.9	.640E+00	3.40	10.45	3.40	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

234.79	.00	.00	1605.7	.623E+00	3.47	10.54	3.47	.00
238.39	.00	.00	1618.3	.618E+00	3.47	10.62	3.47	.00
241.98	.00	.00	1630.7	.613E+00	3.47	10.70	3.47	.00

Cumulative travel time = 825. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
241.98	10.70	.00	1630.7	.613E+00	3.47	21.40	3.47	.00
257.14	10.70	.00	1643.8	.608E+00	3.47	21.57	3.47	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.
The x-coordinate of bank attachment is 257.91 m.

272.30	10.70	.00	1656.7	.604E+00	3.47	21.58	3.47	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

287.46	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
302.62	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
317.78	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
332.94	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
348.10	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
363.26	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
378.42	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
393.58	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
408.74	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
423.90	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
439.07	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
454.23	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00

MAC3-1N1.CX1

469.39	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
484.55	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
499.71	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
514.87	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
530.03	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
545.19	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
560.35	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
575.51	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
590.67	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
605.83	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
620.99	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
636.15	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
651.31	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
666.47	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
681.63	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
696.79	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
711.95	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
727.11	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
742.27	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
757.43	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
772.59	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
787.75	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
802.91	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
818.08	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
833.24	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
848.40	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
863.56	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
878.72	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
893.88	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
909.04	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
924.20	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
939.36	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
954.52	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
969.68	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
984.84	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
1000.00	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00

Cumulative travel time = 3464. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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MAC3-1X1.CX1

CORMIX1 PREDICTION FILE:
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CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:
Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION
Site name/label: MACH^BIG^MUDDY^RIVER
Design case: CASE^3^-^PORT^1^MAXIMUM^FLOW
FILE NAME: cormix\sim\MAC3-1X1.cx1
Time of Fortran run: 01/13/20--20:00:41

ENVIRONMENT PARAMETERS (metric units)
Bounded section
BS = 23.71 AS = 107.64 QA = 30.89 ICHREG= 2
HA = 4.54 HD = 4.54
UA = .287 F = .058 USTAR = .2445E-01
UW = 2.000 UWSTAR= .2198E-02
Uniform density environment
STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)
BANK = LEFT DISTB = 11.80
D0 = .076 A0 = .005 H0 = .56
THETA = 30.00 SIGMA = .00
U0 = 5.487 Q0 = .025 = .2502E-01
RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00
C0 = .1000E+04 CUNITS= PPM
IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)
Q0 = .2502E-01 M0 = .1373E+00 J0 =-.3662E-02 SIGNJ0= -1.0
Associated length scales (meters)
LQ = .07 LM = 3.73 Lm = 1.29 Lb = .15
Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS
FR0 = 51.96 R = 19.11

FLOW CLASSIFICATION
1111111111111111111111111111111111111111
1 Flow class (CORMIX1) = NH4 1
1 Applicable layer depth HS = 4.54 1
1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1000E+04 CUNITS= PPM

MAC3-1X1.CX1

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1000.00  XMAX   =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .56      1.0  .100E+04     .04

END OF MOD101: DISCHARGE MODULE
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:          THETAE=     29.04  SIGMAE=       .00
  LE    =       .35  XE    =       .30  YE    =       .00  ZE    =       .74

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .56      1.0  .100E+04     .04
      .30      .00      .74      1.0  .100E+04     .04
      .65      .00      .91      2.0  .503E+03     .08
     1.00      .00     1.08      3.2  .311E+03     .13
     1.37      .00     1.22      4.6  .219E+03     .17
     1.74      .00     1.35      5.9  .168E+03     .22
     2.11      .00     1.46      7.3  .136E+03     .25
     2.49      .00     1.56      8.8  .114E+03     .29
     2.87      .00     1.65     10.1  .988E+02     .32
     3.25      .00     1.73     11.4  .873E+02     .35
     3.65      .00     1.79     12.8  .783E+02     .38
     4.03      .00     1.85     14.0  .715E+02     .41
     4.41      .00     1.90     15.2  .660E+02     .43
     4.81      .00     1.95     16.3  .614E+02     .45
     5.20      .00     1.98     17.3  .577E+02     .47
```

5.60	.00	2.01	18.4	.545E+02	.49
5.98	.00	2.04	19.3	.519E+02	.51
6.37	.00	2.06	20.1	.497E+02	.52
6.77	.00	2.08	21.0	.477E+02	.53
7.16	.00	2.09	21.7	.461E+02	.55
7.54	.00	2.10	22.4	.447E+02	.56
7.94	.00	2.10	23.0	.435E+02	.57

Maximum jet height has been reached.

8.33	.00	2.10	23.6	.424E+02	.58
8.72	.00	2.09	24.2	.413E+02	.59
9.12	.00	2.09	24.9	.401E+02	.60
9.51	.00	2.07	25.7	.389E+02	.61
9.89	.00	2.06	26.5	.378E+02	.62
10.29	.00	2.04	27.4	.366E+02	.63
10.68	.00	2.02	28.3	.354E+02	.64
11.08	.00	1.99	29.2	.342E+02	.66
11.46	.00	1.97	30.2	.331E+02	.67
11.85	.00	1.94	31.3	.320E+02	.69
12.25	.00	1.90	32.4	.308E+02	.70
12.64	.00	1.87	33.6	.298E+02	.71
13.02	.00	1.83	34.8	.287E+02	.73
13.42	.00	1.79	36.1	.277E+02	.75
13.80	.00	1.75	37.4	.268E+02	.76
14.19	.00	1.71	38.7	.258E+02	.78
14.59	.00	1.67	40.1	.249E+02	.79
14.97	.00	1.62	41.5	.241E+02	.81
15.37	.00	1.57	43.0	.232E+02	.83
15.75	.00	1.53	44.5	.225E+02	.84
16.14	.00	1.48	46.0	.217E+02	.86
16.54	.00	1.43	47.6	.210E+02	.88
16.92	.00	1.38	49.2	.203E+02	.89
17.30	.00	1.33	50.9	.197E+02	.91
17.70	.00	1.28	52.6	.190E+02	.93
18.08	.00	1.23	54.3	.184E+02	.94
18.47	.00	1.17	56.0	.179E+02	.96
18.86	.00	1.12	57.8	.173E+02	.98
19.25	.00	1.07	59.6	.168E+02	.99
19.63	.00	1.01	61.4	.163E+02	1.01

Cumulative travel time = 35. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
19.63	.00	1.01	61.4	.163E+02	1.01

MAC3-1X1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
18.62	.00	.00	61.4	.163E+02	.00	.00	.00	.00
18.92	.00	.00	61.4	.163E+02	1.34	.67	1.34	.00
19.23	.00	.00	61.4	.163E+02	1.59	.95	1.59	.00
19.53	.00	.00	61.4	.163E+02	1.75	1.17	1.75	.00
19.83	.00	.00	63.1	.158E+02	1.87	1.35	1.87	.00
20.14	.00	.00	70.9	.141E+02	1.96	1.51	1.96	.00
20.44	.00	.00	81.7	.122E+02	2.02	1.65	2.02	.00
20.74	.00	.00	91.6	.109E+02	2.07	1.78	2.07	.00
21.05	.00	.00	98.4	.102E+02	2.11	1.91	2.11	.00
21.35	.00	.00	102.0	.980E+01	2.13	2.02	2.13	.00
21.66	.00	.00	104.4	.958E+01	2.13	2.13	2.13	.00

Cumulative travel time = 42. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
21.66	.00	.00	104.4	.958E+01	2.13	2.13	2.13	.00
23.90	.00	.00	108.3	.923E+01	1.95	2.43	1.95	.00
26.14	.00	.00	111.9	.894E+01	1.81	2.70	1.81	.00
28.38	.00	.00	115.3	.867E+01	1.70	2.96	1.70	.00
30.62	.00	.00	118.6	.843E+01	1.61	3.21	1.61	.00
32.87	.00	.00	121.8	.821E+01	1.54	3.45	1.54	.00
35.11	.00	.00	125.0	.800E+01	1.48	3.69	1.48	.00
37.35	.00	.00	128.3	.780E+01	1.43	3.91	1.43	.00
39.59	.00	.00	131.6	.760E+01	1.39	4.13	1.39	.00

41.84	.00	.00	135.0	.741E+01	1.35	4.35	1.35	.00
44.08	.00	.00	138.4	.722E+01	1.32	4.56	1.32	.00
46.32	.00	.00	142.0	.704E+01	1.30	4.76	1.30	.00
48.56	.00	.00	145.7	.686E+01	1.28	4.96	1.28	.00
50.80	.00	.00	149.6	.669E+01	1.26	5.16	1.26	.00
53.05	.00	.00	153.6	.651E+01	1.25	5.35	1.25	.00
55.29	.00	.00	157.7	.634E+01	1.24	5.54	1.24	.00
57.53	.00	.00	162.1	.617E+01	1.23	5.72	1.23	.00
59.77	.00	.00	166.5	.600E+01	1.23	5.90	1.23	.00
62.02	.00	.00	171.2	.584E+01	1.23	6.08	1.23	.00
64.26	.00	.00	176.1	.568E+01	1.23	6.26	1.23	.00
66.50	.00	.00	181.1	.552E+01	1.23	6.44	1.23	.00
68.74	.00	.00	186.3	.537E+01	1.23	6.61	1.23	.00
70.99	.00	.00	191.8	.521E+01	1.23	6.78	1.23	.00
73.23	.00	.00	197.4	.507E+01	1.24	6.95	1.24	.00
75.47	.00	.00	203.3	.492E+01	1.25	7.11	1.25	.00
77.71	.00	.00	209.4	.478E+01	1.25	7.28	1.25	.00
79.95	.00	.00	215.6	.464E+01	1.26	7.44	1.26	.00
82.20	.00	.00	222.2	.450E+01	1.27	7.60	1.27	.00
84.44	.00	.00	228.9	.437E+01	1.29	7.76	1.29	.00
86.68	.00	.00	235.9	.424E+01	1.30	7.92	1.30	.00
88.92	.00	.00	243.1	.411E+01	1.31	8.07	1.31	.00
91.17	.00	.00	250.5	.399E+01	1.33	8.22	1.33	.00
93.41	.00	.00	258.2	.387E+01	1.34	8.38	1.34	.00
95.65	.00	.00	266.2	.376E+01	1.36	8.53	1.36	.00
97.89	.00	.00	274.3	.365E+01	1.38	8.68	1.38	.00
100.13	.00	.00	282.8	.354E+01	1.40	8.83	1.40	.00
102.38	.00	.00	291.5	.343E+01	1.42	8.98	1.42	.00
104.62	.00	.00	300.4	.333E+01	1.44	9.12	1.44	.00
106.86	.00	.00	309.6	.323E+01	1.46	9.27	1.46	.00
109.10	.00	.00	319.1	.313E+01	1.48	9.41	1.48	.00
111.35	.00	.00	328.8	.304E+01	1.50	9.55	1.50	.00
113.59	.00	.00	338.8	.295E+01	1.52	9.70	1.52	.00
115.83	.00	.00	349.0	.286E+01	1.55	9.84	1.55	.00
118.07	.00	.00	359.6	.278E+01	1.57	9.98	1.57	.00
120.32	.00	.00	370.4	.270E+01	1.60	10.11	1.60	.00
122.56	.00	.00	381.5	.262E+01	1.62	10.25	1.62	.00
124.80	.00	.00	392.8	.255E+01	1.65	10.39	1.65	.00
127.04	.00	.00	404.5	.247E+01	1.68	10.53	1.68	.00
129.28	.00	.00	416.4	.240E+01	1.70	10.66	1.70	.00
131.53	.00	.00	428.6	.233E+01	1.73	10.79	1.73	.00
133.77	.00	.00	441.1	.227E+01	1.76	10.93	1.76	.00

Cumulative travel time = 433. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

MAC3-1X1.CX1

Vertical diffusivity (initial value) = .222E-01 m^2/s
Horizontal diffusivity (initial value) = .555E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
133.77	.00	.00	441.1	.227E+01	1.76	10.93	1.76	.00
134.42	.00	.00	443.0	.226E+01	1.76	10.95	1.76	.00
135.07	.00	.00	445.0	.225E+01	1.77	10.96	1.77	.00
135.73	.00	.00	446.9	.224E+01	1.77	10.98	1.77	.00
136.38	.00	.00	448.9	.223E+01	1.78	11.00	1.78	.00
137.03	.00	.00	450.9	.222E+01	1.78	11.02	1.78	.00
137.68	.00	.00	452.9	.221E+01	1.79	11.04	1.79	.00
138.34	.00	.00	454.8	.220E+01	1.79	11.05	1.79	.00
138.99	.00	.00	456.8	.219E+01	1.80	11.07	1.80	.00
139.64	.00	.00	458.9	.218E+01	1.80	11.09	1.80	.00
140.29	.00	.00	460.9	.217E+01	1.81	11.11	1.81	.00
140.94	.00	.00	462.9	.216E+01	1.81	11.13	1.81	.00
141.60	.00	.00	465.0	.215E+01	1.82	11.14	1.82	.00
142.25	.00	.00	467.0	.214E+01	1.82	11.16	1.82	.00
142.90	.00	.00	469.1	.213E+01	1.83	11.18	1.83	.00
143.55	.00	.00	471.1	.212E+01	1.83	11.20	1.83	.00
144.21	.00	.00	473.2	.211E+01	1.84	11.21	1.84	.00
144.86	.00	.00	475.3	.210E+01	1.84	11.23	1.84	.00
145.51	.00	.00	477.4	.209E+01	1.85	11.25	1.85	.00
146.16	.00	.00	479.5	.209E+01	1.86	11.27	1.86	.00
146.82	.00	.00	481.7	.208E+01	1.86	11.29	1.86	.00
147.47	.00	.00	483.8	.207E+01	1.87	11.30	1.87	.00
148.12	.00	.00	486.0	.206E+01	1.87	11.32	1.87	.00
148.77	.00	.00	488.1	.205E+01	1.88	11.34	1.88	.00
149.42	.00	.00	490.3	.204E+01	1.88	11.36	1.88	.00
150.08	.00	.00	492.5	.203E+01	1.89	11.37	1.89	.00
150.73	.00	.00	494.6	.202E+01	1.89	11.39	1.89	.00
151.38	.00	.00	496.8	.201E+01	1.90	11.41	1.90	.00
152.03	.00	.00	499.1	.200E+01	1.90	11.42	1.90	.00
152.69	.00	.00	501.3	.199E+01	1.91	11.44	1.91	.00
153.34	.00	.00	503.5	.199E+01	1.92	11.46	1.92	.00
153.99	.00	.00	505.7	.198E+01	1.92	11.48	1.92	.00

154.64	.00	.00	508.0	.197E+01	1.93	11.49	1.93	.00
155.29	.00	.00	510.3	.196E+01	1.93	11.51	1.93	.00
155.95	.00	.00	512.5	.195E+01	1.94	11.53	1.94	.00
156.60	.00	.00	514.8	.194E+01	1.94	11.55	1.94	.00
157.25	.00	.00	517.1	.193E+01	1.95	11.56	1.95	.00
157.90	.00	.00	519.4	.193E+01	1.96	11.58	1.96	.00
158.56	.00	.00	521.8	.192E+01	1.96	11.60	1.96	.00
159.21	.00	.00	524.1	.191E+01	1.97	11.61	1.97	.00
159.86	.00	.00	526.4	.190E+01	1.97	11.63	1.97	.00
160.51	.00	.00	528.8	.189E+01	1.98	11.65	1.98	.00
161.17	.00	.00	531.2	.188E+01	1.98	11.66	1.98	.00
161.82	.00	.00	533.5	.187E+01	1.99	11.68	1.99	.00
162.47	.00	.00	535.9	.187E+01	2.00	11.70	2.00	.00
163.12	.00	.00	538.3	.186E+01	2.00	11.72	2.00	.00
163.77	.00	.00	540.7	.185E+01	2.01	11.73	2.01	.00
164.43	.00	.00	543.2	.184E+01	2.02	11.75	2.02	.00
165.08	.00	.00	545.6	.183E+01	2.02	11.77	2.02	.00
165.73	.00	.00	548.1	.182E+01	2.03	11.78	2.03	.00
166.38	.00	.00	550.5	.182E+01	2.03	11.80	2.03	.00

Cumulative travel time = 546. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
166.38	11.80	.00	550.5	.182E+01	2.03	23.60	2.03	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 174.95 m.

183.06	11.80	.00	601.1	.166E+01	2.20	23.71	2.20	.00
199.73	11.80	.00	647.8	.154E+01	2.38	23.71	2.38	.00
216.40	11.80	.00	700.8	.143E+01	2.58	23.71	2.58	.00
233.07	11.80	.00	757.2	.132E+01	2.78	23.71	2.78	.00
249.75	11.80	.00	816.5	.122E+01	3.00	23.71	3.00	.00
266.42	11.80	.00	878.4	.114E+01	3.23	23.71	3.23	.00
283.09	11.80	.00	942.4	.106E+01	3.47	23.71	3.47	.00
299.76	11.80	.00	1007.9	.992E+00	3.71	23.71	3.71	.00
316.43	11.80	.00	1074.5	.931E+00	3.95	23.71	3.95	.00
333.11	11.80	.00	1141.8	.876E+00	4.20	23.71	4.20	.00
349.78	11.80	.00	1209.4	.827E+00	4.45	23.71	4.45	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

366.45	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

383.12	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
399.80	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00

416.47	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
433.14	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
449.81	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
466.49	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
483.16	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
499.83	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
516.50	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
533.18	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
549.85	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
566.52	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
583.19	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
599.86	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
616.54	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
633.21	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
649.88	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
666.55	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
683.23	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
699.90	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
716.57	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
733.24	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
749.92	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
766.59	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
783.26	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
799.93	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
816.60	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
833.28	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
849.95	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
866.62	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
883.29	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
899.97	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
916.64	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
933.31	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
949.98	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
966.66	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
983.33	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
1000.00	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00

Cumulative travel time = 3448. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

MAC3-3N1.CX1

CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111111

CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:
Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION
Site name/label: Mach^Big^Muddy^River
Design case: Case^3^-^Port^3^Normal^Flow
FILE NAME: cormix\sim\MAC3-3N1.cx1
Time of Fortran run: 01/13/20--19:37:08

ENVIRONMENT PARAMETERS (metric units)
Bounded section
BS = 21.58 AS = 74.88 QA = 21.49 ICHREG= 2
HA = 3.47 HD = 3.47
UA = .287 F = .064 USTAR = .2557E-01
UW = 2.000 UWSTAR= .2198E-02
Uniform density environment
STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)
BANK = LEFT DISTB = 10.70
D0 = .102 A0 = .008 H0 = .55
THETA = 30.00 SIGMA = .00
U0 = 2.866 Q0 = .023 = .2324E-01
RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00
C0 = .1000E+04 CUNITS= PPM
IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)
Q0 = .2324E-01 M0 = .6659E-01 J0 =-.3400E-02 SIGNJ0= -1.0
Associated length scales (meters)
LQ = .09 LM = 2.25 Lm = .90 Lb = .14
Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS
FR0 = 23.50 R = 9.98

FLOW CLASSIFICATION
11111111111111111111111111111111111111111
1 Flow class (CORMIX1) = NH4 1
1 Applicable layer depth HS = 3.47 1
11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1000E+04 CUNITS= PPM

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1000.00  XMAX   =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        10.70 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

      X        Y        Z        S        C        B
     .00      .00      .55     1.0  .100E+04     .05

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.17  SIGMAE=       .00
  LE    =       .43  XE    =       .37  YE    =       .00  ZE    =       .76

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

      X        Y        Z        S        C        B
     .00      .00      .55     1.0  .100E+04     .05
     .37      .00      .76     1.0  .100E+04     .05
     .57      .00      .86     1.4  .720E+03     .08
     .78      .00      .95     1.9  .516E+03     .10
     .99      .00     1.03     2.5  .398E+03     .13
    1.21      .00     1.11     3.1  .320E+03     .15
    1.42      .00     1.17     3.7  .270E+03     .18
    1.64      .00     1.23     4.3  .233E+03     .20
    1.87      .00     1.28     4.9  .205E+03     .22
    2.09      .00     1.32     5.4  .184E+03     .23
    2.31      .00     1.36     6.0  .168E+03     .25
    2.53      .00     1.40     6.5  .155E+03     .26
    2.77      .00     1.42     7.0  .144E+03     .28
    2.99      .00     1.45     7.4  .135E+03     .29
    3.21      .00     1.47     7.8  .128E+03     .30
```

3.45	.00	1.49	8.2	.121E+03	.31
3.67	.00	1.50	8.6	.116E+03	.32
3.90	.00	1.51	8.9	.112E+03	.33
4.13	.00	1.52	9.3	.108E+03	.34
4.35	.00	1.52	9.5	.105E+03	.34

Maximum jet height has been reached.

4.58	.00	1.52	9.8	.102E+03	.35
4.80	.00	1.52	10.1	.994E+02	.36
5.04	.00	1.51	10.4	.964E+02	.36
5.26	.00	1.50	10.7	.935E+02	.37
5.49	.00	1.49	11.0	.905E+02	.38
5.72	.00	1.48	11.4	.874E+02	.39
5.94	.00	1.46	11.8	.844E+02	.39
6.17	.00	1.45	12.3	.815E+02	.40
6.39	.00	1.43	12.7	.786E+02	.41
6.62	.00	1.41	13.2	.756E+02	.42
6.85	.00	1.38	13.7	.728E+02	.43
7.07	.00	1.36	14.3	.701E+02	.44
7.30	.00	1.33	14.8	.674E+02	.45
7.53	.00	1.30	15.4	.649E+02	.46
7.75	.00	1.27	16.0	.625E+02	.47
7.98	.00	1.24	16.6	.601E+02	.49
8.20	.00	1.21	17.3	.578E+02	.50
8.43	.00	1.18	17.9	.557E+02	.51
8.65	.00	1.15	18.6	.537E+02	.52
8.88	.00	1.11	19.4	.517E+02	.53
9.10	.00	1.08	20.1	.498E+02	.54
9.32	.00	1.04	20.8	.481E+02	.55
9.56	.00	1.01	21.6	.463E+02	.56
9.78	.00	.97	22.4	.447E+02	.58
10.00	.00	.93	23.1	.432E+02	.59
10.23	.00	.90	24.0	.417E+02	.60
10.45	.00	.86	24.8	.403E+02	.61
10.67	.00	.82	25.6	.390E+02	.62
10.89	.00	.79	26.5	.378E+02	.63
11.13	.00	.75	27.4	.365E+02	.65
11.35	.00	.71	28.2	.354E+02	.66
11.57	.00	.67	29.1	.343E+02	.67

Cumulative travel time = 20. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
11.57	.00	.67	29.1	.343E+02	.67

MAC3-3N1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.90	.00	.00	29.1	.343E+02	.00	.00	.00	.00
11.10	.00	.00	29.1	.343E+02	.89	.45	.89	.00
11.30	.00	.00	29.1	.343E+02	1.06	.63	1.06	.00
11.50	.00	.00	29.1	.343E+02	1.16	.78	1.16	.00
11.70	.00	.00	29.9	.334E+02	1.24	.90	1.24	.00
11.90	.00	.00	33.6	.297E+02	1.30	1.00	1.30	.00
12.10	.00	.00	38.8	.258E+02	1.34	1.10	1.34	.00
12.30	.00	.00	43.4	.230E+02	1.38	1.18	1.38	.00
12.51	.00	.00	46.6	.214E+02	1.40	1.27	1.40	.00
12.71	.00	.00	48.4	.207E+02	1.41	1.34	1.41	.00
12.91	.00	.00	49.5	.202E+02	1.42	1.42	1.42	.00

Cumulative travel time = 25. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
12.91	.00	.00	49.5	.202E+02	1.42	1.42	1.42	.00
14.85	.00	.00	52.2	.192E+02	1.24	1.71	1.24	.00
16.79	.00	.00	54.5	.183E+02	1.11	1.98	1.11	.00
18.74	.00	.00	56.7	.176E+02	1.03	2.23	1.03	.00
20.68	.00	.00	58.7	.170E+02	.96	2.47	.96	.00
22.63	.00	.00	60.8	.164E+02	.91	2.70	.91	.00
24.57	.00	.00	62.9	.159E+02	.87	2.92	.87	.00
26.51	.00	.00	65.0	.154E+02	.84	3.13	.84	.00
28.46	.00	.00	67.2	.149E+02	.81	3.34	.81	.00

30.40	.00	.00	69.4	.144E+02	.79	3.54	.79	.00
32.34	.00	.00	71.8	.139E+02	.78	3.73	.78	.00
34.29	.00	.00	74.3	.135E+02	.77	3.92	.77	.00
36.23	.00	.00	76.9	.130E+02	.76	4.10	.76	.00
38.18	.00	.00	79.7	.126E+02	.75	4.28	.75	.00
40.12	.00	.00	82.5	.121E+02	.75	4.46	.75	.00
42.06	.00	.00	85.6	.117E+02	.75	4.63	.75	.00
44.01	.00	.00	88.8	.113E+02	.75	4.80	.75	.00
45.95	.00	.00	92.1	.109E+02	.75	4.96	.75	.00
47.90	.00	.00	95.7	.105E+02	.76	5.13	.76	.00
49.84	.00	.00	99.4	.101E+02	.76	5.29	.76	.00
51.78	.00	.00	103.3	.968E+01	.77	5.45	.77	.00
53.73	.00	.00	107.3	.932E+01	.78	5.60	.78	.00
55.67	.00	.00	111.6	.896E+01	.78	5.76	.78	.00
57.61	.00	.00	116.0	.862E+01	.79	5.91	.79	.00
59.56	.00	.00	120.7	.829E+01	.81	6.06	.81	.00
61.50	.00	.00	125.5	.797E+01	.82	6.21	.82	.00
63.45	.00	.00	130.5	.766E+01	.83	6.35	.83	.00
65.39	.00	.00	135.8	.737E+01	.85	6.50	.85	.00
67.33	.00	.00	141.2	.708E+01	.86	6.64	.86	.00
69.28	.00	.00	146.9	.681E+01	.88	6.78	.88	.00
71.22	.00	.00	152.8	.655E+01	.89	6.92	.89	.00
73.17	.00	.00	158.9	.630E+01	.91	7.06	.91	.00
75.11	.00	.00	165.2	.605E+01	.93	7.20	.93	.00
77.05	.00	.00	171.7	.582E+01	.95	7.34	.95	.00
79.00	.00	.00	178.5	.560E+01	.97	7.47	.97	.00
80.94	.00	.00	185.4	.539E+01	.99	7.61	.99	.00
82.88	.00	.00	192.7	.519E+01	1.01	7.74	1.01	.00
84.83	.00	.00	200.1	.500E+01	1.03	7.87	1.03	.00
86.77	.00	.00	207.8	.481E+01	1.05	8.00	1.05	.00
88.72	.00	.00	215.7	.464E+01	1.07	8.13	1.07	.00
90.66	.00	.00	223.9	.447E+01	1.10	8.26	1.10	.00
92.60	.00	.00	232.3	.431E+01	1.12	8.39	1.12	.00
94.55	.00	.00	240.9	.415E+01	1.15	8.51	1.15	.00
96.49	.00	.00	249.8	.400E+01	1.17	8.64	1.17	.00
98.43	.00	.00	259.0	.386E+01	1.20	8.76	1.20	.00
100.38	.00	.00	268.3	.373E+01	1.22	8.89	1.22	.00
102.32	.00	.00	278.0	.360E+01	1.25	9.01	1.25	.00
104.27	.00	.00	287.9	.347E+01	1.28	9.13	1.28	.00
106.21	.00	.00	298.0	.336E+01	1.30	9.25	1.30	.00
108.15	.00	.00	308.4	.324E+01	1.33	9.37	1.33	.00
110.10	.00	.00	319.1	.313E+01	1.36	9.49	1.36	.00

Cumulative travel time = 363. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

MAC3-3N1.CX1

Vertical diffusivity (initial value) = .178E-01 m^2/s
Horizontal diffusivity (initial value) = .444E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
110.10	.00	.00	319.1	.313E+01	1.36	9.49	1.36	.00
111.10	.00	.00	321.9	.311E+01	1.37	9.52	1.37	.00
112.11	.00	.00	324.7	.308E+01	1.38	9.54	1.38	.00
113.11	.00	.00	327.5	.305E+01	1.39	9.57	1.39	.00
114.12	.00	.00	330.3	.303E+01	1.39	9.59	1.39	.00
115.13	.00	.00	333.2	.300E+01	1.40	9.62	1.40	.00
116.13	.00	.00	336.1	.298E+01	1.41	9.64	1.41	.00
117.14	.00	.00	339.1	.295E+01	1.42	9.67	1.42	.00
118.14	.00	.00	342.0	.292E+01	1.43	9.69	1.43	.00
119.15	.00	.00	345.0	.290E+01	1.44	9.72	1.44	.00
120.15	.00	.00	348.1	.287E+01	1.45	9.75	1.45	.00
121.16	.00	.00	351.1	.285E+01	1.45	9.77	1.45	.00
122.16	.00	.00	354.2	.282E+01	1.46	9.80	1.46	.00
123.17	.00	.00	357.3	.280E+01	1.47	9.82	1.47	.00
124.17	.00	.00	360.5	.277E+01	1.48	9.84	1.48	.00
125.18	.00	.00	363.7	.275E+01	1.49	9.87	1.49	.00
126.18	.00	.00	366.9	.273E+01	1.50	9.89	1.50	.00
127.19	.00	.00	370.2	.270E+01	1.51	9.92	1.51	.00
128.20	.00	.00	373.4	.268E+01	1.52	9.94	1.52	.00
129.20	.00	.00	376.8	.265E+01	1.53	9.97	1.53	.00
130.21	.00	.00	380.1	.263E+01	1.54	9.99	1.54	.00
131.21	.00	.00	383.5	.261E+01	1.55	10.02	1.55	.00
132.22	.00	.00	386.9	.258E+01	1.56	10.04	1.56	.00
133.22	.00	.00	390.4	.256E+01	1.57	10.07	1.57	.00
134.23	.00	.00	393.9	.254E+01	1.58	10.09	1.58	.00
135.23	.00	.00	397.4	.252E+01	1.59	10.11	1.59	.00
136.24	.00	.00	401.0	.249E+01	1.60	10.14	1.60	.00
137.24	.00	.00	404.6	.247E+01	1.61	10.16	1.61	.00
138.25	.00	.00	408.2	.245E+01	1.62	10.19	1.62	.00
139.26	.00	.00	411.8	.243E+01	1.63	10.21	1.63	.00
140.26	.00	.00	415.5	.241E+01	1.64	10.23	1.64	.00
141.27	.00	.00	419.3	.239E+01	1.65	10.26	1.65	.00

142.27	.00	.00	423.1	.236E+01	1.67	10.28	1.67	.00
143.28	.00	.00	426.9	.234E+01	1.68	10.31	1.68	.00
144.28	.00	.00	430.7	.232E+01	1.69	10.33	1.69	.00
145.29	.00	.00	434.6	.230E+01	1.70	10.35	1.70	.00
146.29	.00	.00	438.5	.228E+01	1.71	10.38	1.71	.00
147.30	.00	.00	442.5	.226E+01	1.72	10.40	1.72	.00
148.30	.00	.00	446.5	.224E+01	1.73	10.42	1.73	.00
149.31	.00	.00	450.5	.222E+01	1.75	10.45	1.75	.00
150.32	.00	.00	454.6	.220E+01	1.76	10.47	1.76	.00
151.32	.00	.00	458.7	.218E+01	1.77	10.49	1.77	.00
152.33	.00	.00	462.8	.216E+01	1.78	10.52	1.78	.00
153.33	.00	.00	467.0	.214E+01	1.79	10.54	1.79	.00
154.34	.00	.00	471.2	.212E+01	1.81	10.56	1.81	.00
155.34	.00	.00	475.5	.210E+01	1.82	10.59	1.82	.00
156.35	.00	.00	479.8	.208E+01	1.83	10.61	1.83	.00
157.35	.00	.00	484.1	.207E+01	1.84	10.63	1.84	.00
158.36	.00	.00	488.5	.205E+01	1.86	10.65	1.86	.00
159.36	.00	.00	492.9	.203E+01	1.87	10.68	1.87	.00
160.37	.00	.00	497.3	.201E+01	1.88	10.70	1.88	.00

Cumulative travel time = 538. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
160.37	10.70	.00	497.3	.201E+01	1.88	21.40	1.88	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 176.31 m.

177.16	10.70	.00	561.8	.178E+01	2.11	21.58	2.11	.00
193.96	10.70	.00	626.3	.160E+01	2.35	21.58	2.35	.00
210.75	10.70	.00	694.5	.144E+01	2.61	21.58	2.61	.00
227.54	10.70	.00	765.0	.131E+01	2.87	21.58	2.87	.00
244.33	10.70	.00	836.7	.120E+01	3.14	21.58	3.14	.00
261.13	10.70	.00	908.8	.110E+01	3.41	21.58	3.41	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

277.92	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

294.71	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
311.50	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
328.30	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
345.09	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
361.88	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
378.67	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
395.47	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00

412.26	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
429.05	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
445.84	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
462.64	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
479.43	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
496.22	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
513.01	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
529.81	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
546.60	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
563.39	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
580.19	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
596.98	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
613.77	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
630.56	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
647.36	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
664.15	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
680.94	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
697.73	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
714.53	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
731.32	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
748.11	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
764.90	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
781.70	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
798.49	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
815.28	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
832.07	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
848.87	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
865.66	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
882.45	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
899.24	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
916.04	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
932.83	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
949.62	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
966.42	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
983.21	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
1000.00	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00

Cumulative travel time = 3460. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

111111111111111111111111111111111111111111111111111111111111111111111111111111

MAC3-3X1.CX1

CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111

CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:
Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION
Site name/label: MACH^BIG^MUDDY^RIVER
Design case: CASE^3^-^PORT^3^MAXIMUM^FLOW
FILE NAME: cormix\sim\MAC3-3X1.cx1
Time of Fortran run: 01/13/20-:19:56:57

ENVIRONMENT PARAMETERS (metric units)
Bounded section
BS = 23.71 AS = 107.64 QA = 30.89 ICHREG= 2
HA = 4.54 HD = 4.54
UA = .287 F = .058 USTAR = .2445E-01
UW = 2.000 UWSTAR= .2198E-02
Uniform density environment
STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)
BANK = LEFT DISTB = 11.00
D0 = .102 A0 = .008 H0 = .55
THETA = 30.00 SIGMA = .00
U0 = 5.487 Q0 = .044 = .4448E-01
RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00
C0 = .1000E+04 CUNITS= PPM
IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)
Q0 = .4448E-01 M0 = .2441E+00 J0 =-.6510E-02 SIGNJ0= -1.0
Associated length scales (meters)
LQ = .09 LM = 4.30 Lm = 1.72 Lb = .28
Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS
FR0 = 44.99 R = 19.11

FLOW CLASSIFICATION
1111111111111111111111111111111111111111
1 Flow class (CORMIX1) = NH4 1
1 Applicable layer depth HS = 4.54 1
1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1000E+04 CUNITS= PPM

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1000.00  XMAX   =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

      X        Y        Z        S        C        B
     .00      .00      .55      1.0  .100E+04     .05

END OF MOD101: DISCHARGE MODULE
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     29.04  SIGMAE=        .00
  LE    =        .47  XE    =        .40  YE    =        .00  ZE    =        .78

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

      X        Y        Z        S        C        B
     .00      .00      .55      1.0  .100E+04     .05
     .40      .00      .78      1.0  .100E+04     .05
     .75      .00      .97      1.7  .582E+03     .10
    1.13      .00     1.14      2.7  .375E+03     .15
    1.51      .00     1.31      3.7  .272E+03     .19
    1.88      .00     1.45      4.7  .213E+03     .24
    2.27      .00     1.58      5.8  .173E+03     .28
    2.66      .00     1.70      6.9  .146E+03     .32
    3.05      .00     1.80      7.9  .126E+03     .36
    3.45      .00     1.89      9.0  .111E+03     .40
    3.85      .00     1.98     10.0  .997E+02     .43
    4.24      .00     2.05     11.0  .909E+02     .46
    4.65      .00     2.12     12.0  .835E+02     .49
    5.06      .00     2.17     12.9  .775E+02     .51
    5.45      .00     2.22     13.8  .726E+02     .54
```

5.86	.00	2.27	14.6	.684E+02	.56
6.27	.00	2.30	15.4	.649E+02	.58
6.67	.00	2.33	16.1	.619E+02	.60
7.08	.00	2.36	16.9	.593E+02	.62
7.49	.00	2.38	17.5	.571E+02	.63
7.89	.00	2.39	18.1	.552E+02	.65
8.30	.00	2.40	18.7	.535E+02	.66
8.72	.00	2.41	19.2	.521E+02	.67

Maximum jet height has been reached.

9.11	.00	2.41	19.7	.508E+02	.68
9.53	.00	2.40	20.2	.495E+02	.70
9.94	.00	2.39	20.8	.482E+02	.71
10.33	.00	2.38	21.3	.468E+02	.72
10.75	.00	2.36	22.0	.455E+02	.73
11.16	.00	2.34	22.7	.441E+02	.75
11.55	.00	2.32	23.4	.427E+02	.76
11.97	.00	2.29	24.2	.414E+02	.78
12.38	.00	2.26	25.0	.400E+02	.80
12.77	.00	2.22	25.8	.387E+02	.81
13.18	.00	2.19	26.7	.374E+02	.83
13.60	.00	2.14	27.7	.361E+02	.85
13.99	.00	2.10	28.6	.349E+02	.86
14.40	.00	2.06	29.7	.337E+02	.88
14.81	.00	2.01	30.7	.326E+02	.90
15.20	.00	1.96	31.8	.315E+02	.92
15.61	.00	1.91	32.9	.304E+02	.94
16.02	.00	1.85	34.1	.293E+02	.96
16.41	.00	1.80	35.2	.284E+02	.98
16.82	.00	1.74	36.5	.274E+02	1.00
17.23	.00	1.68	37.7	.265E+02	1.02
17.62	.00	1.62	39.0	.257E+02	1.04
18.03	.00	1.56	40.3	.248E+02	1.06
18.44	.00	1.50	41.7	.240E+02	1.08
18.83	.00	1.44	43.0	.232E+02	1.10
19.24	.00	1.38	44.4	.225E+02	1.12
19.65	.00	1.31	45.9	.218E+02	1.14
20.04	.00	1.25	47.3	.211E+02	1.16
20.45	.00	1.18	48.8	.205E+02	1.18

Cumulative travel time = 33. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
20.45	.00	1.18	48.8	.205E+02	1.18

MAC3-3X1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
19.27	.00	.00	48.8	.205E+02	.00	.00	.00	.00
19.62	.00	.00	48.8	.205E+02	1.59	.80	1.59	.00
19.97	.00	.00	48.8	.205E+02	1.89	1.13	1.89	.00
20.33	.00	.00	48.8	.205E+02	2.08	1.39	2.08	.00
20.68	.00	.00	50.1	.200E+02	2.22	1.60	2.22	.00
21.04	.00	.00	56.3	.178E+02	2.32	1.79	2.32	.00
21.39	.00	.00	64.9	.154E+02	2.40	1.96	2.40	.00
21.75	.00	.00	72.7	.137E+02	2.46	2.12	2.46	.00
22.10	.00	.00	78.1	.128E+02	2.50	2.27	2.50	.00
22.46	.00	.00	81.0	.123E+02	2.53	2.40	2.53	.00
22.81	.00	.00	82.9	.121E+02	2.53	2.53	2.53	.00

Cumulative travel time = 41. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
22.81	.00	.00	82.9	.121E+02	2.53	2.53	2.53	.00
24.47	.00	.00	85.2	.117E+02	2.36	2.80	2.36	.00
26.12	.00	.00	87.2	.115E+02	2.21	3.05	2.21	.00
27.77	.00	.00	89.1	.112E+02	2.10	3.30	2.10	.00
29.43	.00	.00	90.9	.110E+02	2.00	3.53	2.00	.00
31.08	.00	.00	92.7	.108E+02	1.91	3.76	1.91	.00
32.74	.00	.00	94.3	.106E+02	1.84	3.98	1.84	.00
34.39	.00	.00	95.9	.104E+02	1.77	4.19	1.77	.00
36.05	.00	.00	97.5	.103E+02	1.72	4.40	1.72	.00

37.70	.00	.00	99.1	.101E+02	1.67	4.61	1.67	.00
39.36	.00	.00	100.6	.994E+01	1.62	4.81	1.62	.00
41.01	.00	.00	102.2	.979E+01	1.58	5.00	1.58	.00
42.66	.00	.00	103.7	.964E+01	1.55	5.19	1.55	.00
44.32	.00	.00	105.3	.950E+01	1.52	5.38	1.52	.00
45.97	.00	.00	106.8	.936E+01	1.49	5.57	1.49	.00
47.63	.00	.00	108.4	.923E+01	1.46	5.75	1.46	.00
49.28	.00	.00	110.0	.909E+01	1.44	5.93	1.44	.00
50.94	.00	.00	111.6	.896E+01	1.42	6.10	1.42	.00
52.59	.00	.00	113.2	.883E+01	1.40	6.28	1.40	.00
54.25	.00	.00	114.9	.870E+01	1.38	6.45	1.38	.00
55.90	.00	.00	116.6	.858E+01	1.37	6.62	1.37	.00
57.55	.00	.00	118.3	.845E+01	1.35	6.79	1.35	.00
59.21	.00	.00	120.1	.833E+01	1.34	6.95	1.34	.00
60.86	.00	.00	121.9	.821E+01	1.33	7.11	1.33	.00
62.52	.00	.00	123.7	.808E+01	1.32	7.28	1.32	.00
64.17	.00	.00	125.6	.796E+01	1.31	7.43	1.31	.00
65.83	.00	.00	127.5	.784E+01	1.30	7.59	1.30	.00
67.48	.00	.00	129.4	.773E+01	1.29	7.75	1.29	.00
69.14	.00	.00	131.4	.761E+01	1.29	7.90	1.29	.00
70.79	.00	.00	133.5	.749E+01	1.28	8.06	1.28	.00
72.44	.00	.00	135.6	.738E+01	1.28	8.21	1.28	.00
74.10	.00	.00	137.7	.726E+01	1.28	8.36	1.28	.00
75.75	.00	.00	139.9	.715E+01	1.27	8.51	1.27	.00
77.41	.00	.00	142.1	.704E+01	1.27	8.66	1.27	.00
79.06	.00	.00	144.4	.693E+01	1.27	8.80	1.27	.00
80.72	.00	.00	146.7	.682E+01	1.27	8.95	1.27	.00
82.37	.00	.00	149.1	.671E+01	1.27	9.09	1.27	.00
84.03	.00	.00	151.6	.660E+01	1.27	9.23	1.27	.00
85.68	.00	.00	154.0	.649E+01	1.27	9.38	1.27	.00
87.34	.00	.00	156.6	.639E+01	1.28	9.52	1.28	.00
88.99	.00	.00	159.2	.628E+01	1.28	9.66	1.28	.00
90.64	.00	.00	161.9	.618E+01	1.28	9.79	1.28	.00
92.30	.00	.00	164.6	.608E+01	1.28	9.93	1.28	.00
93.95	.00	.00	167.3	.598E+01	1.29	10.07	1.29	.00
95.61	.00	.00	170.2	.588E+01	1.29	10.20	1.29	.00
97.26	.00	.00	173.1	.578E+01	1.30	10.34	1.30	.00
98.92	.00	.00	176.0	.568E+01	1.30	10.47	1.30	.00
100.57	.00	.00	179.0	.559E+01	1.31	10.61	1.31	.00
102.23	.00	.00	182.1	.549E+01	1.31	10.74	1.31	.00
103.88	.00	.00	185.3	.540E+01	1.32	10.87	1.32	.00
105.53	.00	.00	188.4	.531E+01	1.33	11.00	1.33	.00

Cumulative travel time = 329. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

MAC3-3X1.CX1

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
105.53	11.00	.00	188.4	.531E+01	1.33	22.00	1.33	.00
105.98	11.00	.00	189.2	.528E+01	1.33	22.03	1.33	.00
106.42	11.00	.00	190.0	.526E+01	1.33	22.07	1.33	.00
106.87	11.00	.00	190.8	.524E+01	1.34	22.10	1.34	.00
107.31	11.00	.00	191.6	.522E+01	1.34	22.14	1.34	.00
107.76	11.00	.00	192.4	.520E+01	1.34	22.17	1.34	.00
108.20	11.00	.00	193.2	.517E+01	1.35	22.21	1.35	.00
108.65	11.00	.00	194.1	.515E+01	1.35	22.24	1.35	.00
109.09	11.00	.00	194.9	.513E+01	1.36	22.28	1.36	.00
109.53	11.00	.00	195.7	.511E+01	1.36	22.31	1.36	.00
109.98	11.00	.00	196.5	.509E+01	1.36	22.35	1.36	.00
110.42	11.00	.00	197.3	.507E+01	1.37	22.38	1.37	.00
110.87	11.00	.00	198.1	.505E+01	1.37	22.42	1.37	.00
111.31	11.00	.00	199.0	.503E+01	1.37	22.45	1.37	.00
111.76	11.00	.00	199.8	.501E+01	1.38	22.49	1.38	.00
112.20	11.00	.00	200.6	.498E+01	1.38	22.52	1.38	.00
112.64	11.00	.00	201.4	.496E+01	1.38	22.56	1.38	.00
113.09	11.00	.00	202.3	.494E+01	1.39	22.59	1.39	.00
113.53	11.00	.00	203.1	.492E+01	1.39	22.62	1.39	.00
113.98	11.00	.00	203.9	.490E+01	1.39	22.66	1.39	.00
114.42	11.00	.00	204.8	.488E+01	1.40	22.69	1.40	.00
114.87	11.00	.00	205.6	.486E+01	1.40	22.73	1.40	.00
115.31	11.00	.00	206.5	.484E+01	1.41	22.76	1.41	.00
115.76	11.00	.00	207.3	.482E+01	1.41	22.80	1.41	.00
116.20	11.00	.00	208.2	.480E+01	1.41	22.83	1.41	.00
116.64	11.00	.00	209.0	.478E+01	1.42	22.86	1.42	.00
117.09	11.00	.00	209.9	.476E+01	1.42	22.90	1.42	.00
117.53	11.00	.00	210.7	.475E+01	1.42	22.93	1.42	.00
117.98	11.00	.00	211.6	.473E+01	1.43	22.97	1.43	.00
118.42	11.00	.00	212.5	.471E+01	1.43	23.00	1.43	.00
118.87	11.00	.00	213.3	.469E+01	1.44	23.04	1.44	.00
119.31	11.00	.00	214.2	.467E+01	1.44	23.07	1.44	.00
119.76	11.00	.00	215.1	.465E+01	1.44	23.10	1.44	.00
120.20	11.00	.00	215.9	.463E+01	1.45	23.14	1.45	.00
120.64	11.00	.00	216.8	.461E+01	1.45	23.17	1.45	.00
121.09	11.00	.00	217.7	.459E+01	1.45	23.21	1.45	.00
121.53	11.00	.00	218.6	.458E+01	1.46	23.24	1.46	.00
121.98	11.00	.00	219.4	.456E+01	1.46	23.27	1.46	.00
122.42	11.00	.00	220.3	.454E+01	1.46	23.31	1.46	.00
122.87	11.00	.00	221.2	.452E+01	1.47	23.34	1.47	.00
123.31	11.00	.00	222.1	.450E+01	1.47	23.38	1.47	.00
123.76	11.00	.00	223.0	.448E+01	1.48	23.41	1.48	.00
124.20	11.00	.00	223.9	.447E+01	1.48	23.44	1.48	.00
124.64	11.00	.00	224.8	.445E+01	1.48	23.48	1.48	.00
125.09	11.00	.00	225.7	.443E+01	1.49	23.51	1.49	.00
125.53	11.00	.00	226.6	.441E+01	1.49	23.54	1.49	.00

125.98	11.00	.00	227.5	.440E+01	1.50	23.58	1.50	.00
126.42	11.00	.00	228.4	.438E+01	1.50	23.61	1.50	.00
126.87	11.00	.00	229.3	.436E+01	1.50	23.65	1.50	.00
127.31	11.00	.00	230.2	.434E+01	1.51	23.68	1.51	.00
127.75	11.00	.00	231.1	.433E+01	1.51	23.71	1.51	.00

Cumulative travel time = 406. sec
Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .222E-01 m^2/s
Horizontal diffusivity (initial value) = .555E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
127.75	11.00	.00	231.1	.433E+01	1.51	23.71	1.51	.00
145.20	11.00	.00	239.8	.417E+01	1.57	23.71	1.57	.00
162.64	11.00	.00	248.9	.402E+01	1.63	23.71	1.63	.00
180.09	11.00	.00	258.7	.387E+01	1.69	23.71	1.69	.00
197.53	11.00	.00	269.0	.372E+01	1.76	23.71	1.76	.00
214.98	11.00	.00	280.1	.357E+01	1.83	23.71	1.83	.00
232.42	11.00	.00	291.8	.343E+01	1.91	23.71	1.91	.00
249.87	11.00	.00	304.3	.329E+01	1.99	23.71	1.99	.00
267.31	11.00	.00	317.5	.315E+01	2.08	23.71	2.08	.00
284.76	11.00	.00	331.6	.302E+01	2.17	23.71	2.17	.00
302.20	11.00	.00	346.6	.289E+01	2.26	23.71	2.26	.00
319.65	11.00	.00	362.4	.276E+01	2.37	23.71	2.37	.00
337.09	11.00	.00	379.2	.264E+01	2.48	23.71	2.48	.00
354.54	11.00	.00	397.0	.252E+01	2.59	23.71	2.59	.00
371.98	11.00	.00	415.7	.241E+01	2.72	23.71	2.72	.00
389.43	11.00	.00	435.4	.230E+01	2.85	23.71	2.85	.00
406.87	11.00	.00	456.1	.219E+01	2.98	23.71	2.98	.00
424.32	11.00	.00	477.8	.209E+01	3.12	23.71	3.12	.00
441.76	11.00	.00	500.4	.200E+01	3.27	23.71	3.27	.00
459.21	11.00	.00	524.0	.191E+01	3.42	23.71	3.42	.00

476.65	11.00	.00	548.4	.182E+01	3.58	23.71	3.58	.00
494.10	11.00	.00	573.6	.174E+01	3.75	23.71	3.75	.00
511.54	11.00	.00	599.7	.167E+01	3.92	23.71	3.92	.00
528.99	11.00	.00	626.4	.160E+01	4.09	23.71	4.09	.00
546.43	11.00	.00	653.7	.153E+01	4.27	23.71	4.27	.00
563.88	11.00	.00	681.6	.147E+01	4.45	23.71	4.45	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

581.32	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

598.77	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
616.21	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
633.66	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
651.10	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
668.55	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
685.99	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
703.44	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
720.88	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
738.33	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
755.77	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
773.22	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
790.66	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
808.11	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
825.55	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
843.00	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
860.44	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
877.89	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
895.33	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
912.78	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
930.22	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
947.66	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
965.11	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
982.55	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
1000.00	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00

Cumulative travel time = 3441. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111

MAC4-1N1.CX1

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:        MACH^BIG^MUDDY^RIVER
 Design case:            CASE^4^-^PORT^1^NORMAL^FLOW
 FILE NAME:              cormix\sim\MAC4-1N1.cx1
 Time of Fortran run:    01/13/20--20:12:32

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     30.89  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .287 F     =       .058 USTAR = .2445E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.00
 D0    =       .076 A0    =       .005 H0    =       .56
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .013       = .1307E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .1307E-01  M0    = .3746E-01  J0    =-.1913E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .07  LM    =      1.95  Lm    =       .67  Lb    =       .08
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     27.14  R     =      9.98

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
```

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1000.00  XMAX   =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .100E+04     .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.17  SIGMAE=       .00
  LE    =       .32  XE    =       .28  YE    =       .00  ZE    =       .72

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .100E+04     .04
       .28      .00      .72     1.0  .100E+04     .04
       .48      .00      .82     1.6  .640E+03     .07
       .68      .00      .90     2.3  .433E+03     .09
       .90      .00      .98     3.1  .321E+03     .12
      1.11      .00     1.05     3.9  .256E+03     .14
      1.33      .00     1.10     4.7  .212E+03     .16
      1.55      .00     1.15     5.5  .183E+03     .18
      1.77      .00     1.19     6.2  .161E+03     .19
      2.00      .00     1.23     6.9  .144E+03     .21
      2.22      .00     1.26     7.6  .132E+03     .22
      2.44      .00     1.28     8.2  .122E+03     .23
      2.67      .00     1.31     8.8  .114E+03     .24
      2.89      .00     1.32     9.3  .107E+03     .25
      3.12      .00     1.34     9.9  .101E+03     .26
```

3.34	.00	1.35	10.3	.970E+02	.27
3.57	.00	1.36	10.7	.931E+02	.28
3.79	.00	1.36	11.1	.899E+02	.28
4.02	.00	1.36	11.5	.872E+02	.29

Maximum jet height has been reached.

4.24	.00	1.36	11.8	.848E+02	.30
4.47	.00	1.36	12.2	.823E+02	.30
4.69	.00	1.35	12.6	.796E+02	.31
4.92	.00	1.34	13.0	.769E+02	.31
5.15	.00	1.33	13.5	.742E+02	.32
5.37	.00	1.32	14.0	.715E+02	.33
5.59	.00	1.31	14.5	.689E+02	.34
5.82	.00	1.29	15.1	.662E+02	.34
6.04	.00	1.27	15.7	.637E+02	.35
6.27	.00	1.25	16.4	.611E+02	.36
6.49	.00	1.23	17.0	.588E+02	.37
6.72	.00	1.21	17.7	.564E+02	.38
6.94	.00	1.18	18.5	.542E+02	.39
7.16	.00	1.16	19.2	.521E+02	.40
7.39	.00	1.13	20.0	.500E+02	.41
7.61	.00	1.11	20.8	.480E+02	.42
7.84	.00	1.08	21.7	.461E+02	.43
8.06	.00	1.05	22.5	.444E+02	.43
8.28	.00	1.02	23.4	.427E+02	.44
8.51	.00	.99	24.3	.411E+02	.45
8.73	.00	.96	25.3	.396E+02	.46
8.95	.00	.93	26.2	.381E+02	.47
9.17	.00	.90	27.2	.368E+02	.48
9.39	.00	.87	28.2	.355E+02	.49
9.62	.00	.84	29.2	.342E+02	.50
9.84	.00	.81	30.2	.331E+02	.51
10.07	.00	.78	31.3	.319E+02	.52
10.29	.00	.74	32.4	.309E+02	.53
10.52	.00	.71	33.5	.299E+02	.54
10.74	.00	.68	34.6	.289E+02	.55
10.96	.00	.65	35.7	.280E+02	.56
11.18	.00	.62	36.8	.271E+02	.57
11.40	.00	.58	38.0	.263E+02	.58

Cumulative travel time = 22. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
11.40	.00	.58	38.0	.263E+02	.58

MAC4-1N1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.82	.00	.00	38.0	.263E+02	.00	.00	.00	.00
11.00	.00	.00	38.0	.263E+02	.76	.38	.76	.00
11.17	.00	.00	38.0	.263E+02	.90	.54	.90	.00
11.35	.00	.00	38.0	.263E+02	1.00	.66	1.00	.00
11.52	.00	.00	39.0	.256E+02	1.06	.77	1.06	.00
11.70	.00	.00	43.8	.228E+02	1.11	.86	1.11	.00
11.87	.00	.00	50.5	.198E+02	1.15	.94	1.15	.00
12.04	.00	.00	56.6	.177E+02	1.18	1.01	1.18	.00
12.22	.00	.00	60.8	.164E+02	1.20	1.08	1.20	.00
12.39	.00	.00	63.1	.159E+02	1.21	1.15	1.21	.00
12.57	.00	.00	64.5	.155E+02	1.21	1.21	1.21	.00

Cumulative travel time = 26. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
12.57	.00	.00	64.5	.155E+02	1.21	1.21	1.21	.00
13.75	.00	.00	66.7	.150E+02	1.12	1.36	1.12	.00
14.93	.00	.00	68.8	.145E+02	1.04	1.50	1.04	.00
16.11	.00	.00	70.7	.141E+02	.99	1.63	.99	.00
17.29	.00	.00	72.6	.138E+02	.94	1.76	.94	.00
18.47	.00	.00	74.5	.134E+02	.90	1.89	.90	.00
19.65	.00	.00	76.3	.131E+02	.87	2.01	.87	.00
20.83	.00	.00	78.2	.128E+02	.84	2.12	.84	.00
22.01	.00	.00	80.1	.125E+02	.82	2.24	.82	.00

23.18	.00	.00	82.0	.122E+02	.80	2.35	.80	.00
24.36	.00	.00	84.0	.119E+02	.78	2.46	.78	.00
25.54	.00	.00	86.0	.116E+02	.76	2.56	.76	.00
26.72	.00	.00	88.2	.113E+02	.75	2.67	.75	.00
27.90	.00	.00	90.3	.111E+02	.74	2.77	.74	.00
29.08	.00	.00	92.6	.108E+02	.74	2.87	.74	.00
30.26	.00	.00	94.9	.105E+02	.73	2.96	.73	.00
31.44	.00	.00	97.4	.103E+02	.72	3.06	.72	.00
32.62	.00	.00	99.9	.100E+02	.72	3.16	.72	.00
33.80	.00	.00	102.5	.976E+01	.72	3.25	.72	.00
34.98	.00	.00	105.2	.951E+01	.72	3.34	.72	.00
36.16	.00	.00	108.0	.926E+01	.72	3.43	.72	.00
37.34	.00	.00	110.9	.902E+01	.72	3.52	.72	.00
38.52	.00	.00	113.9	.878E+01	.72	3.61	.72	.00
39.70	.00	.00	117.1	.854E+01	.72	3.70	.72	.00
40.88	.00	.00	120.3	.831E+01	.72	3.79	.72	.00
42.06	.00	.00	123.7	.809E+01	.73	3.87	.73	.00
43.24	.00	.00	127.1	.787E+01	.73	3.96	.73	.00
44.42	.00	.00	130.7	.765E+01	.74	4.04	.74	.00
45.60	.00	.00	134.4	.744E+01	.74	4.12	.74	.00
46.78	.00	.00	138.3	.723E+01	.75	4.20	.75	.00
47.96	.00	.00	142.2	.703E+01	.76	4.29	.76	.00
49.13	.00	.00	146.3	.683E+01	.76	4.37	.76	.00
50.31	.00	.00	150.5	.664E+01	.77	4.45	.77	.00
51.49	.00	.00	154.9	.646E+01	.78	4.52	.78	.00
52.67	.00	.00	159.4	.628E+01	.79	4.60	.79	.00
53.85	.00	.00	164.0	.610E+01	.80	4.68	.80	.00
55.03	.00	.00	168.7	.593E+01	.81	4.76	.81	.00
56.21	.00	.00	173.6	.576E+01	.82	4.83	.82	.00
57.39	.00	.00	178.6	.560E+01	.83	4.91	.83	.00
58.57	.00	.00	183.8	.544E+01	.84	4.98	.84	.00
59.75	.00	.00	189.1	.529E+01	.85	5.06	.85	.00
60.93	.00	.00	194.5	.514E+01	.86	5.13	.86	.00
62.11	.00	.00	200.1	.500E+01	.87	5.21	.87	.00
63.29	.00	.00	205.8	.486E+01	.89	5.28	.89	.00
64.47	.00	.00	211.7	.472E+01	.90	5.35	.90	.00
65.65	.00	.00	217.7	.459E+01	.91	5.43	.91	.00
66.83	.00	.00	223.8	.447E+01	.93	5.50	.93	.00
68.01	.00	.00	230.2	.434E+01	.94	5.57	.94	.00
69.19	.00	.00	236.6	.423E+01	.96	5.64	.96	.00
70.37	.00	.00	243.2	.411E+01	.97	5.71	.97	.00
71.55	.00	.00	250.0	.400E+01	.99	5.78	.99	.00

Cumulative travel time = 231. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

MAC4-1N1.CX1

Vertical diffusivity (initial value) = .222E-01 m^2/s
Horizontal diffusivity (initial value) = .555E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
71.55	.00	.00	250.0	.400E+01	.99	5.78	.99	.00
74.43	.00	.00	258.8	.386E+01	.99	5.93	.99	.00
77.31	.00	.00	267.7	.374E+01	1.00	6.07	1.00	.00
80.20	.00	.00	276.6	.361E+01	1.01	6.22	1.01	.00
83.08	.00	.00	285.7	.350E+01	1.02	6.36	1.02	.00
85.96	.00	.00	294.9	.339E+01	1.03	6.49	1.03	.00
88.85	.00	.00	304.3	.329E+01	1.05	6.63	1.05	.00
91.73	.00	.00	313.8	.319E+01	1.06	6.76	1.06	.00
94.61	.00	.00	323.5	.309E+01	1.07	6.89	1.07	.00
97.49	.00	.00	333.4	.300E+01	1.08	7.01	1.08	.00
100.38	.00	.00	343.5	.291E+01	1.10	7.14	1.10	.00
103.26	.00	.00	353.9	.283E+01	1.11	7.26	1.11	.00
106.14	.00	.00	364.5	.274E+01	1.12	7.38	1.12	.00
109.03	.00	.00	375.3	.266E+01	1.14	7.49	1.14	.00
111.91	.00	.00	386.5	.259E+01	1.16	7.61	1.16	.00
114.79	.00	.00	398.0	.251E+01	1.17	7.72	1.17	.00
117.68	.00	.00	409.7	.244E+01	1.19	7.84	1.19	.00
120.56	.00	.00	421.9	.237E+01	1.21	7.95	1.21	.00
123.44	.00	.00	434.4	.230E+01	1.23	8.06	1.23	.00
126.33	.00	.00	447.2	.224E+01	1.25	8.17	1.25	.00
129.21	.00	.00	460.5	.217E+01	1.27	8.27	1.27	.00
132.09	.00	.00	474.2	.211E+01	1.29	8.38	1.29	.00
134.98	.00	.00	488.3	.205E+01	1.31	8.48	1.31	.00
137.86	.00	.00	502.9	.199E+01	1.33	8.58	1.33	.00
140.74	.00	.00	518.0	.193E+01	1.36	8.69	1.36	.00
143.63	.00	.00	533.6	.187E+01	1.38	8.79	1.38	.00
146.51	.00	.00	549.7	.182E+01	1.41	8.89	1.41	.00
149.39	.00	.00	566.3	.177E+01	1.44	8.98	1.44	.00
152.28	.00	.00	583.6	.171E+01	1.46	9.08	1.46	.00
155.16	.00	.00	601.4	.166E+01	1.49	9.18	1.49	.00
158.04	.00	.00	619.8	.161E+01	1.52	9.27	1.52	.00
160.93	.00	.00	638.9	.157E+01	1.55	9.37	1.55	.00

163.81	.00	.00	658.6	.152E+01	1.59	9.46	1.59	.00
166.69	.00	.00	679.0	.147E+01	1.62	9.55	1.62	.00
169.58	.00	.00	700.1	.143E+01	1.65	9.64	1.65	.00
172.46	.00	.00	721.9	.139E+01	1.69	9.73	1.69	.00
175.34	.00	.00	744.4	.134E+01	1.73	9.82	1.73	.00
178.23	.00	.00	767.7	.130E+01	1.76	9.91	1.76	.00
181.11	.00	.00	791.7	.126E+01	1.80	10.00	1.80	.00
183.99	.00	.00	816.5	.122E+01	1.84	10.09	1.84	.00
186.87	.00	.00	842.0	.119E+01	1.88	10.17	1.88	.00
189.76	.00	.00	868.4	.115E+01	1.93	10.26	1.93	.00
192.64	.00	.00	895.5	.112E+01	1.97	10.34	1.97	.00
195.52	.00	.00	923.4	.108E+01	2.02	10.43	2.02	.00
198.41	.00	.00	952.1	.105E+01	2.06	10.51	2.06	.00
201.29	.00	.00	981.6	.102E+01	2.11	10.59	2.11	.00
204.17	.00	.00	1011.8	.988E+00	2.16	10.68	2.16	.00
207.06	.00	.00	1042.9	.959E+00	2.21	10.76	2.21	.00
209.94	.00	.00	1074.7	.931E+00	2.26	10.84	2.26	.00
212.82	.00	.00	1107.2	.903E+00	2.31	10.92	2.31	.00
215.71	.00	.00	1140.5	.877E+00	2.36	11.00	2.36	.00

Cumulative travel time = 733. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
215.71	11.00	.00	1140.5	.877E+00	2.36	22.00	2.36	.00
231.39	11.00	.00	1295.5	.772E+00	2.66	22.22	2.66	.00
247.08	11.00	.00	1459.4	.685E+00	2.96	22.43	2.96	.00
262.76	11.00	.00	1629.4	.614E+00	3.28	22.64	3.28	.00
278.45	11.00	.00	1803.0	.555E+00	3.59	22.85	3.59	.00
294.14	11.00	.00	1978.4	.505E+00	3.91	23.06	3.91	.00
309.82	11.00	.00	2154.1	.464E+00	4.22	23.26	4.22	.00
325.51	11.00	.00	2329.4	.429E+00	4.52	23.47	4.52	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

341.19	11.00	.00	2359.9	.424E+00	4.54	23.67	4.54	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.
The x-coordinate of bank attachment is 344.33 m.

356.88	11.00	.00	2379.9	.420E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

372.57	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
388.25	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
403.94	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
419.62	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
435.31	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00

450.99	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
466.68	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
482.37	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
498.05	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
513.74	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
529.42	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
545.11	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
560.80	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
576.48	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
592.17	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
607.85	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
623.54	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
639.23	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
654.91	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
670.60	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
686.28	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
701.97	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
717.65	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
733.34	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
749.03	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
764.71	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
780.40	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
796.08	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
811.77	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
827.46	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
843.14	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
858.83	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
874.51	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
890.20	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
905.88	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
921.57	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
937.26	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
952.94	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
968.63	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
984.31	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
1000.00	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00

Cumulative travel time = 3465. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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MAC4-1X1.CX1

CORMIX1 PREDICTION FILE:
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CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:
Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION
Site name/label: MACH^BIG^MUDDY^RIVER
Design case: CASE^4^-^PORT^1^MAXIMUM^FLOW
FILE NAME: cormix\sim\MAC4-1X1.cx1
Time of Fortran run: 01/13/20--20:38:34

ENVIRONMENT PARAMETERS (metric units)
Bounded section
BS = 23.71 AS = 107.64 QA = 38.11 ICHREG= 2
HA = 4.54 HD = 4.54
UA = .354 F = .058 USTAR = .3016E-01
UW = 2.000 UWSTAR= .2198E-02
Uniform density environment
STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)
BANK = LEFT DISTB = 11.00
D0 = .076 A0 = .005 H0 = .56
THETA = 30.00 SIGMA = .00
U0 = 5.487 Q0 = .025 = .2502E-01
RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00
C0 = .1000E+04 CUNITS= PPM
IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)
Q0 = .2502E-01 M0 = .1373E+00 J0 =-.3662E-02 SIGNJ0= -1.0
Associated length scales (meters)
LQ = .07 LM = 3.73 Lm = 1.05 Lb = .08
Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS
FR0 = 51.96 R = 15.50

FLOW CLASSIFICATION
1111111111111111111111111111111111111111
1 Flow class (CORMIX1) = NH4 1
1 Applicable layer depth HS = 4.54 1
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MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1000E+04 CUNITS= PPM

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1000.00  XMAX   =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .56      1.0  .100E+04     .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.82  SIGMAE=       .00
  LE    =       .34  XE    =       .30  YE    =       .00  ZE    =       .73

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .56      1.0  .100E+04     .04
      .30      .00      .73      1.0  .100E+04     .04
      .69      .00      .93      2.2  .457E+03     .09
     1.09      .00     1.10      3.7  .273E+03     .14
     1.51      .00     1.24      5.2  .191E+03     .19
     1.93      .00     1.37      6.9  .146E+03     .23
     2.36      .00     1.47      8.4  .118E+03     .27
     2.80      .00     1.56     10.0  .996E+02     .30
     3.23      .00     1.64     11.5  .867E+02     .33
     3.67      .00     1.70     13.0  .772E+02     .36
     4.10      .00     1.76     14.3  .699E+02     .39
     4.54      .00     1.81     15.6  .642E+02     .41
     4.99      .00     1.85     16.8  .595E+02     .43
     5.43      .00     1.88     17.9  .557E+02     .45
     5.87      .00     1.91     19.0  .527E+02     .47
```

6.30	.00	1.94	20.0	.501E+02	.48
6.74	.00	1.96	20.9	.479E+02	.49
7.19	.00	1.97	21.7	.460E+02	.51
7.63	.00	1.98	22.5	.445E+02	.52
8.07	.00	1.99	23.2	.431E+02	.53
8.51	.00	1.99	23.8	.420E+02	.54

Maximum jet height has been reached.

8.95	.00	1.99	24.4	.409E+02	.54
9.40	.00	1.98	25.1	.398E+02	.55
9.84	.00	1.97	25.8	.387E+02	.56
10.28	.00	1.96	26.6	.375E+02	.57
10.72	.00	1.95	27.5	.364E+02	.58
11.16	.00	1.93	28.4	.352E+02	.60
11.61	.00	1.91	29.4	.341E+02	.61
12.05	.00	1.89	30.4	.329E+02	.62
12.49	.00	1.86	31.4	.318E+02	.63
12.93	.00	1.83	32.6	.307E+02	.65
13.36	.00	1.80	33.7	.297E+02	.66
13.81	.00	1.77	35.0	.286E+02	.67
14.25	.00	1.74	36.2	.276E+02	.69
14.69	.00	1.70	37.5	.267E+02	.70
15.13	.00	1.66	38.9	.257E+02	.72
15.57	.00	1.63	40.3	.248E+02	.73
16.01	.00	1.59	41.7	.240E+02	.74
16.45	.00	1.55	43.2	.232E+02	.76
16.89	.00	1.50	44.7	.224E+02	.77
17.33	.00	1.46	46.2	.216E+02	.79
17.76	.00	1.42	47.8	.209E+02	.80
18.20	.00	1.37	49.4	.202E+02	.82
18.65	.00	1.33	51.1	.196E+02	.83
19.09	.00	1.28	52.8	.189E+02	.85
19.52	.00	1.24	54.5	.184E+02	.87
19.96	.00	1.19	56.2	.178E+02	.88
20.40	.00	1.15	58.0	.172E+02	.90
20.85	.00	1.10	59.8	.167E+02	.91
21.28	.00	1.05	61.6	.162E+02	.93
21.72	.00	1.00	63.5	.158E+02	.94
22.16	.00	.96	65.3	.153E+02	.96

Cumulative travel time = 36. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
22.16	.00	.96	65.3	.153E+02	.96

MAC4-1X1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
21.20	.00	.00	65.3	.153E+02	.00	.00	.00	.00
21.49	.00	.00	65.3	.153E+02	1.25	.63	1.25	.00
21.77	.00	.00	65.3	.153E+02	1.48	.89	1.48	.00
22.06	.00	.00	65.3	.153E+02	1.63	1.09	1.63	.00
22.35	.00	.00	67.1	.149E+02	1.73	1.25	1.73	.00
22.63	.00	.00	75.5	.133E+02	1.82	1.40	1.82	.00
22.92	.00	.00	87.0	.115E+02	1.88	1.53	1.88	.00
23.21	.00	.00	97.4	.103E+02	1.92	1.66	1.92	.00
23.50	.00	.00	104.6	.956E+01	1.96	1.77	1.96	.00
23.78	.00	.00	108.5	.921E+01	1.98	1.88	1.98	.00
24.07	.00	.00	111.1	.900E+01	1.98	1.98	1.98	.00

Cumulative travel time = 42. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
24.07	.00	.00	111.1	.900E+01	1.98	1.98	1.98	.00
25.06	.00	.00	112.9	.886E+01	1.92	2.08	1.92	.00
26.05	.00	.00	114.6	.873E+01	1.86	2.18	1.86	.00
27.04	.00	.00	116.3	.860E+01	1.81	2.27	1.81	.00
28.03	.00	.00	118.0	.847E+01	1.76	2.37	1.76	.00
29.02	.00	.00	119.7	.835E+01	1.72	2.46	1.72	.00
30.01	.00	.00	121.4	.824E+01	1.68	2.55	1.68	.00
31.00	.00	.00	123.1	.813E+01	1.65	2.64	1.65	.00
31.99	.00	.00	124.8	.801E+01	1.62	2.72	1.62	.00

32.98	.00	.00	126.5	.791E+01	1.59	2.81	1.59	.00
33.97	.00	.00	128.2	.780E+01	1.57	2.89	1.57	.00
34.96	.00	.00	130.0	.770E+01	1.54	2.98	1.54	.00
35.95	.00	.00	131.7	.759E+01	1.52	3.06	1.52	.00
36.94	.00	.00	133.5	.749E+01	1.50	3.14	1.50	.00
37.93	.00	.00	135.3	.739E+01	1.49	3.22	1.49	.00
38.92	.00	.00	137.2	.729E+01	1.47	3.30	1.47	.00
39.91	.00	.00	139.1	.719E+01	1.46	3.37	1.46	.00
40.90	.00	.00	141.0	.709E+01	1.44	3.45	1.44	.00
41.89	.00	.00	142.9	.700E+01	1.43	3.53	1.43	.00
42.88	.00	.00	144.9	.690E+01	1.42	3.60	1.42	.00
43.87	.00	.00	146.9	.681E+01	1.41	3.68	1.41	.00
44.86	.00	.00	149.0	.671E+01	1.40	3.75	1.40	.00
45.85	.00	.00	151.1	.662E+01	1.40	3.82	1.40	.00
46.84	.00	.00	153.3	.652E+01	1.39	3.90	1.39	.00
47.83	.00	.00	155.5	.643E+01	1.38	3.97	1.38	.00
48.83	.00	.00	157.7	.634E+01	1.38	4.04	1.38	.00
49.82	.00	.00	160.0	.625E+01	1.38	4.11	1.38	.00
50.81	.00	.00	162.3	.616E+01	1.37	4.18	1.37	.00
51.80	.00	.00	164.7	.607E+01	1.37	4.25	1.37	.00
52.79	.00	.00	167.2	.598E+01	1.37	4.32	1.37	.00
53.78	.00	.00	169.7	.589E+01	1.37	4.38	1.37	.00
54.77	.00	.00	172.2	.581E+01	1.37	4.45	1.37	.00
55.76	.00	.00	174.8	.572E+01	1.37	4.52	1.37	.00
56.75	.00	.00	177.4	.564E+01	1.37	4.59	1.37	.00
57.74	.00	.00	180.1	.555E+01	1.37	4.65	1.37	.00
58.73	.00	.00	182.9	.547E+01	1.37	4.72	1.37	.00
59.72	.00	.00	185.7	.538E+01	1.37	4.78	1.37	.00
60.71	.00	.00	188.6	.530E+01	1.37	4.85	1.37	.00
61.70	.00	.00	191.5	.522E+01	1.38	4.91	1.38	.00
62.69	.00	.00	194.5	.514E+01	1.38	4.98	1.38	.00
63.68	.00	.00	197.5	.506E+01	1.39	5.04	1.39	.00
64.67	.00	.00	200.6	.498E+01	1.39	5.10	1.39	.00
65.66	.00	.00	203.8	.491E+01	1.39	5.16	1.39	.00
66.65	.00	.00	207.0	.483E+01	1.40	5.23	1.40	.00
67.64	.00	.00	210.3	.475E+01	1.41	5.29	1.41	.00
68.63	.00	.00	213.7	.468E+01	1.41	5.35	1.41	.00
69.62	.00	.00	217.1	.461E+01	1.42	5.41	1.42	.00
70.61	.00	.00	220.6	.453E+01	1.42	5.47	1.42	.00
71.60	.00	.00	224.1	.446E+01	1.43	5.53	1.43	.00
72.59	.00	.00	227.7	.439E+01	1.44	5.59	1.44	.00
73.58	.00	.00	231.4	.432E+01	1.45	5.65	1.45	.00

Cumulative travel time = 181. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

MAC4-1X1.CX1

Vertical diffusivity (initial value) = .274E-01 m^2/s
Horizontal diffusivity (initial value) = .685E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
73.58	.00	.00	231.4	.432E+01	1.45	5.65	1.45	.00
76.51	.00	.00	240.4	.416E+01	1.46	5.81	1.46	.00
79.44	.00	.00	249.5	.401E+01	1.48	5.96	1.48	.00
82.38	.00	.00	258.7	.387E+01	1.50	6.11	1.50	.00
85.31	.00	.00	268.1	.373E+01	1.52	6.25	1.52	.00
88.24	.00	.00	277.7	.360E+01	1.54	6.39	1.54	.00
91.17	.00	.00	287.4	.348E+01	1.56	6.53	1.56	.00
94.10	.00	.00	297.4	.336E+01	1.58	6.66	1.58	.00
97.03	.00	.00	307.5	.325E+01	1.60	6.80	1.60	.00
99.97	.00	.00	317.9	.315E+01	1.62	6.93	1.62	.00
102.90	.00	.00	328.6	.304E+01	1.65	7.05	1.65	.00
105.83	.00	.00	339.5	.295E+01	1.67	7.18	1.67	.00
108.76	.00	.00	350.7	.285E+01	1.70	7.30	1.70	.00
111.69	.00	.00	362.2	.276E+01	1.72	7.42	1.72	.00
114.62	.00	.00	374.0	.267E+01	1.75	7.54	1.75	.00
117.56	.00	.00	386.2	.259E+01	1.78	7.66	1.78	.00
120.49	.00	.00	398.6	.251E+01	1.81	7.77	1.81	.00
123.42	.00	.00	411.5	.243E+01	1.84	7.89	1.84	.00
126.35	.00	.00	424.6	.236E+01	1.88	8.00	1.88	.00
129.28	.00	.00	438.2	.228E+01	1.91	8.11	1.91	.00
132.21	.00	.00	452.1	.221E+01	1.94	8.22	1.94	.00
135.15	.00	.00	466.4	.214E+01	1.98	8.33	1.98	.00
138.08	.00	.00	481.2	.208E+01	2.02	8.43	2.02	.00
141.01	.00	.00	496.3	.201E+01	2.05	8.54	2.05	.00
143.94	.00	.00	511.8	.195E+01	2.09	8.64	2.09	.00
146.87	.00	.00	527.8	.189E+01	2.13	8.75	2.13	.00
149.80	.00	.00	544.2	.184E+01	2.17	8.85	2.17	.00
152.73	.00	.00	561.1	.178E+01	2.22	8.95	2.22	.00
155.67	.00	.00	578.3	.173E+01	2.26	9.05	2.26	.00
158.60	.00	.00	596.0	.168E+01	2.30	9.14	2.30	.00
161.53	.00	.00	614.2	.163E+01	2.35	9.24	2.35	.00
164.46	.00	.00	632.8	.158E+01	2.40	9.34	2.40	.00

167.39	.00	.00	651.8	.153E+01	2.44	9.43	2.44	.00
170.32	.00	.00	671.2	.149E+01	2.49	9.52	2.49	.00
173.26	.00	.00	691.1	.145E+01	2.54	9.62	2.54	.00
176.19	.00	.00	711.4	.141E+01	2.59	9.71	2.59	.00
179.12	.00	.00	732.1	.137E+01	2.64	9.80	2.64	.00
182.05	.00	.00	753.3	.133E+01	2.69	9.89	2.69	.00
184.98	.00	.00	774.8	.129E+01	2.74	9.98	2.74	.00
187.91	.00	.00	796.7	.126E+01	2.80	10.07	2.80	.00
190.85	.00	.00	819.0	.122E+01	2.85	10.16	2.85	.00
193.78	.00	.00	841.7	.119E+01	2.90	10.25	2.90	.00
196.71	.00	.00	864.8	.116E+01	2.96	10.33	2.96	.00
199.64	.00	.00	888.2	.113E+01	3.01	10.42	3.01	.00
202.57	.00	.00	911.9	.110E+01	3.07	10.50	3.07	.00
205.50	.00	.00	936.0	.107E+01	3.12	10.59	3.12	.00
208.44	.00	.00	960.5	.104E+01	3.18	10.67	3.18	.00
211.37	.00	.00	985.2	.102E+01	3.24	10.75	3.24	.00
214.30	.00	.00	1010.2	.990E+00	3.29	10.84	3.29	.00
217.23	.00	.00	1035.5	.966E+00	3.35	10.92	3.35	.00
220.16	.00	.00	1061.1	.942E+00	3.41	11.00	3.41	.00

Cumulative travel time = 595. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
220.16	11.00	.00	1061.1	.942E+00	3.41	22.00	3.41	.00
235.76	11.00	.00	1167.7	.856E+00	3.72	22.21	3.72	.00
251.36	11.00	.00	1275.4	.784E+00	4.02	22.43	4.02	.00
266.95	11.00	.00	1383.4	.723E+00	4.32	22.64	4.32	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

282.55	11.00	.00	1467.4	.681E+00	4.54	22.85	4.54	.00
298.15	11.00	.00	1480.7	.675E+00	4.54	23.05	4.54	.00
313.74	11.00	.00	1493.8	.669E+00	4.54	23.26	4.54	.00
329.34	11.00	.00	1506.8	.664E+00	4.54	23.46	4.54	.00
344.94	11.00	.00	1519.8	.658E+00	4.54	23.66	4.54	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.
The x-coordinate of bank attachment is 348.83 m.

360.53	11.00	.00	1532.6	.653E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

376.13	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
391.73	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
407.32	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
422.92	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
438.52	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00

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454.11	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
469.71	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
485.31	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
500.90	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
516.50	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
532.10	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
547.69	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
563.29	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
578.89	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
594.48	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
610.08	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
625.68	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
641.27	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
656.87	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
672.47	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
688.06	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
703.66	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
719.26	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
734.85	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
750.45	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
766.05	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
781.64	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
797.24	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
812.84	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
828.44	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
844.03	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
859.63	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
875.23	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
890.82	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
906.42	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
922.02	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
937.61	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
953.21	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
968.81	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
984.40	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
1000.00	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00

Cumulative travel time = 2797. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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MAC4-3N1.CX1

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^4^-^PORT^3^NORMAL^FLOW
 FILE NAME:               cormix\sim\MAC4-3N1.cx1
 Time of Fortran run:     01/13/20--20:09:41

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     30.89  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =      .287  F     =      .058 USTAR = .2445E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.00
 D0    =      .102 A0    =      .008 H0    =       .55
 THETA =     30.00  SIGMA =       .00
 U0    =     2.866 Q0    =       .023       = .2324E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .2324E-01  M0    = .6659E-01  J0    =-.3400E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .09  LM    =      2.25  Lm    =       .90  Lb    =       .14
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     23.50  R     =      9.98

FLOW CLASSIFICATION
 1111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
```

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1000.00  XMAX   =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .55      1.0  .100E+04     .05

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.17  SIGMAE=       .00
  LE    =       .43  XE    =       .37  YE    =       .00  ZE    =       .76

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .55      1.0  .100E+04     .05
      .37      .00      .76      1.0  .100E+04     .05
      .57      .00      .86      1.4  .720E+03     .08
      .78      .00      .95      1.9  .516E+03     .10
      .99      .00     1.03      2.5  .398E+03     .13
     1.21      .00     1.11      3.1  .320E+03     .15
     1.42      .00     1.17      3.7  .270E+03     .18
     1.64      .00     1.23      4.3  .233E+03     .20
     1.87      .00     1.28      4.9  .205E+03     .22
     2.09      .00     1.32      5.4  .184E+03     .23
     2.31      .00     1.36      6.0  .168E+03     .25
     2.53      .00     1.40      6.5  .155E+03     .26
     2.77      .00     1.42      7.0  .144E+03     .28
     2.99      .00     1.45      7.4  .135E+03     .29
     3.21      .00     1.47      7.8  .128E+03     .30
```

3.45	.00	1.49	8.2	.121E+03	.31
3.67	.00	1.50	8.6	.116E+03	.32
3.90	.00	1.51	8.9	.112E+03	.33
4.13	.00	1.52	9.3	.108E+03	.34
4.35	.00	1.52	9.5	.105E+03	.34

Maximum jet height has been reached.

4.58	.00	1.52	9.8	.102E+03	.35
4.80	.00	1.52	10.1	.994E+02	.36
5.04	.00	1.51	10.4	.964E+02	.36
5.26	.00	1.50	10.7	.935E+02	.37
5.49	.00	1.49	11.0	.905E+02	.38
5.72	.00	1.48	11.4	.874E+02	.39
5.94	.00	1.46	11.8	.844E+02	.39
6.17	.00	1.45	12.3	.815E+02	.40
6.39	.00	1.43	12.7	.786E+02	.41
6.62	.00	1.41	13.2	.756E+02	.42
6.85	.00	1.38	13.7	.728E+02	.43
7.07	.00	1.36	14.3	.701E+02	.44
7.30	.00	1.33	14.8	.674E+02	.45
7.53	.00	1.30	15.4	.649E+02	.46
7.75	.00	1.27	16.0	.625E+02	.47
7.98	.00	1.24	16.6	.601E+02	.49
8.20	.00	1.21	17.3	.578E+02	.50
8.43	.00	1.18	17.9	.557E+02	.51
8.65	.00	1.15	18.6	.537E+02	.52
8.88	.00	1.11	19.4	.517E+02	.53
9.10	.00	1.08	20.1	.498E+02	.54
9.32	.00	1.04	20.8	.481E+02	.55
9.56	.00	1.01	21.6	.463E+02	.56
9.78	.00	.97	22.4	.447E+02	.58
10.00	.00	.93	23.1	.432E+02	.59
10.23	.00	.90	24.0	.417E+02	.60
10.45	.00	.86	24.8	.403E+02	.61
10.67	.00	.82	25.6	.390E+02	.62
10.89	.00	.79	26.5	.378E+02	.63
11.13	.00	.75	27.4	.365E+02	.65
11.35	.00	.71	28.2	.354E+02	.66
11.57	.00	.67	29.1	.343E+02	.67

Cumulative travel time = 20. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
11.57	.00	.67	29.1	.343E+02	.67

MAC4-3N1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.90	.00	.00	29.1	.343E+02	.00	.00	.00	.00
11.10	.00	.00	29.1	.343E+02	.89	.45	.89	.00
11.30	.00	.00	29.1	.343E+02	1.06	.63	1.06	.00
11.50	.00	.00	29.1	.343E+02	1.16	.78	1.16	.00
11.70	.00	.00	29.9	.334E+02	1.24	.90	1.24	.00
11.90	.00	.00	33.6	.297E+02	1.30	1.00	1.30	.00
12.10	.00	.00	38.8	.258E+02	1.34	1.10	1.34	.00
12.30	.00	.00	43.4	.230E+02	1.38	1.18	1.38	.00
12.51	.00	.00	46.6	.214E+02	1.40	1.27	1.40	.00
12.71	.00	.00	48.4	.207E+02	1.41	1.34	1.41	.00
12.91	.00	.00	49.5	.202E+02	1.42	1.42	1.42	.00

Cumulative travel time = 25. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
12.91	.00	.00	49.5	.202E+02	1.42	1.42	1.42	.00
15.13	.00	.00	52.5	.190E+02	1.21	1.75	1.21	.00
17.36	.00	.00	55.1	.182E+02	1.08	2.06	1.08	.00
19.59	.00	.00	57.4	.174E+02	.99	2.34	.99	.00
21.82	.00	.00	59.7	.168E+02	.93	2.61	.93	.00
24.04	.00	.00	61.9	.162E+02	.87	2.86	.87	.00
26.27	.00	.00	64.2	.156E+02	.84	3.11	.84	.00
28.50	.00	.00	66.5	.150E+02	.80	3.34	.80	.00
30.73	.00	.00	68.9	.145E+02	.78	3.57	.78	.00

32.95	.00	.00	71.4	.140E+02	.76	3.79	.76	.00
35.18	.00	.00	74.1	.135E+02	.75	4.00	.75	.00
37.41	.00	.00	76.9	.130E+02	.74	4.21	.74	.00
39.64	.00	.00	79.8	.125E+02	.73	4.41	.73	.00
41.86	.00	.00	82.9	.121E+02	.73	4.61	.73	.00
44.09	.00	.00	86.2	.116E+02	.73	4.81	.73	.00
46.32	.00	.00	89.7	.111E+02	.73	5.00	.73	.00
48.55	.00	.00	93.4	.107E+02	.73	5.18	.73	.00
50.77	.00	.00	97.2	.103E+02	.73	5.37	.73	.00
53.00	.00	.00	101.3	.987E+01	.74	5.55	.74	.00
55.23	.00	.00	105.6	.947E+01	.75	5.72	.75	.00
57.45	.00	.00	110.0	.909E+01	.76	5.90	.76	.00
59.68	.00	.00	114.8	.871E+01	.77	6.07	.77	.00
61.91	.00	.00	119.7	.835E+01	.78	6.24	.78	.00
64.14	.00	.00	124.9	.801E+01	.79	6.41	.79	.00
66.36	.00	.00	130.3	.768E+01	.80	6.57	.80	.00
68.59	.00	.00	135.9	.736E+01	.82	6.74	.82	.00
70.82	.00	.00	141.8	.705E+01	.83	6.90	.83	.00
73.05	.00	.00	147.9	.676E+01	.85	7.06	.85	.00
75.27	.00	.00	154.3	.648E+01	.87	7.21	.87	.00
77.50	.00	.00	160.9	.621E+01	.88	7.37	.88	.00
79.73	.00	.00	167.8	.596E+01	.90	7.52	.90	.00
81.96	.00	.00	175.0	.571E+01	.92	7.68	.92	.00
84.18	.00	.00	182.4	.548E+01	.94	7.83	.94	.00
86.41	.00	.00	190.1	.526E+01	.96	7.98	.96	.00
88.64	.00	.00	198.1	.505E+01	.99	8.13	.99	.00
90.87	.00	.00	206.3	.485E+01	1.01	8.27	1.01	.00
93.09	.00	.00	214.8	.466E+01	1.03	8.42	1.03	.00
95.32	.00	.00	223.6	.447E+01	1.06	8.56	1.06	.00
97.55	.00	.00	232.7	.430E+01	1.08	8.71	1.08	.00
99.78	.00	.00	242.0	.413E+01	1.11	8.85	1.11	.00
102.00	.00	.00	251.7	.397E+01	1.13	8.99	1.13	.00
104.23	.00	.00	261.6	.382E+01	1.16	9.13	1.16	.00
106.46	.00	.00	271.8	.368E+01	1.19	9.27	1.19	.00
108.69	.00	.00	282.4	.354E+01	1.22	9.41	1.22	.00
110.91	.00	.00	293.2	.341E+01	1.24	9.54	1.24	.00
113.14	.00	.00	304.3	.329E+01	1.27	9.68	1.27	.00
115.37	.00	.00	315.7	.317E+01	1.30	9.81	1.30	.00
117.60	.00	.00	327.5	.305E+01	1.33	9.95	1.33	.00
119.82	.00	.00	339.5	.295E+01	1.36	10.08	1.36	.00
122.05	.00	.00	351.8	.284E+01	1.39	10.21	1.39	.00
124.28	.00	.00	364.5	.274E+01	1.43	10.34	1.43	.00

Cumulative travel time = 412. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

MAC4-3N1.CX1

Vertical diffusivity (initial value) = .222E-01 m^2/s
Horizontal diffusivity (initial value) = .555E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
124.28	.00	.00	364.5	.274E+01	1.43	10.34	1.43	.00
124.74	.00	.00	365.6	.274E+01	1.43	10.36	1.43	.00
125.20	.00	.00	366.8	.273E+01	1.43	10.37	1.43	.00
125.66	.00	.00	367.9	.272E+01	1.43	10.38	1.43	.00
126.12	.00	.00	369.1	.271E+01	1.44	10.40	1.44	.00
126.58	.00	.00	370.2	.270E+01	1.44	10.41	1.44	.00
127.04	.00	.00	371.4	.269E+01	1.44	10.42	1.44	.00
127.51	.00	.00	372.5	.268E+01	1.44	10.44	1.44	.00
127.97	.00	.00	373.7	.268E+01	1.45	10.45	1.45	.00
128.43	.00	.00	374.9	.267E+01	1.45	10.46	1.45	.00
128.89	.00	.00	376.0	.266E+01	1.45	10.48	1.45	.00
129.35	.00	.00	377.2	.265E+01	1.46	10.49	1.46	.00
129.81	.00	.00	378.4	.264E+01	1.46	10.50	1.46	.00
130.27	.00	.00	379.6	.263E+01	1.46	10.52	1.46	.00
130.73	.00	.00	380.8	.263E+01	1.46	10.53	1.46	.00
131.19	.00	.00	381.9	.262E+01	1.47	10.54	1.47	.00
131.66	.00	.00	383.1	.261E+01	1.47	10.56	1.47	.00
132.12	.00	.00	384.3	.260E+01	1.47	10.57	1.47	.00
132.58	.00	.00	385.6	.259E+01	1.47	10.58	1.47	.00
133.04	.00	.00	386.8	.259E+01	1.48	10.60	1.48	.00
133.50	.00	.00	388.0	.258E+01	1.48	10.61	1.48	.00
133.96	.00	.00	389.2	.257E+01	1.48	10.62	1.48	.00
134.42	.00	.00	390.4	.256E+01	1.49	10.64	1.49	.00
134.88	.00	.00	391.6	.255E+01	1.49	10.65	1.49	.00
135.34	.00	.00	392.9	.255E+01	1.49	10.66	1.49	.00
135.81	.00	.00	394.1	.254E+01	1.49	10.68	1.49	.00
136.27	.00	.00	395.4	.253E+01	1.50	10.69	1.50	.00
136.73	.00	.00	396.6	.252E+01	1.50	10.70	1.50	.00
137.19	.00	.00	397.9	.251E+01	1.50	10.72	1.50	.00
137.65	.00	.00	399.1	.251E+01	1.51	10.73	1.51	.00
138.11	.00	.00	400.4	.250E+01	1.51	10.74	1.51	.00
138.57	.00	.00	401.6	.249E+01	1.51	10.76	1.51	.00

139.03	.00	.00	402.9	.248E+01	1.51	10.77	1.51	.00
139.49	.00	.00	404.2	.247E+01	1.52	10.78	1.52	.00
139.96	.00	.00	405.5	.247E+01	1.52	10.79	1.52	.00
140.42	.00	.00	406.7	.246E+01	1.52	10.81	1.52	.00
140.88	.00	.00	408.0	.245E+01	1.53	10.82	1.53	.00
141.34	.00	.00	409.3	.244E+01	1.53	10.83	1.53	.00
141.80	.00	.00	410.6	.244E+01	1.53	10.85	1.53	.00
142.26	.00	.00	411.9	.243E+01	1.54	10.86	1.54	.00
142.72	.00	.00	413.2	.242E+01	1.54	10.87	1.54	.00
143.18	.00	.00	414.5	.241E+01	1.54	10.88	1.54	.00
143.65	.00	.00	415.8	.240E+01	1.54	10.90	1.54	.00
144.11	.00	.00	417.2	.240E+01	1.55	10.91	1.55	.00
144.57	.00	.00	418.5	.239E+01	1.55	10.92	1.55	.00
145.03	.00	.00	419.8	.238E+01	1.55	10.94	1.55	.00
145.49	.00	.00	421.2	.237E+01	1.56	10.95	1.56	.00
145.95	.00	.00	422.5	.237E+01	1.56	10.96	1.56	.00
146.41	.00	.00	423.9	.236E+01	1.56	10.97	1.56	.00
146.87	.00	.00	425.2	.235E+01	1.57	10.99	1.57	.00
147.33	.00	.00	426.6	.234E+01	1.57	11.00	1.57	.00

Cumulative travel time = 493. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
147.33	11.00	.00	426.6	.234E+01	1.57	22.00	1.57	.00
164.39	11.00	.00	465.4	.215E+01	1.69	22.23	1.69	.00
181.44	11.00	.00	509.1	.196E+01	1.83	22.47	1.83	.00
198.49	11.00	.00	558.2	.179E+01	1.99	22.70	1.99	.00
215.55	11.00	.00	612.9	.163E+01	2.16	22.92	2.16	.00
232.60	11.00	.00	673.4	.148E+01	2.36	23.15	2.36	.00
249.65	11.00	.00	739.7	.135E+01	2.56	23.37	2.56	.00
266.71	11.00	.00	811.6	.123E+01	2.79	23.59	2.79	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 276.00 m.

283.76	11.00	.00	888.7	.113E+01	3.02	23.71	3.02	.00
300.81	11.00	.00	957.3	.104E+01	3.27	23.71	3.27	.00
317.87	11.00	.00	1031.8	.969E+00	3.52	23.71	3.52	.00
334.92	11.00	.00	1107.7	.903E+00	3.78	23.71	3.78	.00
351.97	11.00	.00	1184.6	.844E+00	4.04	23.71	4.04	.00
369.03	11.00	.00	1261.9	.792E+00	4.31	23.71	4.31	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

386.08	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

403.13	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
420.19	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
437.24	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
454.29	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
471.35	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
488.40	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
505.45	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
522.51	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
539.56	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
556.61	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
573.67	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
590.72	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
607.77	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
624.83	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
641.88	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
658.93	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
675.99	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
693.04	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
710.09	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
727.15	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
744.20	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
761.25	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
778.31	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
795.36	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
812.41	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
829.47	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
846.52	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
863.57	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
880.63	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
897.68	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
914.73	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
931.79	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
948.84	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
965.89	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
982.95	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
1000.00	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00

Cumulative travel time = 3461. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111111

MAC4-3X1.CX1

CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111

CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:
Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION
Site name/label: MACH^BIG^MUDDY^RIVER
Design case: CASE^4^-^PORT^3^MAXIMUM^FLOW
FILE NAME: cormix\sim\MAC4-3X1.cx1
Time of Fortran run: 01/13/20--20:35:48

ENVIRONMENT PARAMETERS (metric units)
Bounded section
BS = 23.71 AS = 107.64 QA = 38.11 ICHREG= 2
HA = 4.54 HD = 4.54
UA = .354 F = .058 USTAR = .3016E-01
UW = 2.000 UWSTAR= .2198E-02
Uniform density environment
STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)
BANK = LEFT DISTB = 11.00
D0 = .102 A0 = .008 H0 = .55
THETA = 30.00 SIGMA = .00
U0 = 5.487 Q0 = .044 = .4448E-01
RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00
C0 = .1000E+04 CUNITS= PPM
IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)
Q0 = .4448E-01 M0 = .2441E+00 J0 =-.6510E-02 SIGNJ0= -1.0
Associated length scales (meters)
LQ = .09 LM = 4.30 Lm = 1.40 Lb = .15
Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS
FR0 = 44.99 R = 15.50

FLOW CLASSIFICATION
1111111111111111111111111111111111111111
1 Flow class (CORMIX1) = NH4 1
1 Applicable layer depth HS = 4.54 1
1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1000E+04 CUNITS= PPM

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1000.00  XMAX   =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .55     1.0  .100E+04     .05

END OF MOD101: DISCHARGE MODULE
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.82  SIGMAE=       .00
 LE    =       .46  XE    =       .40  YE    =       .00  ZE    =       .77

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .55     1.0  .100E+04     .05
      .40      .00      .77     1.0  .100E+04     .05
      .79      .00      .98     1.9  .538E+03     .10
     1.21      .00     1.17     3.0  .336E+03     .16
     1.63      .00     1.33     4.1  .242E+03     .21
     2.07      .00     1.47     5.4  .186E+03     .26
     2.50      .00     1.59     6.6  .152E+03     .30
     2.94      .00     1.70     7.8  .128E+03     .34
     3.38      .00     1.80     9.0  .111E+03     .38
     3.83      .00     1.88    10.2  .985E+02     .41
     4.28      .00     1.95    11.2  .890E+02     .44
     4.73      .00     2.02    12.3  .812E+02     .47
     5.19      .00     2.07    13.3  .750E+02     .49
     5.63      .00     2.12    14.3  .701E+02     .52
     6.09      .00     2.16    15.2  .660E+02     .54
```

6.54	.00	2.19	16.0	.625E+02	.56
7.00	.00	2.22	16.8	.596E+02	.57
7.44	.00	2.24	17.5	.571E+02	.59
7.90	.00	2.26	18.2	.550E+02	.60
8.35	.00	2.27	18.8	.532E+02	.62
8.81	.00	2.28	19.4	.516E+02	.63
9.26	.00	2.28	19.9	.502E+02	.64

Maximum jet height has been reached.

9.72	.00	2.28	20.4	.490E+02	.65
10.18	.00	2.28	21.0	.477E+02	.66
10.62	.00	2.27	21.5	.464E+02	.67
11.08	.00	2.26	22.2	.451E+02	.68
11.53	.00	2.24	22.8	.438E+02	.70
11.99	.00	2.22	23.6	.424E+02	.71
12.44	.00	2.20	24.3	.411E+02	.72
12.90	.00	2.17	25.1	.398E+02	.74
13.34	.00	2.14	26.0	.385E+02	.75
13.80	.00	2.11	26.9	.372E+02	.77
14.26	.00	2.07	27.8	.359E+02	.78
14.71	.00	2.04	28.8	.348E+02	.80
15.16	.00	2.00	29.8	.336E+02	.82
15.61	.00	1.96	30.8	.324E+02	.83
16.07	.00	1.91	31.9	.313E+02	.85
16.51	.00	1.87	33.0	.303E+02	.87
16.97	.00	1.82	34.2	.292E+02	.88
17.41	.00	1.77	35.4	.283E+02	.90
17.87	.00	1.72	36.6	.273E+02	.92
18.32	.00	1.67	37.8	.264E+02	.94
18.77	.00	1.62	39.1	.256E+02	.96
19.23	.00	1.57	40.5	.247E+02	.97
19.67	.00	1.52	41.8	.239E+02	.99
20.13	.00	1.46	43.2	.232E+02	1.01
20.57	.00	1.41	44.5	.225E+02	1.03
21.03	.00	1.35	46.0	.217E+02	1.05
21.47	.00	1.29	47.4	.211E+02	1.07
21.93	.00	1.24	48.9	.204E+02	1.08
22.37	.00	1.18	50.4	.199E+02	1.10
22.83	.00	1.12	51.9	.193E+02	1.12

Cumulative travel time = 34. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
22.83	.00	1.12	51.9	.193E+02	1.12

MAC4-3X1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
21.71	.00	.00	51.9	.193E+02	.00	.00	.00	.00
22.05	.00	.00	51.9	.193E+02	1.48	.74	1.48	.00
22.38	.00	.00	51.9	.193E+02	1.76	1.05	1.76	.00
22.72	.00	.00	51.9	.193E+02	1.93	1.29	1.93	.00
23.06	.00	.00	53.3	.188E+02	2.06	1.49	2.06	.00
23.39	.00	.00	59.9	.167E+02	2.16	1.66	2.16	.00
23.73	.00	.00	69.1	.145E+02	2.23	1.82	2.23	.00
24.07	.00	.00	77.4	.129E+02	2.29	1.97	2.29	.00
24.40	.00	.00	83.1	.120E+02	2.32	2.11	2.32	.00
24.74	.00	.00	86.2	.116E+02	2.35	2.23	2.35	.00
25.07	.00	.00	88.2	.113E+02	2.35	2.35	2.35	.00

Cumulative travel time = 41. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
25.07	.00	.00	88.2	.113E+02	2.35	2.35	2.35	.00
27.37	.00	.00	91.1	.110E+02	2.18	2.63	2.18	.00
29.66	.00	.00	93.9	.106E+02	2.04	2.90	2.04	.00
31.96	.00	.00	96.5	.104E+02	1.93	3.15	1.93	.00
34.25	.00	.00	99.1	.101E+02	1.84	3.39	1.84	.00
36.55	.00	.00	101.7	.984E+01	1.76	3.63	1.76	.00
38.84	.00	.00	104.2	.960E+01	1.70	3.85	1.70	.00
41.14	.00	.00	106.8	.936E+01	1.65	4.07	1.65	.00
43.43	.00	.00	109.4	.914E+01	1.60	4.29	1.60	.00

45.73	.00	.00	112.1	.892E+01	1.57	4.50	1.57	.00
48.02	.00	.00	114.9	.871E+01	1.54	4.70	1.54	.00
50.31	.00	.00	117.7	.850E+01	1.51	4.90	1.51	.00
52.61	.00	.00	120.7	.829E+01	1.49	5.10	1.49	.00
54.90	.00	.00	123.7	.808E+01	1.47	5.29	1.47	.00
57.20	.00	.00	126.9	.788E+01	1.45	5.48	1.45	.00
59.49	.00	.00	130.1	.769E+01	1.44	5.66	1.44	.00
61.79	.00	.00	133.5	.749E+01	1.43	5.85	1.43	.00
64.08	.00	.00	137.0	.730E+01	1.43	6.03	1.43	.00
66.38	.00	.00	140.7	.711E+01	1.42	6.20	1.42	.00
68.67	.00	.00	144.5	.692E+01	1.42	6.38	1.42	.00
70.97	.00	.00	148.4	.674E+01	1.42	6.55	1.42	.00
73.26	.00	.00	152.5	.656E+01	1.43	6.72	1.43	.00
75.56	.00	.00	156.7	.638E+01	1.43	6.89	1.43	.00
77.85	.00	.00	161.1	.621E+01	1.43	7.06	1.43	.00
80.14	.00	.00	165.7	.604E+01	1.44	7.22	1.44	.00
82.44	.00	.00	170.4	.587E+01	1.45	7.38	1.45	.00
84.73	.00	.00	175.3	.571E+01	1.46	7.54	1.46	.00
87.03	.00	.00	180.3	.555E+01	1.47	7.70	1.47	.00
89.32	.00	.00	185.5	.539E+01	1.48	7.86	1.48	.00
91.62	.00	.00	190.9	.524E+01	1.50	8.01	1.50	.00
93.91	.00	.00	196.5	.509E+01	1.51	8.17	1.51	.00
96.21	.00	.00	202.2	.495E+01	1.53	8.32	1.53	.00
98.50	.00	.00	208.1	.480E+01	1.54	8.47	1.54	.00
100.80	.00	.00	214.2	.467E+01	1.56	8.62	1.56	.00
103.09	.00	.00	220.5	.454E+01	1.58	8.77	1.58	.00
105.39	.00	.00	227.0	.441E+01	1.60	8.92	1.60	.00
107.68	.00	.00	233.6	.428E+01	1.62	9.06	1.62	.00
109.97	.00	.00	240.5	.416E+01	1.64	9.21	1.64	.00
112.27	.00	.00	247.5	.404E+01	1.66	9.35	1.66	.00
114.56	.00	.00	254.8	.393E+01	1.69	9.49	1.69	.00
116.86	.00	.00	262.2	.381E+01	1.71	9.64	1.71	.00
119.15	.00	.00	269.9	.371E+01	1.73	9.78	1.73	.00
121.45	.00	.00	277.7	.360E+01	1.76	9.92	1.76	.00
123.74	.00	.00	285.7	.350E+01	1.79	10.06	1.79	.00
126.04	.00	.00	294.0	.340E+01	1.81	10.19	1.81	.00
128.33	.00	.00	302.4	.331E+01	1.84	10.33	1.84	.00
130.63	.00	.00	311.1	.321E+01	1.87	10.47	1.87	.00
132.92	.00	.00	320.0	.313E+01	1.90	10.60	1.90	.00
135.21	.00	.00	329.0	.304E+01	1.93	10.73	1.93	.00
137.51	.00	.00	338.3	.296E+01	1.96	10.87	1.96	.00
139.80	.00	.00	347.8	.287E+01	1.99	11.00	1.99	.00

Cumulative travel time = 364. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

MAC4-3X1.CX1

Discharge is non-buoyant or weakly buoyant.
Therefore BUOYANT SPREADING REGIME is ABSENT.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .274E-01 m^2/s
Horizontal diffusivity (initial value) = .685E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
139.80	11.00	.00	347.8	.287E+01	1.99	22.00	1.99	.00
157.01	11.00	.00	380.8	.263E+01	2.15	22.24	2.15	.00
174.21	11.00	.00	417.3	.240E+01	2.33	22.47	2.33	.00
191.42	11.00	.00	457.3	.219E+01	2.53	22.70	2.53	.00
208.62	11.00	.00	500.8	.200E+01	2.74	22.93	2.74	.00
225.82	11.00	.00	547.7	.183E+01	2.97	23.16	2.97	.00
243.03	11.00	.00	597.5	.167E+01	3.21	23.38	3.21	.00
260.23	11.00	.00	650.0	.154E+01	3.46	23.60	3.46	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.
The x-coordinate of bank attachment is 268.54 m.

277.44	11.00	.00	704.7	.142E+01	3.72	23.71	3.72	.00
294.64	11.00	.00	750.6	.133E+01	3.98	23.71	3.98	.00
311.84	11.00	.00	800.2	.125E+01	4.24	23.71	4.24	.00
329.05	11.00	.00	849.9	.118E+01	4.50	23.71	4.50	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

346.25	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

363.46	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
380.66	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
397.86	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00

415.07	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
432.27	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
449.47	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
466.68	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
483.88	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
501.09	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
518.29	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
535.49	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
552.70	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
569.90	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
587.11	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
604.31	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
621.51	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
638.72	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
655.92	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
673.13	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
690.33	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
707.53	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
724.74	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
741.94	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
759.15	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
776.35	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
793.55	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
810.76	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
827.96	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
845.16	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
862.37	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
879.57	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
896.78	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
913.98	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
931.18	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
948.39	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
965.59	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
982.80	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
1000.00	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00

Cumulative travel time = 2791. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

11111111111111111111111111111111111111111111111111111111111111111111111111111111

MAC4-4N1.CX1

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^4^-^PORT^4^NORMAL^FLOW
 FILE NAME:               cormix\sim\MAC4-4N1.cx1
 Time of Fortran run:     01/13/20--20:05:56

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     30.89  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .287 F     =       .058 USTAR = .2445E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.00
 D0    =       .152 A0    =       .018 H0    =       .53
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .052       = .5228E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .5228E-01  M0    = .1498E+00  J0    =-.7651E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .14  LM    =      2.75  Lm    =      1.35  Lb    =       .32
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     19.19  R     =      9.98

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
```

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1000.00  XMAX   =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .53     1.0  .100E+04     .08

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.17  SIGMAE=       .00
  LE    =       .64  XE    =       .56  YE    =       .00  ZE    =       .84

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .53     1.0  .100E+04     .08
      .56      .00      .84     1.0  .100E+04     .08
      .76      .00      .94     1.2  .820E+03     .10
      .97      .00     1.04     1.6  .633E+03     .13
     1.19      .00     1.13     2.0  .506E+03     .16
     1.41      .00     1.22     2.4  .424E+03     .18
     1.64      .00     1.29     2.8  .361E+03     .21
     1.86      .00     1.36     3.2  .317E+03     .23
     2.09      .00     1.43     3.6  .280E+03     .26
     2.31      .00     1.48     3.9  .253E+03     .28
     2.55      .00     1.54     4.3  .231E+03     .30
     2.77      .00     1.58     4.7  .213E+03     .32
     3.01      .00     1.62     5.1  .198E+03     .33
     3.24      .00     1.66     5.4  .186E+03     .35
     3.48      .00     1.69     5.7  .175E+03     .37
```

3.71	.00	1.71	6.0	.166E+03	.38
3.95	.00	1.74	6.3	.158E+03	.39
4.18	.00	1.75	6.6	.152E+03	.40
4.42	.00	1.77	6.8	.146E+03	.41
4.65	.00	1.78	7.1	.141E+03	.42
4.89	.00	1.78	7.3	.137E+03	.43
5.12	.00	1.79	7.5	.133E+03	.44

Maximum jet height has been reached.

5.36	.00	1.79	7.7	.130E+03	.45
5.59	.00	1.78	7.9	.127E+03	.46
5.84	.00	1.78	8.1	.123E+03	.47
6.07	.00	1.77	8.4	.120E+03	.47
6.31	.00	1.75	8.6	.116E+03	.48
6.54	.00	1.74	8.9	.112E+03	.49
6.78	.00	1.72	9.2	.109E+03	.50
7.01	.00	1.70	9.5	.105E+03	.51
7.25	.00	1.67	9.8	.102E+03	.53
7.48	.00	1.65	10.2	.982E+02	.54
7.70	.00	1.62	10.5	.949E+02	.55
7.94	.00	1.59	10.9	.915E+02	.56
8.17	.00	1.56	11.3	.884E+02	.57
8.41	.00	1.52	11.7	.851E+02	.59
8.64	.00	1.49	12.2	.822E+02	.60
8.88	.00	1.45	12.6	.792E+02	.61
9.10	.00	1.41	13.1	.765E+02	.63
9.34	.00	1.37	13.6	.737E+02	.64
9.57	.00	1.33	14.1	.712E+02	.66
9.81	.00	1.28	14.6	.686E+02	.67
10.03	.00	1.24	15.1	.663E+02	.68
10.27	.00	1.20	15.6	.640E+02	.70
10.50	.00	1.15	16.2	.618E+02	.71
10.73	.00	1.10	16.8	.597E+02	.73
10.96	.00	1.06	17.3	.577E+02	.74
11.20	.00	1.01	17.9	.558E+02	.76
11.42	.00	.96	18.5	.540E+02	.77
11.66	.00	.91	19.1	.522E+02	.79
11.88	.00	.87	19.8	.506E+02	.80
12.12	.00	.82	20.4	.491E+02	.82

Cumulative travel time = 18. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
12.12	.00	.82	20.4	.491E+02	.82

MAC4-4N1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
11.31	.00	.00	20.4	.491E+02	.00	.00	.00	.00
11.55	.00	.00	20.4	.491E+02	1.12	.56	1.12	.00
11.79	.00	.00	20.4	.491E+02	1.32	.79	1.32	.00
12.04	.00	.00	20.4	.491E+02	1.46	.97	1.46	.00
12.28	.00	.00	20.9	.478E+02	1.56	1.12	1.56	.00
12.53	.00	.00	23.5	.425E+02	1.63	1.26	1.63	.00
12.77	.00	.00	27.1	.369E+02	1.68	1.38	1.68	.00
13.02	.00	.00	30.4	.329E+02	1.73	1.49	1.73	.00
13.26	.00	.00	32.6	.306E+02	1.75	1.59	1.75	.00
13.51	.00	.00	33.9	.295E+02	1.77	1.69	1.77	.00
13.75	.00	.00	34.7	.289E+02	1.78	1.78	1.78	.00

Cumulative travel time = 23. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
13.75	.00	.00	34.7	.289E+02	1.78	1.78	1.78	.00
15.36	.00	.00	36.2	.276E+02	1.57	2.10	1.57	.00
16.97	.00	.00	37.5	.266E+02	1.42	2.41	1.42	.00
18.57	.00	.00	38.7	.258E+02	1.31	2.69	1.31	.00
20.18	.00	.00	39.8	.251E+02	1.22	2.96	1.22	.00
21.79	.00	.00	40.8	.245E+02	1.15	3.22	1.15	.00
23.39	.00	.00	41.7	.240E+02	1.09	3.47	1.09	.00
25.00	.00	.00	42.6	.235E+02	1.05	3.71	1.05	.00
26.61	.00	.00	43.5	.230E+02	1.00	3.95	1.00	.00

28.22	.00	.00	44.4	.225E+02	.97	4.17	.97	.00
29.82	.00	.00	45.2	.221E+02	.94	4.39	.94	.00
31.43	.00	.00	46.1	.217E+02	.91	4.61	.91	.00
33.04	.00	.00	46.9	.213E+02	.89	4.82	.89	.00
34.64	.00	.00	47.8	.209E+02	.87	5.02	.87	.00
36.25	.00	.00	48.7	.205E+02	.85	5.22	.85	.00
37.86	.00	.00	49.6	.202E+02	.83	5.42	.83	.00
39.46	.00	.00	50.5	.198E+02	.82	5.61	.82	.00
41.07	.00	.00	51.4	.194E+02	.81	5.81	.81	.00
42.68	.00	.00	52.4	.191E+02	.80	5.99	.80	.00
44.29	.00	.00	53.4	.187E+02	.79	6.18	.79	.00
45.89	.00	.00	54.4	.184E+02	.78	6.36	.78	.00
47.50	.00	.00	55.4	.181E+02	.77	6.54	.77	.00
49.11	.00	.00	56.4	.177E+02	.77	6.72	.77	.00
50.71	.00	.00	57.5	.174E+02	.76	6.89	.76	.00
52.32	.00	.00	58.6	.171E+02	.76	7.06	.76	.00
53.93	.00	.00	59.8	.167E+02	.75	7.23	.75	.00
55.53	.00	.00	61.0	.164E+02	.75	7.40	.75	.00
57.14	.00	.00	62.2	.161E+02	.75	7.57	.75	.00
58.75	.00	.00	63.4	.158E+02	.75	7.73	.75	.00
60.36	.00	.00	64.7	.155E+02	.75	7.89	.75	.00
61.96	.00	.00	66.0	.151E+02	.75	8.05	.75	.00
63.57	.00	.00	67.4	.148E+02	.75	8.21	.75	.00
65.18	.00	.00	68.8	.145E+02	.75	8.37	.75	.00
66.78	.00	.00	70.2	.142E+02	.75	8.53	.75	.00
68.39	.00	.00	71.7	.140E+02	.75	8.68	.75	.00
70.00	.00	.00	73.2	.137E+02	.75	8.84	.75	.00
71.60	.00	.00	74.7	.134E+02	.76	8.99	.76	.00
73.21	.00	.00	76.3	.131E+02	.76	9.14	.76	.00
74.82	.00	.00	77.9	.128E+02	.76	9.29	.76	.00
76.43	.00	.00	79.6	.126E+02	.77	9.44	.77	.00
78.03	.00	.00	81.3	.123E+02	.77	9.59	.77	.00
79.64	.00	.00	83.1	.120E+02	.78	9.73	.78	.00
81.25	.00	.00	84.9	.118E+02	.78	9.88	.78	.00
82.85	.00	.00	86.7	.115E+02	.79	10.02	.79	.00
84.46	.00	.00	88.6	.113E+02	.79	10.16	.79	.00
86.07	.00	.00	90.6	.110E+02	.80	10.31	.80	.00
87.67	.00	.00	92.6	.108E+02	.81	10.45	.81	.00
89.28	.00	.00	94.6	.106E+02	.81	10.59	.81	.00
90.89	.00	.00	96.7	.103E+02	.82	10.73	.82	.00
92.50	.00	.00	98.8	.101E+02	.83	10.86	.83	.00
94.10	.00	.00	101.0	.991E+01	.84	11.00	.84	.00

Cumulative travel time = 303. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

MAC4-4N1.CX1

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
94.10	11.00	.00	101.0	.991E+01	.84	22.00	.84	.00
94.51	11.00	.00	101.5	.985E+01	.84	22.03	.84	.00
94.92	11.00	.00	102.0	.980E+01	.84	22.07	.84	.00
95.33	11.00	.00	102.5	.975E+01	.84	22.10	.84	.00
95.74	11.00	.00	103.0	.970E+01	.85	22.14	.85	.00
96.16	11.00	.00	103.6	.965E+01	.85	22.17	.85	.00
96.57	11.00	.00	104.1	.961E+01	.85	22.21	.85	.00
96.98	11.00	.00	104.6	.956E+01	.86	22.24	.86	.00
97.39	11.00	.00	105.2	.951E+01	.86	22.28	.86	.00
97.80	11.00	.00	105.7	.946E+01	.86	22.31	.86	.00
98.21	11.00	.00	106.2	.941E+01	.87	22.35	.87	.00
98.62	11.00	.00	106.8	.937E+01	.87	22.38	.87	.00
99.03	11.00	.00	107.3	.932E+01	.87	22.42	.87	.00
99.44	11.00	.00	107.9	.927E+01	.87	22.45	.87	.00
99.85	11.00	.00	108.4	.923E+01	.88	22.49	.88	.00
100.26	11.00	.00	108.9	.918E+01	.88	22.52	.88	.00
100.67	11.00	.00	109.5	.913E+01	.88	22.55	.88	.00
101.08	11.00	.00	110.0	.909E+01	.89	22.59	.89	.00
101.49	11.00	.00	110.6	.904E+01	.89	22.62	.89	.00
101.90	11.00	.00	111.1	.900E+01	.89	22.66	.89	.00
102.31	11.00	.00	111.7	.895E+01	.90	22.69	.90	.00
102.72	11.00	.00	112.2	.891E+01	.90	22.73	.90	.00
103.14	11.00	.00	112.8	.887E+01	.90	22.76	.90	.00
103.55	11.00	.00	113.3	.882E+01	.91	22.79	.91	.00
103.96	11.00	.00	113.9	.878E+01	.91	22.83	.91	.00
104.37	11.00	.00	114.5	.874E+01	.91	22.86	.91	.00
104.78	11.00	.00	115.0	.869E+01	.91	22.90	.91	.00
105.19	11.00	.00	115.6	.865E+01	.92	22.93	.92	.00
105.60	11.00	.00	116.2	.861E+01	.92	22.97	.92	.00
106.01	11.00	.00	116.7	.857E+01	.92	23.00	.92	.00
106.42	11.00	.00	117.3	.853E+01	.93	23.03	.93	.00
106.83	11.00	.00	117.9	.848E+01	.93	23.07	.93	.00
107.24	11.00	.00	118.4	.844E+01	.93	23.10	.93	.00
107.65	11.00	.00	119.0	.840E+01	.94	23.14	.94	.00
108.06	11.00	.00	119.6	.836E+01	.94	23.17	.94	.00
108.47	11.00	.00	120.2	.832E+01	.94	23.20	.94	.00
108.88	11.00	.00	120.7	.828E+01	.95	23.24	.95	.00
109.29	11.00	.00	121.3	.824E+01	.95	23.27	.95	.00
109.71	11.00	.00	121.9	.820E+01	.95	23.31	.95	.00
110.12	11.00	.00	122.5	.816E+01	.96	23.34	.96	.00
110.53	11.00	.00	123.1	.813E+01	.96	23.37	.96	.00
110.94	11.00	.00	123.7	.809E+01	.96	23.41	.96	.00
111.35	11.00	.00	124.3	.805E+01	.97	23.44	.97	.00
111.76	11.00	.00	124.8	.801E+01	.97	23.47	.97	.00
112.17	11.00	.00	125.4	.797E+01	.97	23.51	.97	.00
112.58	11.00	.00	126.0	.793E+01	.97	23.54	.97	.00

112.99	11.00	.00	126.6	.790E+01	.98	23.58	.98	.00
113.40	11.00	.00	127.2	.786E+01	.98	23.61	.98	.00
113.81	11.00	.00	127.8	.782E+01	.98	23.64	.98	.00
114.22	11.00	.00	128.4	.779E+01	.99	23.68	.99	.00
114.63	11.00	.00	129.0	.775E+01	.99	23.71	.99	.00

Cumulative travel time = 374. sec
Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .222E-01 m^2/s
Horizontal diffusivity (initial value) = .555E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
114.63	11.00	.00	129.0	.775E+01	.99	23.71	.99	.00
132.34	11.00	.00	131.8	.759E+01	1.01	23.71	1.01	.00
150.05	11.00	.00	134.7	.742E+01	1.03	23.71	1.03	.00
167.75	11.00	.00	137.7	.726E+01	1.06	23.71	1.06	.00
185.46	11.00	.00	140.9	.710E+01	1.08	23.71	1.08	.00
203.17	11.00	.00	144.2	.693E+01	1.11	23.71	1.11	.00
220.88	11.00	.00	147.6	.677E+01	1.13	23.71	1.13	.00
238.58	11.00	.00	151.2	.661E+01	1.16	23.71	1.16	.00
256.29	11.00	.00	155.0	.645E+01	1.19	23.71	1.19	.00
274.00	11.00	.00	158.9	.629E+01	1.22	23.71	1.22	.00
291.71	11.00	.00	163.0	.614E+01	1.25	23.71	1.25	.00
309.41	11.00	.00	167.3	.598E+01	1.28	23.71	1.28	.00
327.12	11.00	.00	171.8	.582E+01	1.32	23.71	1.32	.00
344.83	11.00	.00	176.5	.567E+01	1.36	23.71	1.36	.00
362.54	11.00	.00	181.5	.551E+01	1.39	23.71	1.39	.00
380.24	11.00	.00	186.7	.536E+01	1.43	23.71	1.43	.00
397.95	11.00	.00	192.1	.521E+01	1.48	23.71	1.48	.00
415.66	11.00	.00	197.9	.505E+01	1.52	23.71	1.52	.00
433.36	11.00	.00	203.9	.490E+01	1.57	23.71	1.57	.00
451.07	11.00	.00	210.2	.476E+01	1.61	23.71	1.61	.00

468.78	11.00	.00	216.9	.461E+01	1.67	23.71	1.67	.00
486.49	11.00	.00	224.0	.446E+01	1.72	23.71	1.72	.00
504.19	11.00	.00	231.4	.432E+01	1.78	23.71	1.78	.00
521.90	11.00	.00	239.2	.418E+01	1.84	23.71	1.84	.00
539.61	11.00	.00	247.5	.404E+01	1.90	23.71	1.90	.00
557.32	11.00	.00	256.2	.390E+01	1.97	23.71	1.97	.00
575.02	11.00	.00	265.4	.377E+01	2.04	23.71	2.04	.00
592.73	11.00	.00	275.1	.364E+01	2.11	23.71	2.11	.00
610.44	11.00	.00	285.3	.351E+01	2.19	23.71	2.19	.00
628.15	11.00	.00	296.0	.338E+01	2.27	23.71	2.27	.00
645.85	11.00	.00	307.4	.325E+01	2.36	23.71	2.36	.00
663.56	11.00	.00	319.3	.313E+01	2.45	23.71	2.45	.00
681.27	11.00	.00	331.9	.301E+01	2.55	23.71	2.55	.00
698.97	11.00	.00	345.1	.290E+01	2.65	23.71	2.65	.00
716.68	11.00	.00	358.9	.279E+01	2.76	23.71	2.76	.00
734.39	11.00	.00	373.5	.268E+01	2.87	23.71	2.87	.00
752.10	11.00	.00	388.7	.257E+01	2.99	23.71	2.99	.00
769.80	11.00	.00	404.5	.247E+01	3.11	23.71	3.11	.00
787.51	11.00	.00	421.1	.237E+01	3.23	23.71	3.23	.00
805.22	11.00	.00	438.3	.228E+01	3.37	23.71	3.37	.00
822.93	11.00	.00	456.2	.219E+01	3.50	23.71	3.50	.00
840.63	11.00	.00	474.7	.211E+01	3.65	23.71	3.65	.00
858.34	11.00	.00	493.9	.202E+01	3.79	23.71	3.79	.00
876.05	11.00	.00	513.6	.195E+01	3.95	23.71	3.95	.00
893.76	11.00	.00	533.9	.187E+01	4.10	23.71	4.10	.00
911.46	11.00	.00	554.7	.180E+01	4.26	23.71	4.26	.00
929.17	11.00	.00	576.0	.174E+01	4.42	23.71	4.42	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
prediction interval.

946.88	11.00	.00	591.1	.169E+01	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are
NO FURTHER CHANGES with downstream direction.

964.58	11.00	.00	591.1	.169E+01	4.54	23.71	4.54	.00
982.29	11.00	.00	591.1	.169E+01	4.54	23.71	4.54	.00
1000.00	11.00	.00	591.1	.169E+01	4.54	23.71	4.54	.00

Cumulative travel time = 3454. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111111

MAC4-4X1.CX1

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CORMIX1 PRESCRIPTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^4^-^PORT^4^MAXIMUM^FLOW
 FILE NAME:               cormix\sim\MAC4-4X1.cx1
 Time of Fortran run:     01/13/20--20:40:50

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     38.11  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .354 F     =       .058 USTAR = .3016E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.00
 D0    =       .152 A0    =       .018 H0    =       .53
 THETA =     30.00  SIGMA =       .00
 U0    =      5.487 Q0    =       .100       = .1001E+00
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .1001E+00  M0    = .5492E+00  J0    =-.1465E-01  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .14  LM    =      5.27  Lm    =      2.09  Lb    =       .33
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     36.74  R     =     15.50

FLOW CLASSIFICATION
 1111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
```

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1000.00  XMAX   =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

      X        Y        Z        S        C        B
     .00      .00      .53      1.0  .100E+04     .08

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.82  SIGMAE=       .00
  LE    =       .68  XE    =       .59  YE    =       .00  ZE    =       .86

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

      X        Y        Z        S        C        B
     .00      .00      .53      1.0  .100E+04     .08
     .59      .00      .86      1.0  .100E+04     .08
    1.00      .00     1.07      1.5  .650E+03     .13
    1.44      .00     1.28      2.3  .438E+03     .19
    1.88      .00     1.47      3.1  .325E+03     .24
    2.33      .00     1.64      3.9  .256E+03     .30
    2.79      .00     1.79      4.7  .211E+03     .35
    3.25      .00     1.93      5.6  .179E+03     .40
    3.71      .00     2.06      6.4  .156E+03     .44
    4.18      .00     2.17      7.3  .138E+03     .48
    4.65      .00     2.27      8.1  .124E+03     .52
    5.13      .00     2.35      8.9  .113E+03     .56
    5.60      .00     2.43      9.6  .104E+03     .59
    6.08      .00     2.50     10.3  .967E+02     .62
    6.56      .00     2.56     11.0  .906E+02     .65
```

7.03	.00	2.61	11.7	.855E+02	.68
7.51	.00	2.66	12.3	.811E+02	.70
7.99	.00	2.70	12.9	.774E+02	.73
8.47	.00	2.73	13.5	.742E+02	.75
8.96	.00	2.75	14.0	.715E+02	.77
9.44	.00	2.77	14.5	.691E+02	.78
9.92	.00	2.79	14.9	.670E+02	.80
10.40	.00	2.79	15.3	.652E+02	.81
10.88	.00	2.80	15.7	.636E+02	.83

Maximum jet height has been reached.

11.36	.00	2.79	16.1	.621E+02	.84
11.84	.00	2.79	16.5	.605E+02	.85
12.32	.00	2.77	17.0	.589E+02	.87
12.81	.00	2.76	17.5	.572E+02	.88
13.29	.00	2.73	18.0	.556E+02	.90
13.77	.00	2.71	18.5	.540E+02	.92
14.25	.00	2.67	19.1	.523E+02	.94
14.73	.00	2.64	19.7	.507E+02	.95
15.21	.00	2.60	20.4	.491E+02	.97
15.69	.00	2.56	21.1	.475E+02	.99
16.17	.00	2.51	21.8	.460E+02	1.01
16.65	.00	2.46	22.5	.445E+02	1.03
17.12	.00	2.41	23.3	.430E+02	1.05
17.60	.00	2.36	24.1	.416E+02	1.08
18.08	.00	2.30	24.9	.402E+02	1.10
18.56	.00	2.24	25.7	.389E+02	1.12
19.04	.00	2.18	26.6	.376E+02	1.14
19.51	.00	2.12	27.5	.363E+02	1.17
19.99	.00	2.05	28.4	.352E+02	1.19
20.47	.00	1.98	29.4	.340E+02	1.21
20.94	.00	1.92	30.4	.329E+02	1.24
21.42	.00	1.85	31.4	.319E+02	1.26
21.90	.00	1.78	32.4	.309E+02	1.28
22.37	.00	1.70	33.5	.299E+02	1.31
22.85	.00	1.63	34.5	.290E+02	1.33
23.32	.00	1.56	35.6	.281E+02	1.36
23.80	.00	1.48	36.7	.272E+02	1.38
24.28	.00	1.40	37.8	.264E+02	1.40

Cumulative travel time = 32. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
24.28	.00	1.40	37.8	.264E+02	1.40

MAC4-4X1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
22.87	.00	.00	37.8	.264E+02	.00	.00	.00	.00
23.29	.00	.00	37.8	.264E+02	1.90	.95	1.90	.00
23.71	.00	.00	37.8	.264E+02	2.25	1.35	2.25	.00
24.14	.00	.00	37.8	.264E+02	2.48	1.65	2.48	.00
24.56	.00	.00	38.9	.257E+02	2.64	1.91	2.64	.00
24.98	.00	.00	43.7	.229E+02	2.77	2.13	2.77	.00
25.40	.00	.00	50.4	.199E+02	2.86	2.34	2.86	.00
25.82	.00	.00	56.4	.177E+02	2.93	2.52	2.93	.00
26.24	.00	.00	60.6	.165E+02	2.98	2.70	2.98	.00
26.66	.00	.00	62.9	.159E+02	3.01	2.86	3.01	.00
27.08	.00	.00	64.3	.155E+02	3.02	3.02	3.02	.00

Cumulative travel time = 40. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
27.08	.00	.00	64.3	.155E+02	3.02	3.02	3.02	.00
28.54	.00	.00	65.6	.152E+02	2.85	3.25	2.85	.00
30.00	.00	.00	66.9	.150E+02	2.72	3.48	2.72	.00
31.45	.00	.00	68.0	.147E+02	2.60	3.70	2.60	.00
32.91	.00	.00	69.1	.145E+02	2.50	3.91	2.50	.00
34.37	.00	.00	70.1	.143E+02	2.41	4.12	2.41	.00
35.82	.00	.00	71.2	.141E+02	2.33	4.32	2.33	.00
37.28	.00	.00	72.1	.139E+02	2.25	4.52	2.25	.00
38.74	.00	.00	73.1	.137E+02	2.19	4.72	2.19	.00

40.19	.00	.00	74.0	.135E+02	2.13	4.91	2.13	.00
41.65	.00	.00	74.9	.133E+02	2.08	5.09	2.08	.00
43.10	.00	.00	75.8	.132E+02	2.03	5.28	2.03	.00
44.56	.00	.00	76.7	.130E+02	1.99	5.46	1.99	.00
46.02	.00	.00	77.6	.129E+02	1.95	5.63	1.95	.00
47.47	.00	.00	78.5	.127E+02	1.91	5.81	1.91	.00
48.93	.00	.00	79.4	.126E+02	1.88	5.98	1.88	.00
50.39	.00	.00	80.3	.125E+02	1.85	6.15	1.85	.00
51.84	.00	.00	81.2	.123E+02	1.82	6.32	1.82	.00
53.30	.00	.00	82.1	.122E+02	1.79	6.48	1.79	.00
54.76	.00	.00	82.9	.121E+02	1.77	6.64	1.77	.00
56.21	.00	.00	83.8	.119E+02	1.74	6.80	1.74	.00
57.67	.00	.00	84.8	.118E+02	1.72	6.96	1.72	.00
59.13	.00	.00	85.7	.117E+02	1.70	7.12	1.70	.00
60.58	.00	.00	86.6	.115E+02	1.68	7.28	1.68	.00
62.04	.00	.00	87.5	.114E+02	1.67	7.43	1.67	.00
63.50	.00	.00	88.5	.113E+02	1.65	7.58	1.65	.00
64.95	.00	.00	89.4	.112E+02	1.64	7.73	1.64	.00
66.41	.00	.00	90.4	.111E+02	1.62	7.88	1.62	.00
67.87	.00	.00	91.4	.109E+02	1.61	8.03	1.61	.00
69.32	.00	.00	92.4	.108E+02	1.60	8.17	1.60	.00
70.78	.00	.00	93.4	.107E+02	1.59	8.32	1.59	.00
72.24	.00	.00	94.4	.106E+02	1.58	8.46	1.58	.00
73.69	.00	.00	95.5	.105E+02	1.57	8.61	1.57	.00
75.15	.00	.00	96.5	.104E+02	1.56	8.75	1.56	.00
76.61	.00	.00	97.6	.102E+02	1.55	8.89	1.55	.00
78.06	.00	.00	98.7	.101E+02	1.55	9.03	1.55	.00
79.52	.00	.00	99.8	.100E+02	1.54	9.17	1.54	.00
80.97	.00	.00	100.9	.991E+01	1.53	9.30	1.53	.00
82.43	.00	.00	102.1	.980E+01	1.53	9.44	1.53	.00
83.89	.00	.00	103.2	.969E+01	1.52	9.57	1.52	.00
85.34	.00	.00	104.4	.958E+01	1.52	9.71	1.52	.00
86.80	.00	.00	105.6	.947E+01	1.52	9.84	1.52	.00
88.26	.00	.00	106.9	.936E+01	1.51	9.97	1.51	.00
89.71	.00	.00	108.1	.925E+01	1.51	10.10	1.51	.00
91.17	.00	.00	109.4	.914E+01	1.51	10.24	1.51	.00
92.63	.00	.00	110.7	.904E+01	1.51	10.37	1.51	.00
94.08	.00	.00	112.0	.893E+01	1.51	10.49	1.51	.00
95.54	.00	.00	113.3	.883E+01	1.51	10.62	1.51	.00
97.00	.00	.00	114.7	.872E+01	1.51	10.75	1.51	.00
98.45	.00	.00	116.0	.862E+01	1.51	10.88	1.51	.00
99.91	.00	.00	117.4	.852E+01	1.51	11.00	1.51	.00

Cumulative travel time = 245. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

MAC4-4X1.CX1

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
99.91	11.00	.00	117.4	.852E+01	1.51	22.00	1.51	.00
100.32	11.00	.00	117.8	.849E+01	1.51	22.03	1.51	.00
100.72	11.00	.00	118.1	.847E+01	1.51	22.07	1.51	.00
101.13	11.00	.00	118.5	.844E+01	1.52	22.10	1.52	.00
101.53	11.00	.00	118.8	.842E+01	1.52	22.14	1.52	.00
101.94	11.00	.00	119.2	.839E+01	1.52	22.17	1.52	.00
102.35	11.00	.00	119.5	.837E+01	1.52	22.21	1.52	.00
102.75	11.00	.00	119.9	.834E+01	1.52	22.24	1.52	.00
103.16	11.00	.00	120.2	.832E+01	1.53	22.28	1.53	.00
103.56	11.00	.00	120.6	.829E+01	1.53	22.31	1.53	.00
103.97	11.00	.00	120.9	.827E+01	1.53	22.35	1.53	.00
104.37	11.00	.00	121.3	.824E+01	1.53	22.38	1.53	.00
104.78	11.00	.00	121.7	.822E+01	1.53	22.42	1.53	.00
105.19	11.00	.00	122.0	.820E+01	1.54	22.45	1.54	.00
105.59	11.00	.00	122.4	.817E+01	1.54	22.49	1.54	.00
106.00	11.00	.00	122.7	.815E+01	1.54	22.52	1.54	.00
106.40	11.00	.00	123.1	.812E+01	1.54	22.55	1.54	.00
106.81	11.00	.00	123.5	.810E+01	1.54	22.59	1.54	.00
107.22	11.00	.00	123.8	.808E+01	1.55	22.62	1.55	.00
107.62	11.00	.00	124.2	.805E+01	1.55	22.66	1.55	.00
108.03	11.00	.00	124.5	.803E+01	1.55	22.69	1.55	.00
108.43	11.00	.00	124.9	.801E+01	1.55	22.73	1.55	.00
108.84	11.00	.00	125.3	.798E+01	1.56	22.76	1.56	.00
109.24	11.00	.00	125.6	.796E+01	1.56	22.80	1.56	.00
109.65	11.00	.00	126.0	.794E+01	1.56	22.83	1.56	.00
110.06	11.00	.00	126.4	.791E+01	1.56	22.86	1.56	.00
110.46	11.00	.00	126.8	.789E+01	1.56	22.90	1.56	.00
110.87	11.00	.00	127.1	.787E+01	1.57	22.93	1.57	.00
111.27	11.00	.00	127.5	.784E+01	1.57	22.97	1.57	.00
111.68	11.00	.00	127.9	.782E+01	1.57	23.00	1.57	.00
112.09	11.00	.00	128.2	.780E+01	1.57	23.03	1.57	.00
112.49	11.00	.00	128.6	.777E+01	1.58	23.07	1.58	.00
112.90	11.00	.00	129.0	.775E+01	1.58	23.10	1.58	.00
113.30	11.00	.00	129.4	.773E+01	1.58	23.14	1.58	.00
113.71	11.00	.00	129.8	.771E+01	1.58	23.17	1.58	.00
114.11	11.00	.00	130.1	.768E+01	1.59	23.20	1.59	.00
114.52	11.00	.00	130.5	.766E+01	1.59	23.24	1.59	.00
114.93	11.00	.00	130.9	.764E+01	1.59	23.27	1.59	.00
115.33	11.00	.00	131.3	.762E+01	1.59	23.31	1.59	.00
115.74	11.00	.00	131.7	.759E+01	1.59	23.34	1.59	.00
116.14	11.00	.00	132.1	.757E+01	1.60	23.37	1.60	.00
116.55	11.00	.00	132.4	.755E+01	1.60	23.41	1.60	.00
116.96	11.00	.00	132.8	.753E+01	1.60	23.44	1.60	.00
117.36	11.00	.00	133.2	.751E+01	1.60	23.48	1.60	.00
117.77	11.00	.00	133.6	.748E+01	1.61	23.51	1.61	.00
118.17	11.00	.00	134.0	.746E+01	1.61	23.54	1.61	.00

118.58	11.00	.00	134.4	.744E+01	1.61	23.58	1.61	.00
118.98	11.00	.00	134.8	.742E+01	1.61	23.61	1.61	.00
119.39	11.00	.00	135.2	.740E+01	1.62	23.64	1.62	.00
119.80	11.00	.00	135.6	.738E+01	1.62	23.68	1.62	.00
120.20	11.00	.00	136.0	.736E+01	1.62	23.71	1.62	.00

Cumulative travel time = 302. sec
Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .274E-01 m^2/s
Horizontal diffusivity (initial value) = .685E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
120.20	11.00	.00	136.0	.736E+01	1.62	23.71	1.62	.00
137.80	11.00	.00	140.1	.714E+01	1.67	23.71	1.67	.00
155.39	11.00	.00	144.6	.692E+01	1.72	23.71	1.72	.00
172.99	11.00	.00	149.2	.670E+01	1.78	23.71	1.78	.00
190.59	11.00	.00	154.1	.649E+01	1.84	23.71	1.84	.00
208.18	11.00	.00	159.2	.628E+01	1.90	23.71	1.90	.00
225.78	11.00	.00	164.6	.608E+01	1.96	23.71	1.96	.00
243.37	11.00	.00	170.3	.587E+01	2.03	23.71	2.03	.00
260.97	11.00	.00	176.3	.567E+01	2.10	23.71	2.10	.00
278.57	11.00	.00	182.6	.548E+01	2.18	23.71	2.18	.00
296.16	11.00	.00	189.3	.528E+01	2.26	23.71	2.26	.00
313.76	11.00	.00	196.3	.510E+01	2.34	23.71	2.34	.00
331.35	11.00	.00	203.6	.491E+01	2.43	23.71	2.43	.00
348.95	11.00	.00	211.4	.473E+01	2.52	23.71	2.52	.00
366.55	11.00	.00	219.5	.456E+01	2.62	23.71	2.62	.00
384.14	11.00	.00	228.0	.439E+01	2.72	23.71	2.72	.00
401.74	11.00	.00	236.9	.422E+01	2.82	23.71	2.82	.00
419.33	11.00	.00	246.3	.406E+01	2.94	23.71	2.94	.00
436.93	11.00	.00	256.0	.391E+01	3.05	23.71	3.05	.00
454.53	11.00	.00	266.2	.376E+01	3.17	23.71	3.17	.00

472.12	11.00	.00	276.8	.361E+01	3.30	23.71	3.30	.00
489.72	11.00	.00	287.8	.347E+01	3.43	23.71	3.43	.00
507.31	11.00	.00	299.2	.334E+01	3.57	23.71	3.57	.00
524.91	11.00	.00	311.0	.322E+01	3.71	23.71	3.71	.00
542.51	11.00	.00	323.2	.309E+01	3.85	23.71	3.85	.00
560.10	11.00	.00	335.7	.298E+01	4.00	23.71	4.00	.00
577.70	11.00	.00	348.6	.287E+01	4.16	23.71	4.16	.00
595.29	11.00	.00	361.8	.276E+01	4.31	23.71	4.31	.00
612.89	11.00	.00	375.3	.266E+01	4.47	23.71	4.47	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

630.48	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

648.08	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
665.68	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
683.27	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
700.87	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
718.46	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
736.06	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
753.66	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
771.25	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
788.85	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
806.44	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
824.04	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
841.64	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
859.23	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
876.83	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
894.42	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
912.02	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
929.62	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
947.21	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
964.81	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
982.40	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
1000.00	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00

Cumulative travel time = 2781. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111111

MAC5-1N1.CX1

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^5^-^PORT^1^-^NORMAL^FLOW
 FILE NAME:               cormix\sim\MAC5-1N1.cx1
 Time of Fortran run:     01/09/20--13:10:35

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     25.76  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .239 F     =       .058 USTAR = .2039E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.80
 D0    =       .076 A0    =       .005 H0    =       .56
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .013       = .1300E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .1300E-01  M0    = .3726E-01  J0    =-.1903E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .07  LM    =      1.94  Lm    =       .81  Lb    =       .14
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     27.17  R     =     11.97

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
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 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1200.00  XMAX   =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .56      1.0  .100E+04     .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:          THETAE=     28.47  SIGMAE=       .00
  LE    =       .33  XE    =       .29  YE    =       .00  ZE    =       .72

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .56      1.0  .100E+04     .04
      .29      .00      .72      1.0  .100E+04     .04
      .47      .00      .82      1.5  .678E+03     .06
      .65      .00      .90      2.1  .471E+03     .09
      .84      .00      .97      2.8  .357E+03     .11
     1.03      .00     1.04      3.5  .286E+03     .13
     1.22      .00     1.10      4.2  .238E+03     .15
     1.42      .00     1.15      4.9  .204E+03     .17
     1.62      .00     1.20      5.6  .178E+03     .19
     1.82      .00     1.24      6.3  .159E+03     .20
     2.02      .00     1.27      6.9  .145E+03     .22
     2.22      .00     1.30      7.5  .133E+03     .23
     2.42      .00     1.33      8.1  .123E+03     .24
     2.62      .00     1.35      8.6  .116E+03     .26
     2.82      .00     1.37      9.2  .109E+03     .27
```

3.03	.00	1.39	9.6	.104E+03	.27
3.23	.00	1.40	10.1	.992E+02	.28
3.43	.00	1.40	10.5	.953E+02	.29
3.63	.00	1.41	10.9	.921E+02	.30
3.83	.00	1.41	11.2	.893E+02	.30

Maximum jet height has been reached.

4.04	.00	1.41	11.5	.868E+02	.31
4.24	.00	1.41	11.9	.843E+02	.32
4.44	.00	1.40	12.2	.816E+02	.32
4.65	.00	1.39	12.7	.790E+02	.33
4.85	.00	1.38	13.1	.763E+02	.34
5.05	.00	1.37	13.6	.736E+02	.34
5.26	.00	1.36	14.1	.708E+02	.35
5.46	.00	1.34	14.7	.682E+02	.36
5.66	.00	1.32	15.2	.656E+02	.37
5.86	.00	1.30	15.8	.631E+02	.38
6.06	.00	1.28	16.5	.607E+02	.39
6.26	.00	1.25	17.1	.583E+02	.40
6.46	.00	1.23	17.8	.561E+02	.41
6.67	.00	1.20	18.6	.538E+02	.42
6.87	.00	1.17	19.3	.517E+02	.43
7.07	.00	1.14	20.1	.497E+02	.44
7.27	.00	1.11	20.9	.478E+02	.45
7.47	.00	1.08	21.8	.460E+02	.46
7.67	.00	1.05	22.6	.442E+02	.47
7.87	.00	1.02	23.5	.425E+02	.48
8.07	.00	.99	24.4	.410E+02	.49
8.27	.00	.95	25.3	.395E+02	.50
8.47	.00	.92	26.3	.380E+02	.51
8.67	.00	.89	27.2	.367E+02	.52
8.87	.00	.85	28.2	.354E+02	.53
9.07	.00	.82	29.3	.342E+02	.54
9.27	.00	.78	30.3	.330E+02	.55
9.47	.00	.75	31.4	.319E+02	.56
9.67	.00	.71	32.4	.309E+02	.57
9.87	.00	.68	33.5	.299E+02	.58
10.07	.00	.64	34.6	.289E+02	.60
10.27	.00	.61	35.7	.280E+02	.61

Cumulative travel time = 21. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
10.27	.00	.61	35.7	.280E+02	.61

MAC5-1N1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
9.67	.00	.00	35.7	.280E+02	.00	.00	.00	.00
9.85	.00	.00	35.7	.280E+02	.81	.41	.81	.00
10.03	.00	.00	35.7	.280E+02	.96	.57	.96	.00
10.21	.00	.00	35.7	.280E+02	1.05	.70	1.05	.00
10.40	.00	.00	36.7	.273E+02	1.12	.81	1.12	.00
10.58	.00	.00	41.2	.243E+02	1.18	.91	1.18	.00
10.76	.00	.00	47.5	.210E+02	1.22	.99	1.22	.00
10.94	.00	.00	53.2	.188E+02	1.25	1.07	1.25	.00
11.12	.00	.00	57.2	.175E+02	1.27	1.15	1.27	.00
11.30	.00	.00	59.3	.169E+02	1.28	1.22	1.28	.00
11.49	.00	.00	60.7	.165E+02	1.28	1.28	1.28	.00

Cumulative travel time = 26. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
11.49	.00	.00	60.7	.165E+02	1.28	1.28	1.28	.00
13.64	.00	.00	64.7	.155E+02	1.09	1.62	1.09	.00
15.80	.00	.00	68.0	.147E+02	.96	1.92	.96	.00
17.96	.00	.00	71.1	.141E+02	.88	2.20	.88	.00
20.12	.00	.00	74.0	.135E+02	.82	2.46	.82	.00
22.28	.00	.00	76.9	.130E+02	.77	2.71	.77	.00
24.44	.00	.00	79.9	.125E+02	.74	2.95	.74	.00
26.60	.00	.00	83.0	.121E+02	.71	3.18	.71	.00
28.75	.00	.00	86.1	.116E+02	.69	3.40	.69	.00

30.91	.00	.00	89.5	.112E+02	.67	3.62	.67	.00
33.07	.00	.00	93.0	.107E+02	.66	3.82	.66	.00
35.23	.00	.00	96.8	.103E+02	.65	4.03	.65	.00
37.39	.00	.00	100.7	.993E+01	.65	4.22	.65	.00
39.55	.00	.00	104.9	.953E+01	.65	4.42	.65	.00
41.71	.00	.00	109.4	.914E+01	.65	4.61	.65	.00
43.86	.00	.00	114.1	.877E+01	.65	4.79	.65	.00
46.02	.00	.00	119.0	.840E+01	.65	4.97	.65	.00
48.18	.00	.00	124.3	.804E+01	.66	5.15	.66	.00
50.34	.00	.00	129.8	.770E+01	.66	5.33	.66	.00
52.50	.00	.00	135.7	.737E+01	.67	5.50	.67	.00
54.66	.00	.00	141.8	.705E+01	.68	5.67	.68	.00
56.82	.00	.00	148.3	.674E+01	.69	5.83	.69	.00
58.97	.00	.00	155.0	.645E+01	.70	6.00	.70	.00
61.13	.00	.00	162.1	.617E+01	.71	6.16	.71	.00
63.29	.00	.00	169.6	.590E+01	.73	6.32	.73	.00
65.45	.00	.00	177.3	.564E+01	.74	6.48	.74	.00
67.61	.00	.00	185.4	.539E+01	.76	6.64	.76	.00
69.77	.00	.00	193.9	.516E+01	.78	6.79	.78	.00
71.93	.00	.00	202.7	.493E+01	.79	6.94	.79	.00
74.08	.00	.00	211.8	.472E+01	.81	7.10	.81	.00
76.24	.00	.00	221.4	.452E+01	.83	7.25	.83	.00
78.40	.00	.00	231.2	.432E+01	.85	7.39	.85	.00
80.56	.00	.00	241.5	.414E+01	.87	7.54	.87	.00
82.72	.00	.00	252.1	.397E+01	.89	7.69	.89	.00
84.88	.00	.00	263.2	.380E+01	.91	7.83	.91	.00
87.04	.00	.00	274.6	.364E+01	.94	7.97	.94	.00
89.19	.00	.00	286.3	.349E+01	.96	8.11	.96	.00
91.35	.00	.00	298.5	.335E+01	.98	8.25	.98	.00
93.51	.00	.00	311.1	.321E+01	1.01	8.39	1.01	.00
95.67	.00	.00	324.1	.309E+01	1.03	8.53	1.03	.00
97.83	.00	.00	337.5	.296E+01	1.06	8.67	1.06	.00
99.99	.00	.00	351.2	.285E+01	1.08	8.80	1.08	.00
102.14	.00	.00	365.4	.274E+01	1.11	8.94	1.11	.00
104.30	.00	.00	380.1	.263E+01	1.14	9.07	1.14	.00
106.46	.00	.00	395.1	.253E+01	1.17	9.20	1.17	.00
108.62	.00	.00	410.5	.244E+01	1.19	9.33	1.19	.00
110.78	.00	.00	426.4	.235E+01	1.22	9.47	1.22	.00
112.94	.00	.00	442.7	.226E+01	1.25	9.60	1.25	.00
115.10	.00	.00	459.5	.218E+01	1.28	9.72	1.28	.00
117.25	.00	.00	476.6	.210E+01	1.31	9.85	1.31	.00
119.41	.00	.00	494.2	.202E+01	1.35	9.98	1.35	.00

Cumulative travel time = 477. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

MAC5-1N1.CX1

Vertical diffusivity (initial value) = .185E-01 m^2/s
Horizontal diffusivity (initial value) = .463E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
119.41	.00	.00	494.2	.202E+01	1.35	9.98	1.35	.00
120.72	.00	.00	498.7	.201E+01	1.35	10.02	1.35	.00
122.02	.00	.00	503.1	.199E+01	1.36	10.06	1.36	.00
123.33	.00	.00	507.6	.197E+01	1.37	10.10	1.37	.00
124.63	.00	.00	512.2	.195E+01	1.37	10.14	1.37	.00
125.93	.00	.00	516.8	.193E+01	1.38	10.18	1.38	.00
127.24	.00	.00	521.5	.192E+01	1.39	10.22	1.39	.00
128.54	.00	.00	526.2	.190E+01	1.39	10.25	1.39	.00
129.85	.00	.00	530.9	.188E+01	1.40	10.29	1.40	.00
131.15	.00	.00	535.7	.187E+01	1.41	10.33	1.41	.00
132.46	.00	.00	540.5	.185E+01	1.42	10.37	1.42	.00
133.76	.00	.00	545.4	.183E+01	1.42	10.41	1.42	.00
135.07	.00	.00	550.4	.182E+01	1.43	10.45	1.43	.00
136.37	.00	.00	555.4	.180E+01	1.44	10.48	1.44	.00
137.67	.00	.00	560.4	.178E+01	1.45	10.52	1.45	.00
138.98	.00	.00	565.5	.177E+01	1.45	10.56	1.45	.00
140.28	.00	.00	570.7	.175E+01	1.46	10.60	1.46	.00
141.59	.00	.00	575.9	.174E+01	1.47	10.63	1.47	.00
142.89	.00	.00	581.2	.172E+01	1.48	10.67	1.48	.00
144.20	.00	.00	586.5	.171E+01	1.49	10.71	1.49	.00
145.50	.00	.00	591.9	.169E+01	1.50	10.75	1.50	.00
146.81	.00	.00	597.3	.167E+01	1.50	10.78	1.50	.00
148.11	.00	.00	602.8	.166E+01	1.51	10.82	1.51	.00
149.41	.00	.00	608.4	.164E+01	1.52	10.86	1.52	.00
150.72	.00	.00	614.0	.163E+01	1.53	10.89	1.53	.00
152.02	.00	.00	619.7	.161E+01	1.54	10.93	1.54	.00
153.33	.00	.00	625.4	.160E+01	1.55	10.96	1.55	.00
154.63	.00	.00	631.2	.158E+01	1.56	11.00	1.56	.00
155.94	.00	.00	637.1	.157E+01	1.57	11.04	1.57	.00
157.24	.00	.00	643.0	.156E+01	1.58	11.07	1.58	.00
158.54	.00	.00	649.0	.154E+01	1.59	11.11	1.59	.00
159.85	.00	.00	655.1	.153E+01	1.60	11.14	1.60	.00

161.15	.00	.00	661.2	.151E+01	1.61	11.18	1.61	.00
162.46	.00	.00	667.5	.150E+01	1.62	11.21	1.62	.00
163.76	.00	.00	673.7	.148E+01	1.63	11.25	1.63	.00
165.07	.00	.00	680.1	.147E+01	1.64	11.28	1.64	.00
166.37	.00	.00	686.5	.146E+01	1.65	11.32	1.65	.00
167.68	.00	.00	693.0	.144E+01	1.66	11.35	1.66	.00
168.98	.00	.00	699.5	.143E+01	1.67	11.39	1.67	.00
170.28	.00	.00	706.2	.142E+01	1.68	11.42	1.68	.00
171.59	.00	.00	712.9	.140E+01	1.69	11.46	1.69	.00
172.89	.00	.00	719.6	.139E+01	1.70	11.49	1.70	.00
174.20	.00	.00	726.5	.138E+01	1.71	11.53	1.71	.00
175.50	.00	.00	733.4	.136E+01	1.72	11.56	1.72	.00
176.81	.00	.00	740.4	.135E+01	1.73	11.60	1.73	.00
178.11	.00	.00	747.5	.134E+01	1.75	11.63	1.75	.00
179.41	.00	.00	754.7	.133E+01	1.76	11.66	1.76	.00
180.72	.00	.00	762.0	.131E+01	1.77	11.70	1.77	.00
182.02	.00	.00	769.3	.130E+01	1.78	11.73	1.78	.00
183.33	.00	.00	776.7	.129E+01	1.79	11.77	1.79	.00
184.63	.00	.00	784.2	.128E+01	1.81	11.80	1.81	.00

Cumulative travel time = 749. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
184.63	11.80	.00	784.2	.128E+01	1.81	23.60	1.81	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 193.20 m.

204.94	11.80	.00	882.2	.113E+01	2.01	23.71	2.01	.00
225.25	11.80	.00	976.6	.102E+01	2.24	23.71	2.24	.00
245.55	11.80	.00	1086.9	.920E+00	2.49	23.71	2.49	.00
265.86	11.80	.00	1206.4	.829E+00	2.76	23.71	2.76	.00
286.17	11.80	.00	1333.5	.750E+00	3.06	23.71	3.06	.00
306.48	11.80	.00	1466.5	.682E+00	3.36	23.71	3.36	.00
326.78	11.80	.00	1603.3	.624E+00	3.67	23.71	3.67	.00
347.09	11.80	.00	1742.4	.574E+00	3.99	23.71	3.99	.00
367.40	11.80	.00	1882.2	.531E+00	4.31	23.71	4.31	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

387.71	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

408.01	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
428.32	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
448.63	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
468.94	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00

MAC5-1N1.CX1

489.24	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
509.55	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
529.86	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
550.16	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
570.47	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
590.78	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
611.09	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
631.39	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
651.70	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
672.01	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
692.32	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
712.62	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
732.93	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
753.24	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
773.55	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
793.85	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
814.16	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
834.47	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
854.78	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
875.08	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
895.39	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
915.70	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
936.00	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
956.31	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
976.62	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
996.93	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1017.23	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1037.54	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1057.85	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1078.16	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1098.46	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1118.77	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1139.08	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1159.39	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1179.69	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1200.00	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00

Cumulative travel time = 4990. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

11111111111111111111111111111111111111111111111111111111111111111111111111111111

MAC5-1X1.CX1

CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111

CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:
Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION
Site name/label: MACH^BIG^MUDDY^RIVER
Design case: CASE^5^-^PORT^1^-^MAXIMUM^FLOW
FILE NAME: cormix\sim\MAC5-1X1.cx1
Time of Fortran run: 01/09/20--13:28:45

ENVIRONMENT PARAMETERS (metric units)
Bounded section
BS = 23.71 AS = 107.64 QA = 84.50 ICHREG= 2
HA = 4.54 HD = 4.54
UA = .785 F = .058 USTAR = .6688E-01
UW = 2.000 UWSTAR= .2198E-02
Uniform density environment
STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)
BANK = LEFT DISTB = 11.80
D0 = .076 A0 = .005 H0 = .56
THETA = 30.00 SIGMA = .00
U0 = 5.487 Q0 = .025 = .2489E-01
RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00
C0 = .1000E+04 CUNITS= PPM
IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)
Q0 = .2489E-01 M0 = .1366E+00 J0 =-.3643E-02 SIGNJ0= -1.0
Associated length scales (meters)
LQ = .07 LM = 3.72 Lm = .47 Lb = .01
Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS
FR0 = 52.02 R = 6.98

FLOW CLASSIFICATION
1111111111111111111111111111111111111111
1 Flow class (CORMIX1) = NH4 1
1 Applicable layer depth HS = 4.54 1
1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1000E+04 CUNITS= PPM

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .56     1.0  .100E+04     .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     27.38  SIGMAE=       .00
  LE    =       .29  XE    =       .26  YE    =       .00  ZE    =       .70

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .56     1.0  .100E+04     .04
      .26      .00      .70     1.0  .100E+04     .04
      .95      .00      .96     3.5  .282E+03     .12
     1.67      .00     1.11     6.3  .160E+03     .17
     2.40      .00     1.22     8.7  .115E+03     .21
     3.14      .00     1.29    10.9  .919E+02     .25
     3.88      .00     1.35    12.8  .779E+02     .27
     4.62      .00     1.40    14.6  .685E+02     .29
     5.35      .00     1.44    16.2  .618E+02     .31
     6.09      .00     1.47    17.6  .567E+02     .33
     6.83      .00     1.49    19.0  .528E+02     .34
     7.57      .00     1.51    20.2  .496E+02     .35
     8.31      .00     1.53    21.2  .471E+02     .36
     9.05      .00     1.54    22.2  .450E+02     .37
     9.79      .00     1.55    23.1  .433E+02     .38
```

10.53	.00	1.55	23.9	.419E+02	.39

Maximum jet height has been reached.

11.27	.00	1.55	24.6	.407E+02	.39
12.01	.00	1.55	25.3	.396E+02	.40
12.75	.00	1.55	26.0	.384E+02	.41
13.49	.00	1.54	26.9	.372E+02	.41
14.23	.00	1.53	27.8	.360E+02	.42
14.97	.00	1.52	28.8	.348E+02	.43
15.71	.00	1.51	29.8	.336E+02	.44
16.45	.00	1.49	30.9	.324E+02	.44
17.19	.00	1.47	32.0	.312E+02	.45
17.94	.00	1.45	33.3	.301E+02	.46
18.67	.00	1.43	34.5	.290E+02	.47
19.41	.00	1.41	35.8	.279E+02	.48
20.15	.00	1.39	37.2	.269E+02	.49
20.89	.00	1.36	38.6	.259E+02	.50
21.63	.00	1.34	40.0	.250E+02	.51
22.37	.00	1.31	41.5	.241E+02	.52
23.11	.00	1.29	43.0	.232E+02	.53
23.85	.00	1.26	44.6	.224E+02	.54
24.59	.00	1.23	46.2	.217E+02	.55
25.33	.00	1.20	47.8	.209E+02	.56
26.07	.00	1.18	49.4	.202E+02	.57
26.81	.00	1.15	51.1	.196E+02	.58
27.55	.00	1.12	52.8	.189E+02	.59
28.29	.00	1.09	54.6	.183E+02	.60
29.03	.00	1.06	56.3	.178E+02	.61
29.77	.00	1.03	58.1	.172E+02	.62
30.51	.00	1.00	59.9	.167E+02	.63
31.24	.00	.97	61.7	.162E+02	.64
31.99	.00	.94	63.6	.157E+02	.65
32.73	.00	.91	65.5	.153E+02	.66
33.46	.00	.88	67.4	.148E+02	.67
34.20	.00	.84	69.3	.144E+02	.68
34.95	.00	.81	71.2	.140E+02	.69
35.68	.00	.78	73.2	.137E+02	.70
36.42	.00	.75	75.1	.133E+02	.71
37.16	.00	.72	77.1	.130E+02	.72

Cumulative travel time = 37. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
37.16	.00	.72	77.1	.130E+02	.72

MAC5-1X1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
36.44	.00	.00	77.1	.130E+02	.00	.00	.00	.00
36.66	.00	.00	77.1	.130E+02	.91	.46	.91	.00
36.87	.00	.00	77.1	.130E+02	1.07	.64	1.07	.00
37.09	.00	.00	77.1	.130E+02	1.18	.79	1.18	.00
37.31	.00	.00	79.2	.126E+02	1.26	.91	1.26	.00
37.52	.00	.00	89.1	.112E+02	1.32	1.02	1.32	.00
37.74	.00	.00	102.6	.974E+01	1.37	1.12	1.37	.00
37.95	.00	.00	115.0	.869E+01	1.40	1.21	1.40	.00
38.17	.00	.00	123.5	.810E+01	1.42	1.29	1.42	.00
38.39	.00	.00	128.1	.781E+01	1.44	1.37	1.44	.00
38.60	.00	.00	131.1	.763E+01	1.44	1.44	1.44	.00

Cumulative travel time = 39. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Discharge is non-buoyant or weakly buoyant.
Therefore BUOYANT SPREADING REGIME is ABSENT.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .607E-01 m^2/s
Horizontal diffusivity (initial value) = .152E+00 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution

MAC5-1X1.CX1

C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
38.60	.00	.00	131.1	.763E+01	1.44	1.44	1.44	.00
43.12	.00	.00	213.7	.468E+01	1.54	2.20	1.54	.00
47.63	.00	.00	290.5	.344E+01	1.67	2.75	1.67	.00
52.15	.00	.00	369.9	.270E+01	1.83	3.21	1.83	.00
56.66	.00	.00	453.4	.221E+01	1.99	3.61	1.99	.00
61.18	.00	.00	541.2	.185E+01	2.16	3.97	2.16	.00
65.69	.00	.00	632.6	.158E+01	2.33	4.31	2.33	.00
70.21	.00	.00	726.9	.138E+01	2.50	4.61	2.50	.00
74.72	.00	.00	823.7	.121E+01	2.66	4.90	2.66	.00
79.24	.00	.00	922.4	.108E+01	2.83	5.17	2.83	.00
83.75	.00	.00	1022.6	.978E+00	2.98	5.43	2.98	.00
88.27	.00	.00	1124.0	.890E+00	3.14	5.68	3.14	.00
92.78	.00	.00	1226.5	.815E+00	3.29	5.92	3.29	.00
97.30	.00	.00	1329.8	.752E+00	3.43	6.14	3.43	.00
101.81	.00	.00	1433.8	.697E+00	3.57	6.36	3.57	.00
106.33	.00	.00	1538.3	.650E+00	3.71	6.57	3.71	.00
110.84	.00	.00	1643.4	.609E+00	3.84	6.78	3.84	.00
115.36	.00	.00	1748.8	.572E+00	3.97	6.98	3.97	.00
119.88	.00	.00	1854.6	.539E+00	4.10	7.17	4.10	.00
124.39	.00	.00	1960.7	.510E+00	4.22	7.36	4.22	.00
128.91	.00	.00	2067.1	.484E+00	4.34	7.55	4.34	.00
133.42	.00	.00	2173.7	.460E+00	4.46	7.73	4.46	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

137.94	.00	.00	2262.8	.442E+00	4.54	7.90	4.54	.00
142.45	.00	.00	2312.0	.433E+00	4.54	8.07	4.54	.00
146.97	.00	.00	2360.1	.424E+00	4.54	8.24	4.54	.00
151.48	.00	.00	2407.3	.415E+00	4.54	8.41	4.54	.00
156.00	.00	.00	2453.6	.408E+00	4.54	8.57	4.54	.00
160.51	.00	.00	2499.0	.400E+00	4.54	8.73	4.54	.00
165.03	.00	.00	2543.6	.393E+00	4.54	8.88	4.54	.00
169.54	.00	.00	2587.5	.386E+00	4.54	9.04	4.54	.00
174.06	.00	.00	2630.6	.380E+00	4.54	9.19	4.54	.00
178.57	.00	.00	2673.0	.374E+00	4.54	9.33	4.54	.00
183.09	.00	.00	2714.8	.368E+00	4.54	9.48	4.54	.00
187.60	.00	.00	2755.9	.363E+00	4.54	9.62	4.54	.00
192.12	.00	.00	2796.4	.358E+00	4.54	9.76	4.54	.00
196.63	.00	.00	2836.4	.353E+00	4.54	9.90	4.54	.00
201.15	.00	.00	2875.8	.348E+00	4.54	10.04	4.54	.00
205.66	.00	.00	2914.6	.343E+00	4.54	10.18	4.54	.00
210.18	.00	.00	2953.0	.339E+00	4.54	10.31	4.54	.00
214.69	.00	.00	2990.8	.334E+00	4.54	10.44	4.54	.00
219.21	.00	.00	3028.2	.330E+00	4.54	10.57	4.54	.00

MAC5-1X1.CX1

223.72	.00	.00	3065.1	.326E+00	4.54	10.70	4.54	.00
228.24	.00	.00	3101.6	.322E+00	4.54	10.83	4.54	.00
232.75	.00	.00	3137.7	.319E+00	4.54	10.96	4.54	.00
237.27	.00	.00	3173.3	.315E+00	4.54	11.08	4.54	.00
241.78	.00	.00	3208.6	.312E+00	4.54	11.20	4.54	.00
246.30	.00	.00	3243.4	.308E+00	4.54	11.33	4.54	.00
250.81	.00	.00	3277.9	.305E+00	4.54	11.45	4.54	.00
255.33	.00	.00	3312.1	.302E+00	4.54	11.57	4.54	.00
259.84	.00	.00	3345.9	.299E+00	4.54	11.68	4.54	.00
264.36	.00	.00	3379.3	.296E+00	4.54	11.80	4.54	.00

Cumulative travel time = 327. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
264.36	11.80	.00	3379.3	.296E+00	4.54	23.60	4.54	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 272.92 m.

283.07	11.80	.00	3413.6	.293E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

301.78	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
320.50	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
339.21	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
357.92	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
376.63	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
395.35	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
414.06	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
432.77	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
451.49	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
470.20	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
488.91	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
507.62	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
526.34	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
545.05	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
563.76	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
582.48	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
601.19	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
619.90	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
638.61	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
657.33	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
676.04	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
694.75	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
713.47	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
732.18	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
750.89	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00

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769.60	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
788.32	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
807.03	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
825.74	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
844.46	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
863.17	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
881.88	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
900.59	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
919.31	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
938.02	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
956.73	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
975.45	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
994.16	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1012.87	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1031.58	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1050.30	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1069.01	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1087.72	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1106.44	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1125.15	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1143.86	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1162.57	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1181.29	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1200.00	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00

Cumulative travel time = 1518. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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MAC5-3N1.CX1

CORMIX1 PREDICTION FILE:
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CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:
Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION
Site name/label: MACH^BIG^MUDDY^RIVER
Design case: CASE^5^-^PORT^3^-^NORMAL^FLOW
FILE NAME: cormix\sim\MAC5-3N1.cx1
Time of Fortran run: 01/09/20--13:06:58

ENVIRONMENT PARAMETERS (metric units)
Bounded section
BS = 23.71 AS = 107.64 QA = 25.76 ICHREG= 2
HA = 4.54 HD = 4.54
UA = .239 F = .058 USTAR = .2039E-01
UW = 2.000 UWSTAR= .2198E-02
Uniform density environment
STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)
BANK = LEFT DISTB = 11.80
D0 = .102 A0 = .008 H0 = .55
THETA = 30.00 SIGMA = .00
U0 = 2.866 Q0 = .023 = .2342E-01
RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00
C0 = .1000E+04 CUNITS= PPM
IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)
Q0 = .2342E-01 M0 = .6712E-01 J0 =-.3427E-02 SIGNJ0= -1.0
Associated length scales (meters)
LQ = .09 LM = 2.25 Lm = 1.08 Lb = .25
Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS
FR0 = 23.45 R = 11.97

FLOW CLASSIFICATION
1111111111111111111111111111111111111111111
1 Flow class (CORMIX1) = NH4 1
1 Applicable layer depth HS = 4.54 1
1111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1000E+04 CUNITS= PPM

```
 NTOX  =  0
 NSTD  =  0
 REGMZ =  0
 XINT  =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .55      1.0  .100E+04     .05

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.47  SIGMAE=       .00
  LE    =       .44  XE    =       .39  YE    =       .00  ZE    =       .77

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .55      1.0  .100E+04     .05
      .39      .00      .77      1.0  .100E+04     .05
      .57      .00      .86      1.3  .754E+03     .08
      .75      .00      .95      1.8  .554E+03     .10
      .94      .00     1.03      2.3  .434E+03     .12
     1.14      .00     1.10      2.8  .355E+03     .15
     1.33      .00     1.17      3.3  .299E+03     .17
     1.53      .00     1.23      3.9  .259E+03     .19
     1.74      .00     1.29      4.4  .227E+03     .21
     1.94      .00     1.33      4.9  .203E+03     .23
     2.14      .00     1.38      5.4  .185E+03     .25
     2.34      .00     1.42      5.9  .170E+03     .26
     2.54      .00     1.45      6.4  .157E+03     .28
     2.74      .00     1.48      6.8  .147E+03     .29
     2.96      .00     1.50      7.2  .138E+03     .30
```

3.16	.00	1.53	7.6	.131E+03	.31
3.37	.00	1.54	8.0	.125E+03	.33
3.57	.00	1.56	8.4	.120E+03	.34
3.78	.00	1.57	8.7	.115E+03	.34
3.99	.00	1.57	9.0	.111E+03	.35
4.20	.00	1.58	9.3	.108E+03	.36

Maximum jet height has been reached.

4.41	.00	1.58	9.5	.105E+03	.37
4.61	.00	1.58	9.8	.102E+03	.37
4.82	.00	1.57	10.1	.994E+02	.38
5.02	.00	1.56	10.4	.964E+02	.39
5.23	.00	1.55	10.7	.934E+02	.40
5.45	.00	1.54	11.1	.902E+02	.40
5.65	.00	1.52	11.5	.871E+02	.41
5.86	.00	1.50	11.9	.841E+02	.42
6.06	.00	1.48	12.3	.812E+02	.43
6.27	.00	1.46	12.8	.783E+02	.44
6.47	.00	1.44	13.3	.754E+02	.45
6.67	.00	1.41	13.8	.727E+02	.46
6.89	.00	1.38	14.3	.698E+02	.48
7.09	.00	1.35	14.9	.673E+02	.49
7.29	.00	1.32	15.4	.648E+02	.50
7.50	.00	1.29	16.0	.624E+02	.51
7.70	.00	1.25	16.6	.601E+02	.52
7.90	.00	1.22	17.3	.579E+02	.53
8.12	.00	1.18	18.0	.556E+02	.55
8.32	.00	1.14	18.6	.536E+02	.56
8.52	.00	1.11	19.3	.517E+02	.57
8.72	.00	1.07	20.1	.499E+02	.58
8.93	.00	1.03	20.8	.481E+02	.59
9.13	.00	.99	21.5	.464E+02	.61
9.34	.00	.95	22.3	.448E+02	.62
9.54	.00	.91	23.1	.432E+02	.63
9.74	.00	.87	23.9	.418E+02	.65
9.94	.00	.82	24.7	.404E+02	.66
10.15	.00	.78	25.6	.391E+02	.67
10.35	.00	.74	26.4	.378E+02	.68
10.56	.00	.70	27.3	.366E+02	.70

Cumulative travel time = 19. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
10.56	.00	.70	27.3	.366E+02	.70

MAC5-3N1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
9.86	.00	.00	27.3	.366E+02	.00	.00	.00	.00
10.07	.00	.00	27.3	.366E+02	.95	.48	.95	.00
10.28	.00	.00	27.3	.366E+02	1.12	.67	1.12	.00
10.49	.00	.00	27.3	.366E+02	1.24	.83	1.24	.00
10.70	.00	.00	28.0	.357E+02	1.32	.95	1.32	.00
10.91	.00	.00	31.5	.317E+02	1.38	1.07	1.38	.00
11.12	.00	.00	36.3	.275E+02	1.43	1.17	1.43	.00
11.33	.00	.00	40.7	.246E+02	1.46	1.26	1.46	.00
11.53	.00	.00	43.7	.229E+02	1.49	1.35	1.49	.00
11.74	.00	.00	45.3	.221E+02	1.50	1.43	1.50	.00
11.95	.00	.00	46.4	.216E+02	1.51	1.51	1.51	.00

Cumulative travel time = 25. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
11.95	.00	.00	46.4	.216E+02	1.51	1.51	1.51	.00
14.02	.00	.00	49.3	.203E+02	1.27	1.90	1.27	.00
16.09	.00	.00	51.7	.193E+02	1.12	2.26	1.12	.00
18.17	.00	.00	53.8	.186E+02	1.02	2.59	1.02	.00
20.24	.00	.00	55.7	.179E+02	.94	2.91	.94	.00
22.31	.00	.00	57.6	.174E+02	.88	3.20	.88	.00
24.38	.00	.00	59.3	.169E+02	.83	3.48	.83	.00
26.45	.00	.00	61.1	.164E+02	.80	3.76	.80	.00
28.52	.00	.00	62.9	.159E+02	.77	4.02	.77	.00

MAC5-3N1.CX1

30.59	.00	.00	64.7	.155E+02	.74	4.27	.74	.00
32.67	.00	.00	66.5	.150E+02	.72	4.52	.72	.00
34.74	.00	.00	68.4	.146E+02	.70	4.76	.70	.00
36.81	.00	.00	70.4	.142E+02	.69	4.99	.69	.00
38.88	.00	.00	72.5	.138E+02	.68	5.22	.68	.00
40.95	.00	.00	74.6	.134E+02	.67	5.44	.67	.00
43.02	.00	.00	76.9	.130E+02	.66	5.66	.66	.00
45.09	.00	.00	79.2	.126E+02	.66	5.88	.66	.00
47.17	.00	.00	81.6	.123E+02	.66	6.09	.66	.00
49.24	.00	.00	84.2	.119E+02	.65	6.30	.65	.00
51.31	.00	.00	86.8	.115E+02	.65	6.50	.65	.00
53.38	.00	.00	89.6	.112E+02	.65	6.70	.65	.00
55.45	.00	.00	92.5	.108E+02	.66	6.90	.66	.00
57.52	.00	.00	95.5	.105E+02	.66	7.09	.66	.00
59.59	.00	.00	98.7	.101E+02	.66	7.28	.66	.00
61.67	.00	.00	101.9	.981E+01	.67	7.47	.67	.00
63.74	.00	.00	105.3	.949E+01	.67	7.66	.67	.00
65.81	.00	.00	108.9	.918E+01	.68	7.85	.68	.00
67.88	.00	.00	112.6	.888E+01	.69	8.03	.69	.00
69.95	.00	.00	116.4	.859E+01	.69	8.21	.69	.00
72.02	.00	.00	120.3	.831E+01	.70	8.39	.70	.00
74.09	.00	.00	124.4	.804E+01	.71	8.57	.71	.00
76.16	.00	.00	128.7	.777E+01	.72	8.74	.72	.00
78.24	.00	.00	133.1	.751E+01	.73	8.92	.73	.00
80.31	.00	.00	137.7	.726E+01	.74	9.09	.74	.00
82.38	.00	.00	142.4	.702E+01	.75	9.26	.75	.00
84.45	.00	.00	147.2	.679E+01	.76	9.43	.76	.00
86.52	.00	.00	152.3	.657E+01	.78	9.59	.78	.00
88.59	.00	.00	157.4	.635E+01	.79	9.76	.79	.00
90.66	.00	.00	162.8	.614E+01	.80	9.92	.80	.00
92.74	.00	.00	168.3	.594E+01	.82	10.09	.82	.00
94.81	.00	.00	173.9	.575E+01	.83	10.25	.83	.00
96.88	.00	.00	179.8	.556E+01	.85	10.41	.85	.00
98.95	.00	.00	185.8	.538E+01	.86	10.57	.86	.00
101.02	.00	.00	192.0	.521E+01	.88	10.73	.88	.00
103.09	.00	.00	198.3	.504E+01	.89	10.88	.89	.00
105.16	.00	.00	204.8	.488E+01	.91	11.04	.91	.00
107.24	.00	.00	211.5	.473E+01	.92	11.19	.92	.00
109.31	.00	.00	218.3	.458E+01	.94	11.35	.94	.00
111.38	.00	.00	225.4	.444E+01	.96	11.50	.96	.00
113.45	.00	.00	232.6	.430E+01	.98	11.65	.98	.00
115.52	.00	.00	240.0	.417E+01	1.00	11.80	1.00	.00

Cumulative travel time = 457. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

MAC5-3N1.CX1

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
115.52	11.80	.00	240.0	.417E+01	1.00	23.60	1.00	.00
115.55	11.80	.00	240.1	.417E+01	1.00	23.60	1.00	.00
115.58	11.80	.00	240.2	.416E+01	1.00	23.60	1.00	.00
115.61	11.80	.00	240.3	.416E+01	1.00	23.61	1.00	.00
115.64	11.80	.00	240.4	.416E+01	1.00	23.61	1.00	.00
115.67	11.80	.00	240.5	.416E+01	1.00	23.61	1.00	.00
115.70	11.80	.00	240.6	.416E+01	1.00	23.61	1.00	.00
115.74	11.80	.00	240.7	.415E+01	1.00	23.62	1.00	.00
115.77	11.80	.00	240.8	.415E+01	1.00	23.62	1.00	.00
115.80	11.80	.00	240.9	.415E+01	1.00	23.62	1.00	.00
115.83	11.80	.00	241.0	.415E+01	1.00	23.62	1.00	.00
115.86	11.80	.00	241.1	.415E+01	1.00	23.62	1.00	.00
115.89	11.80	.00	241.2	.415E+01	1.00	23.63	1.00	.00
115.92	11.80	.00	241.3	.414E+01	1.00	23.63	1.00	.00
115.95	11.80	.00	241.5	.414E+01	1.00	23.63	1.00	.00
115.98	11.80	.00	241.6	.414E+01	1.00	23.63	1.00	.00
116.01	11.80	.00	241.7	.414E+01	1.00	23.64	1.00	.00
116.04	11.80	.00	241.8	.414E+01	1.00	23.64	1.00	.00
116.07	11.80	.00	241.9	.413E+01	1.00	23.64	1.00	.00
116.10	11.80	.00	242.0	.413E+01	1.00	23.64	1.00	.00
116.13	11.80	.00	242.1	.413E+01	1.00	23.64	1.00	.00
116.16	11.80	.00	242.2	.413E+01	1.00	23.65	1.00	.00
116.19	11.80	.00	242.3	.413E+01	1.00	23.65	1.00	.00
116.22	11.80	.00	242.4	.413E+01	1.00	23.65	1.00	.00
116.26	11.80	.00	242.5	.412E+01	1.00	23.65	1.00	.00
116.29	11.80	.00	242.6	.412E+01	1.00	23.66	1.00	.00
116.32	11.80	.00	242.7	.412E+01	1.00	23.66	1.00	.00
116.35	11.80	.00	242.8	.412E+01	1.00	23.66	1.00	.00
116.38	11.80	.00	242.9	.412E+01	1.00	23.66	1.00	.00
116.41	11.80	.00	243.0	.411E+01	1.01	23.66	1.01	.00
116.44	11.80	.00	243.1	.411E+01	1.01	23.67	1.01	.00
116.47	11.80	.00	243.2	.411E+01	1.01	23.67	1.01	.00
116.50	11.80	.00	243.3	.411E+01	1.01	23.67	1.01	.00
116.53	11.80	.00	243.5	.411E+01	1.01	23.67	1.01	.00
116.56	11.80	.00	243.6	.411E+01	1.01	23.67	1.01	.00
116.59	11.80	.00	243.7	.410E+01	1.01	23.68	1.01	.00
116.62	11.80	.00	243.8	.410E+01	1.01	23.68	1.01	.00
116.65	11.80	.00	243.9	.410E+01	1.01	23.68	1.01	.00
116.68	11.80	.00	244.0	.410E+01	1.01	23.68	1.01	.00
116.71	11.80	.00	244.1	.410E+01	1.01	23.69	1.01	.00
116.75	11.80	.00	244.2	.410E+01	1.01	23.69	1.01	.00
116.78	11.80	.00	244.3	.409E+01	1.01	23.69	1.01	.00
116.81	11.80	.00	244.4	.409E+01	1.01	23.69	1.01	.00
116.84	11.80	.00	244.5	.409E+01	1.01	23.69	1.01	.00
116.87	11.80	.00	244.6	.409E+01	1.01	23.70	1.01	.00
116.90	11.80	.00	244.7	.409E+01	1.01	23.70	1.01	.00

116.93	11.80	.00	244.8	.408E+01	1.01	23.70	1.01	.00
116.96	11.80	.00	244.9	.408E+01	1.01	23.70	1.01	.00
116.99	11.80	.00	245.0	.408E+01	1.01	23.71	1.01	.00
117.02	11.80	.00	245.1	.408E+01	1.01	23.71	1.01	.00
117.05	11.80	.00	245.3	.408E+01	1.01	23.71	1.01	.00

Cumulative travel time = 464. sec
Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .185E-01 m^2/s
Horizontal diffusivity (initial value) = .463E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
117.05	11.80	.00	245.3	.408E+01	1.01	23.71	1.01	.00
138.71	11.80	.00	254.9	.392E+01	1.05	23.71	1.05	.00
160.37	11.80	.00	265.4	.377E+01	1.10	23.71	1.10	.00
182.03	11.80	.00	276.5	.362E+01	1.14	23.71	1.14	.00
203.69	11.80	.00	288.6	.347E+01	1.19	23.71	1.19	.00
225.35	11.80	.00	301.6	.332E+01	1.24	23.71	1.24	.00
247.00	11.80	.00	315.7	.317E+01	1.30	23.71	1.30	.00
268.66	11.80	.00	330.9	.302E+01	1.37	23.71	1.37	.00
290.32	11.80	.00	347.4	.288E+01	1.43	23.71	1.43	.00
311.98	11.80	.00	365.3	.274E+01	1.51	23.71	1.51	.00
333.64	11.80	.00	384.8	.260E+01	1.59	23.71	1.59	.00
355.30	11.80	.00	405.9	.246E+01	1.68	23.71	1.68	.00
376.96	11.80	.00	428.9	.233E+01	1.77	23.71	1.77	.00
398.62	11.80	.00	454.0	.220E+01	1.87	23.71	1.87	.00
420.28	11.80	.00	481.2	.208E+01	1.99	23.71	1.99	.00
441.94	11.80	.00	510.8	.196E+01	2.11	23.71	2.11	.00
463.59	11.80	.00	542.9	.184E+01	2.24	23.71	2.24	.00
485.25	11.80	.00	577.6	.173E+01	2.38	23.71	2.38	.00
506.91	11.80	.00	615.1	.163E+01	2.54	23.71	2.54	.00
528.57	11.80	.00	655.3	.153E+01	2.70	23.71	2.70	.00

550.23	11.80	.00	698.3	.143E+01	2.88	23.71	2.88	.00
571.89	11.80	.00	744.0	.134E+01	3.07	23.71	3.07	.00
593.55	11.80	.00	792.4	.126E+01	3.27	23.71	3.27	.00
615.21	11.80	.00	843.2	.119E+01	3.48	23.71	3.48	.00
636.87	11.80	.00	896.3	.112E+01	3.70	23.71	3.70	.00
658.53	11.80	.00	951.4	.105E+01	3.93	23.71	3.93	.00
680.18	11.80	.00	1008.2	.992E+00	4.16	23.71	4.16	.00
701.84	11.80	.00	1066.5	.938E+00	4.40	23.71	4.40	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

723.50	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

745.16	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
766.82	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
788.48	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
810.14	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
831.80	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
853.46	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
875.12	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
896.77	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
918.43	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
940.09	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
961.75	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
983.41	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
1005.07	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
1026.73	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
1048.39	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
1070.05	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
1091.71	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
1113.36	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
1135.02	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
1156.68	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
1178.34	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00
1200.00	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00

Cumulative travel time = 4985. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111

MAC5-3X1.CX1

CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111

CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:
Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION
Site name/label: MACH^BIG^MUDDY^RIVER
Design case: CASE^5^-^PORT^3^-^MAXIMUM^FLOW
FILE NAME: cormix\sim\MAC5-3X1.cx1
Time of Fortran run: 01/09/20--13:34:43

ENVIRONMENT PARAMETERS (metric units)
Bounded section
BS = 23.71 AS = 107.64 QA = 84.50 ICHREG= 2
HA = 4.54 HD = 4.54
UA = .785 F = .058 USTAR = .6688E-01
UW = 2.000 UWSTAR= .2198E-02
Uniform density environment
STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)
BANK = LEFT DISTB = 11.80
D0 = .102 A0 = .008 H0 = .55
THETA = 30.00 SIGMA = .00
U0 = 5.487 Q0 = .045 = .4483E-01
RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00
C0 = .1000E+04 CUNITS= PPM
IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)
Q0 = .4483E-01 M0 = .2460E+00 J0 =-.6561E-02 SIGNJ0= -1.0
Associated length scales (meters)
LQ = .09 LM = 4.31 Lm = .63 Lb = .01
Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS
FR0 = 44.91 R = 6.98

FLOW CLASSIFICATION
1111111111111111111111111111111111111111
1 Flow class (CORMIX1) = NH4 1
1 Applicable layer depth HS = 4.54 1
1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1000E+04 CUNITS= PPM

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .55     1.0  .100E+04     .05

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     27.38  SIGMAE=       .00
  LE    =       .39  XE    =       .34  YE    =       .00  ZE    =       .74

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .55      1.0  .100E+04     .05
      .34      .00      .74      1.0  .100E+04     .05
     1.02      .00     1.01      2.8  .355E+03     .13
     1.73      .00     1.19      4.9  .206E+03     .20
     2.45      .00     1.32      6.8  .148E+03     .25
     3.18      .00     1.42      8.5  .117E+03     .28
     3.91      .00     1.49     10.1  .988E+02     .32
     4.64      .00     1.55     11.6  .864E+02     .34
     5.37      .00     1.60     12.9  .775E+02     .37
     6.10      .00     1.65     14.1  .708E+02     .38
     6.84      .00     1.68     15.2  .656E+02     .40
     7.57      .00     1.71     16.3  .615E+02     .42
     8.31      .00     1.73     17.2  .581E+02     .43
     9.04      .00     1.75     18.1  .554E+02     .44
     9.77      .00     1.76     18.8  .531E+02     .45
```

10.51	.00	1.77	19.5	.512E+02	.46
11.24	.00	1.78	20.2	.496E+02	.47
11.97	.00	1.78	20.7	.482E+02	.48

Maximum jet height has been reached.

12.71	.00	1.78	21.3	.470E+02	.49
13.44	.00	1.77	21.9	.458E+02	.49
14.18	.00	1.77	22.5	.444E+02	.50
14.91	.00	1.76	23.2	.431E+02	.51
15.64	.00	1.74	23.9	.418E+02	.52
16.37	.00	1.73	24.7	.404E+02	.53
17.11	.00	1.71	25.6	.391E+02	.54
17.84	.00	1.69	26.5	.378E+02	.55
18.58	.00	1.67	27.4	.365E+02	.56
19.31	.00	1.65	28.4	.352E+02	.57
20.04	.00	1.62	29.4	.340E+02	.58
20.78	.00	1.60	30.5	.328E+02	.59
21.51	.00	1.57	31.5	.317E+02	.60
22.24	.00	1.54	32.7	.306E+02	.62
22.97	.00	1.51	33.8	.296E+02	.63
23.71	.00	1.48	35.0	.286E+02	.64
24.44	.00	1.45	36.2	.276E+02	.65
25.18	.00	1.42	37.5	.267E+02	.66
25.91	.00	1.39	38.8	.258E+02	.67
26.64	.00	1.35	40.1	.250E+02	.69
27.37	.00	1.32	41.4	.242E+02	.70
28.11	.00	1.29	42.7	.234E+02	.71
28.84	.00	1.25	44.1	.227E+02	.72
29.57	.00	1.22	45.5	.220E+02	.73
30.30	.00	1.18	46.9	.213E+02	.75
31.03	.00	1.14	48.4	.207E+02	.76
31.77	.00	1.11	49.8	.201E+02	.77
32.50	.00	1.07	51.3	.195E+02	.78
33.24	.00	1.04	52.8	.189E+02	.79
33.97	.00	1.00	54.3	.184E+02	.81
34.70	.00	.96	55.8	.179E+02	.82
35.43	.00	.93	57.4	.174E+02	.83
36.16	.00	.89	58.9	.170E+02	.84
36.90	.00	.85	60.5	.165E+02	.85

Cumulative travel time = 35. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
36.90	.00	.85	60.5	.165E+02	.85

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
36.05	.00	.00	60.5	.165E+02	.00	.00	.00	.00
36.31	.00	.00	60.5	.165E+02	1.08	.54	1.08	.00
36.56	.00	.00	60.5	.165E+02	1.28	.77	1.28	.00
36.82	.00	.00	60.5	.165E+02	1.41	.94	1.41	.00
37.07	.00	.00	62.2	.161E+02	1.50	1.08	1.50	.00
37.33	.00	.00	69.9	.143E+02	1.57	1.21	1.57	.00
37.58	.00	.00	80.5	.124E+02	1.63	1.33	1.63	.00
37.84	.00	.00	90.2	.111E+02	1.66	1.43	1.66	.00
38.10	.00	.00	96.9	.103E+02	1.69	1.53	1.69	.00
38.35	.00	.00	100.5	.995E+01	1.71	1.63	1.71	.00
38.61	.00	.00	102.8	.972E+01	1.71	1.71	1.71	.00

Cumulative travel time = 38. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Discharge is non-buoyant or weakly buoyant.
Therefore BUOYANT SPREADING REGIME is ABSENT.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .607E-01 m^2/s
Horizontal diffusivity (initial value) = .152E+00 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution

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C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
38.61	.00	.00	102.8	.972E+01	1.71	1.71	1.71	.00
43.10	.00	.00	148.9	.671E+01	1.79	2.38	1.79	.00
47.58	.00	.00	190.8	.524E+01	1.88	2.90	1.88	.00
52.07	.00	.00	232.4	.430E+01	1.99	3.33	1.99	.00
56.56	.00	.00	275.1	.363E+01	2.11	3.72	2.11	.00
61.05	.00	.00	319.4	.313E+01	2.24	4.07	2.24	.00
65.54	.00	.00	365.4	.274E+01	2.38	4.39	2.38	.00
70.02	.00	.00	413.0	.242E+01	2.51	4.69	2.51	.00
74.51	.00	.00	462.1	.216E+01	2.65	4.97	2.65	.00
79.00	.00	.00	512.6	.195E+01	2.79	5.24	2.79	.00
83.49	.00	.00	564.2	.177E+01	2.93	5.50	2.93	.00
87.98	.00	.00	616.8	.162E+01	3.07	5.74	3.07	.00
92.46	.00	.00	670.2	.149E+01	3.21	5.97	3.21	.00
96.95	.00	.00	724.4	.138E+01	3.34	6.19	3.34	.00
101.44	.00	.00	779.2	.128E+01	3.47	6.41	3.47	.00
105.93	.00	.00	834.6	.120E+01	3.60	6.62	3.60	.00
110.41	.00	.00	890.4	.112E+01	3.73	6.82	3.73	.00
114.90	.00	.00	946.6	.106E+01	3.85	7.02	3.85	.00
119.39	.00	.00	1003.2	.997E+00	3.97	7.21	3.97	.00
123.88	.00	.00	1060.1	.943E+00	4.09	7.40	4.09	.00
128.37	.00	.00	1117.3	.895E+00	4.21	7.58	4.21	.00
132.85	.00	.00	1174.7	.851E+00	4.32	7.76	4.32	.00
137.34	.00	.00	1232.3	.811E+00	4.44	7.93	4.44	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

141.83	.00	.00	1288.0	.776E+00	4.54	8.10	4.54	.00
146.32	.00	.00	1314.5	.761E+00	4.54	8.27	4.54	.00
150.81	.00	.00	1340.4	.746E+00	4.54	8.43	4.54	.00
155.29	.00	.00	1365.9	.732E+00	4.54	8.59	4.54	.00
159.78	.00	.00	1390.9	.719E+00	4.54	8.75	4.54	.00
164.27	.00	.00	1415.4	.706E+00	4.54	8.90	4.54	.00
168.76	.00	.00	1439.6	.695E+00	4.54	9.05	4.54	.00
173.25	.00	.00	1463.3	.683E+00	4.54	9.20	4.54	.00
177.73	.00	.00	1486.7	.673E+00	4.54	9.35	4.54	.00
182.22	.00	.00	1509.7	.662E+00	4.54	9.50	4.54	.00
186.71	.00	.00	1532.3	.653E+00	4.54	9.64	4.54	.00
191.20	.00	.00	1554.6	.643E+00	4.54	9.78	4.54	.00
195.68	.00	.00	1576.6	.634E+00	4.54	9.92	4.54	.00
200.17	.00	.00	1598.3	.626E+00	4.54	10.05	4.54	.00
204.66	.00	.00	1619.7	.617E+00	4.54	10.19	4.54	.00
209.15	.00	.00	1640.9	.609E+00	4.54	10.32	4.54	.00
213.64	.00	.00	1661.7	.602E+00	4.54	10.45	4.54	.00
218.12	.00	.00	1682.3	.594E+00	4.54	10.58	4.54	.00

222.61	.00	.00	1702.7	.587E+00	4.54	10.71	4.54	.00
227.10	.00	.00	1722.8	.580E+00	4.54	10.84	4.54	.00
231.59	.00	.00	1742.7	.574E+00	4.54	10.96	4.54	.00
236.08	.00	.00	1762.3	.567E+00	4.54	11.09	4.54	.00
240.56	.00	.00	1781.8	.561E+00	4.54	11.21	4.54	.00
245.05	.00	.00	1801.0	.555E+00	4.54	11.33	4.54	.00
249.54	.00	.00	1820.0	.549E+00	4.54	11.45	4.54	.00
254.03	.00	.00	1838.9	.544E+00	4.54	11.57	4.54	.00
258.51	.00	.00	1857.5	.538E+00	4.54	11.68	4.54	.00
263.00	.00	.00	1876.0	.533E+00	4.54	11.80	4.54	.00

Cumulative travel time = 323. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
263.00	11.80	.00	1876.0	.533E+00	4.54	23.60	4.54	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 271.57 m.

281.74	11.80	.00	1895.0	.528E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

300.48	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
319.22	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
337.96	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
356.70	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
375.44	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
394.18	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
412.92	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
431.66	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
450.40	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
469.14	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
487.88	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
506.62	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
525.36	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
544.10	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
562.84	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
581.58	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
600.32	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
619.06	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
637.80	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
656.54	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
675.28	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
694.02	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
712.76	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
731.50	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
750.24	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00

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768.98	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
787.72	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
806.46	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
825.20	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
843.94	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
862.68	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
881.42	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
900.16	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
918.90	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
937.64	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
956.38	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
975.12	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
993.86	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1012.60	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1031.34	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1050.08	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1068.82	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1087.56	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1106.30	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1125.04	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1143.78	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1162.52	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1181.26	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1200.00	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00

Cumulative travel time = 1516. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111

MAC5-4N1.CX1

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:        MACH^BIG^MUDDY^RIVER
 Design case:            CASE^5^-^PORT^4^-^NORMAL^FLOW
 FILE NAME:              cormix\sim\MAC5-4N1.cx1
 Time of Fortran run:    01/09/20--13:02:58

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     25.76  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .239 F     =       .058 USTAR = .2039E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.80
 D0    =       .152 A0    =       .018 H0    =       .53
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .052       = .5200E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .5200E-01  M0    = .1490E+00  J0    =-.7611E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .13  LM    =      2.75  Lm    =      1.61  Lb    =       .56
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     19.21  R     =     11.97

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4   1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
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MAC5-4N1.CX1

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 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1200.00  XMAX   =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

      X        Y        Z        S        C        B
     .00      .00      .53     1.0  .100E+04     .08

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.47  SIGMAE=       .00
  LE    =       .66  XE    =       .57  YE    =       .00  ZE    =       .85

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

      X        Y        Z        S        C        B
     .00      .00      .53     1.0  .100E+04     .08
     .57      .00      .85     1.0  .100E+04     .08
     .76      .00      .94     1.2  .847E+03     .10
     .96      .00     1.04     1.5  .657E+03     .13
    1.15      .00     1.13     1.9  .540E+03     .15
    1.36      .00     1.22     2.2  .452E+03     .18
    1.56      .00     1.29     2.6  .391E+03     .20
    1.77      .00     1.37     2.9  .341E+03     .23
    1.97      .00     1.43     3.3  .305E+03     .25
    2.19      .00     1.49     3.6  .274E+03     .27
    2.39      .00     1.55     4.0  .251E+03     .29
    2.61      .00     1.60     4.3  .230E+03     .31
    2.82      .00     1.64     4.7  .214E+03     .33
    3.04      .00     1.68     5.0  .200E+03     .35
    3.24      .00     1.72     5.3  .188E+03     .36
```

3.47	.00	1.75	5.6	.178E+03	.38
3.69	.00	1.78	5.9	.169E+03	.39
3.90	.00	1.80	6.2	.162E+03	.41
4.13	.00	1.82	6.5	.155E+03	.42
4.34	.00	1.83	6.7	.150E+03	.43
4.56	.00	1.84	6.9	.144E+03	.44
4.77	.00	1.85	7.1	.140E+03	.45
5.00	.00	1.85	7.3	.136E+03	.46

Maximum jet height has been reached.

5.21	.00	1.85	7.5	.133E+03	.47
5.43	.00	1.85	7.7	.129E+03	.47
5.64	.00	1.84	7.9	.126E+03	.48
5.87	.00	1.83	8.2	.122E+03	.49
6.08	.00	1.82	8.4	.119E+03	.50
6.30	.00	1.80	8.7	.115E+03	.51
6.53	.00	1.78	9.0	.111E+03	.52
6.74	.00	1.76	9.3	.108E+03	.54
6.96	.00	1.73	9.6	.104E+03	.55
7.17	.00	1.70	9.9	.101E+03	.56
7.39	.00	1.67	10.3	.971E+02	.57
7.60	.00	1.64	10.7	.938E+02	.59
7.82	.00	1.60	11.1	.904E+02	.60
8.03	.00	1.57	11.4	.874E+02	.61
8.25	.00	1.53	11.9	.842E+02	.63
8.46	.00	1.49	12.3	.813E+02	.64
8.68	.00	1.44	12.8	.784E+02	.66
8.88	.00	1.40	13.2	.757E+02	.67
9.10	.00	1.35	13.7	.730E+02	.69
9.32	.00	1.31	14.2	.703E+02	.70
9.53	.00	1.26	14.7	.680E+02	.72
9.75	.00	1.21	15.3	.656E+02	.73
9.95	.00	1.16	15.8	.634E+02	.75
10.17	.00	1.11	16.3	.612E+02	.76
10.38	.00	1.06	16.9	.592E+02	.78
10.60	.00	1.00	17.5	.572E+02	.79
10.80	.00	.95	18.1	.554E+02	.81
11.02	.00	.90	18.7	.535E+02	.83
11.22	.00	.85	19.3	.519E+02	.84

Cumulative travel time = 17. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
11.22	.00	.85	19.3	.519E+02	.84

MAC5-4N1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.38	.00	.00	19.3	.519E+02	.00	.00	.00	.00
10.63	.00	.00	19.3	.519E+02	1.19	.60	1.19	.00
10.88	.00	.00	19.3	.519E+02	1.41	.84	1.41	.00
11.14	.00	.00	19.3	.519E+02	1.55	1.03	1.55	.00
11.39	.00	.00	19.8	.505E+02	1.65	1.19	1.65	.00
11.64	.00	.00	22.3	.449E+02	1.73	1.33	1.73	.00
11.89	.00	.00	25.6	.390E+02	1.79	1.46	1.79	.00
12.15	.00	.00	28.7	.348E+02	1.83	1.58	1.83	.00
12.40	.00	.00	30.9	.324E+02	1.86	1.69	1.86	.00
12.65	.00	.00	32.0	.312E+02	1.88	1.79	1.88	.00
12.91	.00	.00	32.8	.305E+02	1.89	1.89	1.89	.00

Cumulative travel time = 24. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
12.91	.00	.00	32.8	.305E+02	1.89	1.89	1.89	.00
14.27	.00	.00	34.2	.292E+02	1.66	2.24	1.66	.00
15.64	.00	.00	35.5	.282E+02	1.50	2.57	1.50	.00
17.00	.00	.00	36.5	.274E+02	1.38	2.88	1.38	.00
18.37	.00	.00	37.5	.267E+02	1.29	3.17	1.29	.00
19.73	.00	.00	38.3	.261E+02	1.21	3.45	1.21	.00
21.10	.00	.00	39.2	.255E+02	1.15	3.71	1.15	.00
22.46	.00	.00	39.9	.251E+02	1.09	3.97	1.09	.00
23.83	.00	.00	40.6	.246E+02	1.05	4.22	1.05	.00

25.19	.00	.00	41.3	.242E+02	1.01	4.47	1.01	.00
26.56	.00	.00	42.0	.238E+02	.97	4.70	.97	.00
27.92	.00	.00	42.7	.234E+02	.94	4.93	.94	.00
29.29	.00	.00	43.3	.231E+02	.91	5.16	.91	.00
30.65	.00	.00	43.9	.228E+02	.89	5.38	.89	.00
32.02	.00	.00	44.6	.224E+02	.87	5.60	.87	.00
33.38	.00	.00	45.2	.221E+02	.85	5.81	.85	.00
34.75	.00	.00	45.8	.218E+02	.83	6.02	.83	.00
36.11	.00	.00	46.5	.215E+02	.81	6.22	.81	.00
37.48	.00	.00	47.1	.212E+02	.80	6.42	.80	.00
38.85	.00	.00	47.7	.210E+02	.78	6.62	.78	.00
40.21	.00	.00	48.4	.207E+02	.77	6.82	.77	.00
41.58	.00	.00	49.0	.204E+02	.76	7.01	.76	.00
42.94	.00	.00	49.7	.201E+02	.75	7.20	.75	.00
44.31	.00	.00	50.3	.199E+02	.74	7.39	.74	.00
45.67	.00	.00	51.0	.196E+02	.73	7.57	.73	.00
47.04	.00	.00	51.7	.193E+02	.72	7.75	.72	.00
48.40	.00	.00	52.4	.191E+02	.72	7.93	.72	.00
49.77	.00	.00	53.1	.188E+02	.71	8.11	.71	.00
51.13	.00	.00	53.8	.186E+02	.71	8.29	.71	.00
52.50	.00	.00	54.6	.183E+02	.70	8.46	.70	.00
53.86	.00	.00	55.3	.181E+02	.70	8.64	.70	.00
55.23	.00	.00	56.1	.178E+02	.69	8.81	.69	.00
56.59	.00	.00	56.9	.176E+02	.69	8.98	.69	.00
57.96	.00	.00	57.6	.173E+02	.68	9.15	.68	.00
59.32	.00	.00	58.5	.171E+02	.68	9.31	.68	.00
60.69	.00	.00	59.3	.169E+02	.68	9.48	.68	.00
62.06	.00	.00	60.1	.166E+02	.68	9.64	.68	.00
63.42	.00	.00	61.0	.164E+02	.68	9.80	.68	.00
64.79	.00	.00	61.9	.162E+02	.67	9.96	.67	.00
66.15	.00	.00	62.8	.159E+02	.67	10.12	.67	.00
67.52	.00	.00	63.7	.157E+02	.67	10.28	.67	.00
68.88	.00	.00	64.6	.155E+02	.67	10.44	.67	.00
70.25	.00	.00	65.6	.153E+02	.67	10.59	.67	.00
71.61	.00	.00	66.5	.150E+02	.67	10.75	.67	.00
72.98	.00	.00	67.5	.148E+02	.67	10.90	.67	.00
74.34	.00	.00	68.6	.146E+02	.67	11.05	.67	.00
75.71	.00	.00	69.6	.144E+02	.67	11.21	.67	.00
77.07	.00	.00	70.6	.142E+02	.68	11.36	.68	.00
78.44	.00	.00	71.7	.139E+02	.68	11.51	.68	.00
79.80	.00	.00	72.8	.137E+02	.68	11.65	.68	.00
81.17	.00	.00	73.9	.135E+02	.68	11.80	.68	.00

Cumulative travel time = 309. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

MAC5-4N1.CX1

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
81.17	11.80	.00	73.9	.135E+02	.68	23.60	.68	.00
81.19	11.80	.00	73.9	.135E+02	.68	23.60	.68	.00
81.21	11.80	.00	74.0	.135E+02	.68	23.60	.68	.00
81.23	11.80	.00	74.0	.135E+02	.68	23.61	.68	.00
81.25	11.80	.00	74.0	.135E+02	.68	23.61	.68	.00
81.27	11.80	.00	74.0	.135E+02	.68	23.61	.68	.00
81.29	11.80	.00	74.0	.135E+02	.68	23.61	.68	.00
81.31	11.80	.00	74.0	.135E+02	.68	23.62	.68	.00
81.33	11.80	.00	74.1	.135E+02	.68	23.62	.68	.00
81.35	11.80	.00	74.1	.135E+02	.68	23.62	.68	.00
81.38	11.80	.00	74.1	.135E+02	.68	23.62	.68	.00
81.40	11.80	.00	74.1	.135E+02	.68	23.62	.68	.00
81.42	11.80	.00	74.1	.135E+02	.68	23.63	.68	.00
81.44	11.80	.00	74.1	.135E+02	.68	23.63	.68	.00
81.46	11.80	.00	74.1	.135E+02	.68	23.63	.68	.00
81.48	11.80	.00	74.2	.135E+02	.68	23.63	.68	.00
81.50	11.80	.00	74.2	.135E+02	.68	23.64	.68	.00
81.52	11.80	.00	74.2	.135E+02	.68	23.64	.68	.00
81.54	11.80	.00	74.2	.135E+02	.68	23.64	.68	.00
81.56	11.80	.00	74.2	.135E+02	.68	23.64	.68	.00
81.58	11.80	.00	74.2	.135E+02	.68	23.64	.68	.00
81.60	11.80	.00	74.2	.135E+02	.68	23.65	.68	.00
81.62	11.80	.00	74.3	.135E+02	.68	23.65	.68	.00
81.64	11.80	.00	74.3	.135E+02	.68	23.65	.68	.00
81.66	11.80	.00	74.3	.135E+02	.68	23.65	.68	.00
81.69	11.80	.00	74.3	.135E+02	.68	23.66	.68	.00
81.71	11.80	.00	74.3	.135E+02	.68	23.66	.68	.00
81.73	11.80	.00	74.3	.135E+02	.68	23.66	.68	.00
81.75	11.80	.00	74.4	.134E+02	.68	23.66	.68	.00
81.77	11.80	.00	74.4	.134E+02	.68	23.66	.68	.00
81.79	11.80	.00	74.4	.134E+02	.68	23.67	.68	.00
81.81	11.80	.00	74.4	.134E+02	.68	23.67	.68	.00
81.83	11.80	.00	74.4	.134E+02	.68	23.67	.68	.00
81.85	11.80	.00	74.4	.134E+02	.68	23.67	.68	.00
81.87	11.80	.00	74.4	.134E+02	.68	23.68	.68	.00
81.89	11.80	.00	74.5	.134E+02	.68	23.68	.68	.00
81.91	11.80	.00	74.5	.134E+02	.68	23.68	.68	.00
81.93	11.80	.00	74.5	.134E+02	.68	23.68	.68	.00
81.95	11.80	.00	74.5	.134E+02	.68	23.68	.68	.00
81.97	11.80	.00	74.5	.134E+02	.68	23.69	.68	.00
81.99	11.80	.00	74.5	.134E+02	.68	23.69	.68	.00
82.02	11.80	.00	74.6	.134E+02	.68	23.69	.68	.00
82.04	11.80	.00	74.6	.134E+02	.68	23.69	.68	.00
82.06	11.80	.00	74.6	.134E+02	.68	23.69	.68	.00
82.08	11.80	.00	74.6	.134E+02	.68	23.70	.68	.00
82.10	11.80	.00	74.6	.134E+02	.68	23.70	.68	.00

82.12	11.80	.00	74.6	.134E+02	.68	23.70	.68	.00
82.14	11.80	.00	74.6	.134E+02	.68	23.70	.68	.00
82.16	11.80	.00	74.7	.134E+02	.68	23.71	.68	.00
82.18	11.80	.00	74.7	.134E+02	.68	23.71	.68	.00
82.20	11.80	.00	74.7	.134E+02	.68	23.71	.68	.00

Cumulative travel time = 313. sec
Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .185E-01 m^2/s
Horizontal diffusivity (initial value) = .463E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
82.20	11.80	.00	74.7	.134E+02	.68	23.71	.68	.00
104.56	11.80	.00	75.3	.133E+02	.69	23.71	.69	.00
126.91	11.80	.00	76.0	.132E+02	.70	23.71	.70	.00
149.27	11.80	.00	76.7	.130E+02	.70	23.71	.70	.00
171.63	11.80	.00	77.4	.129E+02	.71	23.71	.71	.00
193.98	11.80	.00	78.1	.128E+02	.72	23.71	.72	.00
216.34	11.80	.00	78.8	.127E+02	.72	23.71	.72	.00
238.69	11.80	.00	79.5	.126E+02	.73	23.71	.73	.00
261.05	11.80	.00	80.2	.125E+02	.74	23.71	.74	.00
283.41	11.80	.00	81.0	.123E+02	.74	23.71	.74	.00
305.76	11.80	.00	81.8	.122E+02	.75	23.71	.75	.00
328.12	11.80	.00	82.5	.121E+02	.76	23.71	.76	.00
350.47	11.80	.00	83.3	.120E+02	.76	23.71	.76	.00
372.83	11.80	.00	84.1	.119E+02	.77	23.71	.77	.00
395.18	11.80	.00	85.0	.118E+02	.78	23.71	.78	.00
417.54	11.80	.00	85.8	.117E+02	.79	23.71	.79	.00
439.90	11.80	.00	86.7	.115E+02	.79	23.71	.79	.00
462.25	11.80	.00	87.5	.114E+02	.80	23.71	.80	.00
484.61	11.80	.00	88.4	.113E+02	.81	23.71	.81	.00
506.96	11.80	.00	89.3	.112E+02	.82	23.71	.82	.00

MAC5-4N1.CX1

529.32	11.80	.00	90.3	.111E+02	.83	23.71	.83	.00
551.68	11.80	.00	91.2	.110E+02	.84	23.71	.84	.00
574.03	11.80	.00	92.2	.108E+02	.84	23.71	.84	.00
596.39	11.80	.00	93.2	.107E+02	.85	23.71	.85	.00
618.74	11.80	.00	94.2	.106E+02	.86	23.71	.86	.00
641.10	11.80	.00	95.2	.105E+02	.87	23.71	.87	.00
663.46	11.80	.00	96.2	.104E+02	.88	23.71	.88	.00
685.81	11.80	.00	97.3	.103E+02	.89	23.71	.89	.00
708.17	11.80	.00	98.4	.102E+02	.90	23.71	.90	.00
730.52	11.80	.00	99.5	.100E+02	.91	23.71	.91	.00
752.88	11.80	.00	100.7	.993E+01	.92	23.71	.92	.00
775.24	11.80	.00	101.8	.982E+01	.93	23.71	.93	.00
797.59	11.80	.00	103.0	.971E+01	.94	23.71	.94	.00
819.95	11.80	.00	104.2	.959E+01	.96	23.71	.96	.00
842.30	11.80	.00	105.5	.948E+01	.97	23.71	.97	.00
864.66	11.80	.00	106.8	.937E+01	.98	23.71	.98	.00
887.02	11.80	.00	108.1	.925E+01	.99	23.71	.99	.00
909.37	11.80	.00	109.4	.914E+01	1.00	23.71	1.00	.00
931.73	11.80	.00	110.8	.903E+01	1.02	23.71	1.02	.00
954.08	11.80	.00	112.2	.891E+01	1.03	23.71	1.03	.00
976.44	11.80	.00	113.6	.880E+01	1.04	23.71	1.04	.00
998.80	11.80	.00	115.1	.869E+01	1.06	23.71	1.06	.00
1021.15	11.80	.00	116.6	.857E+01	1.07	23.71	1.07	.00
1043.51	11.80	.00	118.2	.846E+01	1.08	23.71	1.08	.00
1065.86	11.80	.00	119.8	.835E+01	1.10	23.71	1.10	.00
1088.22	11.80	.00	121.4	.824E+01	1.11	23.71	1.11	.00
1110.58	11.80	.00	123.1	.812E+01	1.13	23.71	1.13	.00
1132.93	11.80	.00	124.8	.801E+01	1.14	23.71	1.14	.00
1155.29	11.80	.00	126.6	.790E+01	1.16	23.71	1.16	.00
1177.64	11.80	.00	128.4	.779E+01	1.18	23.71	1.18	.00
1200.00	11.80	.00	130.3	.768E+01	1.19	23.71	1.19	.00

Cumulative travel time = 4975. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

11111111111111111111111111111111111111111111111111111111111111111111111111111

MAC5-4X1.CX1

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:        MACH^BIG^MUDDY^RIVER
 Design case:            CASE^5^-^PORT^4^-^MAXIMUM^FLOW
 FILE NAME:              cormix\sim\MAC5-4X1.cx1
 Time of Fortran run:    01/09/20--13:38:06

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     84.50  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .785 F     =       .058 USTAR = .6688E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.80
 D0    =       .152 A0    =       .018 H0    =       .53
 THETA =     30.00  SIGMA =       .00
 U0    =      5.487 Q0    =       .100       = .9956E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .9956E-01  M0    = .5463E+00  J0    =-.1457E-01  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .13  LM    =      5.26  Lm    =       .94  Lb    =       .03
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     36.79  R     =      6.98

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
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```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

      X        Y        Z        S        C        B
      .00      .00      .53     1.0  .100E+04     .08

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     27.38  SIGMAE=       .00
  LE    =       .58  XE    =       .51  YE    =       .00  ZE    =       .81

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

      X        Y        Z        S        C        B
      .00      .00      .53     1.0  .100E+04     .08
      .51      .00      .81     1.0  .100E+04     .08
     1.19      .00     1.10     2.1  .466E+03     .16
     1.89      .00     1.32     3.5  .285E+03     .23
     2.61      .00     1.48     4.9  .205E+03     .29
     3.33      .00     1.61     6.2  .163E+03     .34
     4.07      .00     1.72     7.4  .136E+03     .39
     4.80      .00     1.80     8.5  .118E+03     .42
     5.54      .00     1.88     9.5  .105E+03     .45
     6.27      .00     1.94    10.5  .957E+02     .48
     7.01      .00     1.99    11.3  .882E+02     .50
     7.75      .00     2.03    12.2  .823E+02     .53
     8.49      .00     2.06    12.9  .774E+02     .54
     9.22      .00     2.09    13.6  .735E+02     .56
     9.97      .00     2.12    14.3  .701E+02     .58
```

10.70	.00	2.14	14.8	.673E+02	.59
11.45	.00	2.15	15.4	.650E+02	.60
12.18	.00	2.16	15.9	.630E+02	.61
12.92	.00	2.17	16.3	.612E+02	.62

Maximum jet height has been reached.

13.66	.00	2.17	16.7	.598E+02	.63
14.40	.00	2.16	17.1	.584E+02	.64
15.14	.00	2.16	17.6	.569E+02	.65
15.88	.00	2.15	18.1	.554E+02	.66
16.61	.00	2.14	18.6	.538E+02	.67
17.36	.00	2.12	19.1	.522E+02	.68
18.09	.00	2.10	19.7	.507E+02	.70
18.84	.00	2.08	20.4	.491E+02	.71
19.57	.00	2.05	21.0	.475E+02	.72
20.31	.00	2.03	21.7	.460E+02	.73
21.05	.00	2.00	22.5	.445E+02	.75
21.79	.00	1.97	23.2	.431E+02	.76
22.52	.00	1.94	24.0	.417E+02	.77
23.27	.00	1.90	24.8	.403E+02	.79
24.00	.00	1.86	25.7	.390E+02	.80
24.73	.00	1.83	26.5	.377E+02	.82
25.48	.00	1.79	27.4	.365E+02	.83
26.21	.00	1.75	28.3	.353E+02	.85
26.95	.00	1.71	29.2	.342E+02	.86
27.69	.00	1.67	30.2	.331E+02	.88
28.43	.00	1.62	31.2	.321E+02	.89
29.16	.00	1.58	32.2	.311E+02	.91
29.90	.00	1.54	33.2	.301E+02	.92
30.64	.00	1.49	34.2	.292E+02	.94
31.38	.00	1.45	35.3	.284E+02	.95
32.11	.00	1.40	36.3	.275E+02	.97
32.86	.00	1.36	37.4	.267E+02	.99
33.59	.00	1.31	38.5	.260E+02	1.00
34.33	.00	1.27	39.6	.252E+02	1.02
35.06	.00	1.22	40.7	.245E+02	1.03
35.81	.00	1.17	41.9	.239E+02	1.05
36.54	.00	1.12	43.0	.232E+02	1.06
37.28	.00	1.08	44.2	.226E+02	1.08

Cumulative travel time = 33. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
37.28	.00	1.08	44.2	.226E+02	1.08

MAC5-4X1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
36.20	.00	.00	44.2	.226E+02	.00	.00	.00	.00
36.53	.00	.00	44.2	.226E+02	1.37	.69	1.37	.00
36.85	.00	.00	44.2	.226E+02	1.63	.98	1.63	.00
37.17	.00	.00	44.2	.226E+02	1.79	1.20	1.79	.00
37.50	.00	.00	45.4	.220E+02	1.91	1.38	1.91	.00
37.82	.00	.00	51.0	.196E+02	2.00	1.54	2.00	.00
38.14	.00	.00	58.8	.170E+02	2.07	1.69	2.07	.00
38.47	.00	.00	65.9	.152E+02	2.12	1.83	2.12	.00
38.79	.00	.00	70.8	.141E+02	2.16	1.95	2.16	.00
39.11	.00	.00	73.4	.136E+02	2.18	2.07	2.18	.00
39.44	.00	.00	75.1	.133E+02	2.18	2.18	2.18	.00

Cumulative travel time = 36. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Discharge is non-buoyant or weakly buoyant.
Therefore BUOYANT SPREADING REGIME is ABSENT.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .607E-01 m^2/s
Horizontal diffusivity (initial value) = .152E+00 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution

MAC5-4X1.CX1

C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
39.44	.00	.00	75.1	.133E+02	2.18	2.18	2.18	.00
43.87	.00	.00	96.1	.104E+02	2.23	2.73	2.23	.00
48.30	.00	.00	115.1	.869E+01	2.29	3.18	2.29	.00
52.73	.00	.00	133.4	.750E+01	2.36	3.58	2.36	.00
57.16	.00	.00	151.4	.660E+01	2.44	3.94	2.44	.00
61.59	.00	.00	169.6	.590E+01	2.52	4.27	2.52	.00
66.02	.00	.00	188.0	.532E+01	2.61	4.57	2.61	.00
70.45	.00	.00	206.9	.483E+01	2.70	4.86	2.70	.00
74.88	.00	.00	226.1	.442E+01	2.80	5.13	2.80	.00
79.31	.00	.00	245.8	.407E+01	2.90	5.38	2.90	.00
83.74	.00	.00	266.0	.376E+01	3.00	5.63	3.00	.00
88.17	.00	.00	286.7	.349E+01	3.10	5.86	3.10	.00
92.60	.00	.00	307.7	.325E+01	3.21	6.09	3.21	.00
97.03	.00	.00	329.2	.304E+01	3.31	6.30	3.31	.00
101.46	.00	.00	351.1	.285E+01	3.42	6.51	3.42	.00
105.89	.00	.00	373.3	.268E+01	3.52	6.72	3.52	.00
110.32	.00	.00	395.8	.253E+01	3.63	6.91	3.63	.00
114.76	.00	.00	418.7	.239E+01	3.74	7.11	3.74	.00
119.19	.00	.00	441.8	.226E+01	3.84	7.29	3.84	.00
123.62	.00	.00	465.2	.215E+01	3.95	7.47	3.95	.00
128.05	.00	.00	488.8	.205E+01	4.05	7.65	4.05	.00
132.48	.00	.00	512.6	.195E+01	4.15	7.83	4.15	.00
136.91	.00	.00	536.6	.186E+01	4.26	8.00	4.26	.00
141.34	.00	.00	560.7	.178E+01	4.36	8.16	4.36	.00
145.77	.00	.00	585.1	.171E+01	4.46	8.33	4.46	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

150.20	.00	.00	607.5	.165E+01	4.54	8.49	4.54	.00
154.63	.00	.00	618.7	.162E+01	4.54	8.64	4.54	.00
159.06	.00	.00	629.8	.159E+01	4.54	8.80	4.54	.00
163.49	.00	.00	640.6	.156E+01	4.54	8.95	4.54	.00
167.92	.00	.00	651.3	.154E+01	4.54	9.10	4.54	.00
172.35	.00	.00	661.8	.151E+01	4.54	9.24	4.54	.00
176.78	.00	.00	672.1	.149E+01	4.54	9.39	4.54	.00
181.21	.00	.00	682.3	.147E+01	4.54	9.53	4.54	.00
185.64	.00	.00	692.3	.144E+01	4.54	9.67	4.54	.00
190.08	.00	.00	702.2	.142E+01	4.54	9.81	4.54	.00
194.51	.00	.00	712.0	.140E+01	4.54	9.94	4.54	.00
198.94	.00	.00	721.6	.139E+01	4.54	10.08	4.54	.00
203.37	.00	.00	731.1	.137E+01	4.54	10.21	4.54	.00
207.80	.00	.00	740.4	.135E+01	4.54	10.34	4.54	.00
212.23	.00	.00	749.7	.133E+01	4.54	10.47	4.54	.00
216.66	.00	.00	758.8	.132E+01	4.54	10.60	4.54	.00

221.09	.00	.00	767.9	.130E+01	4.54	10.73	4.54	.00
225.52	.00	.00	776.8	.129E+01	4.54	10.85	4.54	.00
229.95	.00	.00	785.6	.127E+01	4.54	10.97	4.54	.00
234.38	.00	.00	794.3	.126E+01	4.54	11.10	4.54	.00
238.81	.00	.00	803.0	.125E+01	4.54	11.22	4.54	.00
243.24	.00	.00	811.5	.123E+01	4.54	11.33	4.54	.00
247.67	.00	.00	819.9	.122E+01	4.54	11.45	4.54	.00
252.10	.00	.00	828.3	.121E+01	4.54	11.57	4.54	.00
256.53	.00	.00	836.6	.120E+01	4.54	11.69	4.54	.00
260.96	.00	.00	844.8	.118E+01	4.54	11.80	4.54	.00

Cumulative travel time = 318. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
260.96	11.80	.00	844.8	.118E+01	4.54	23.60	4.54	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 269.54 m.

279.75	11.80	.00	853.4	.117E+01	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

298.53	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
317.31	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
336.09	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
354.87	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
373.65	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
392.43	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
411.21	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
429.99	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
448.77	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
467.55	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
486.33	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
505.11	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
523.89	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
542.67	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
561.46	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
580.24	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
599.02	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
617.80	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
636.58	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
655.36	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
674.14	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
692.92	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
711.70	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
730.48	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
749.26	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00

768.04	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
786.82	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
805.60	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
824.39	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
843.17	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
861.95	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
880.73	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
899.51	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
918.29	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
937.07	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
955.85	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
974.63	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
993.41	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1012.19	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1030.97	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1049.75	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1068.53	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1087.32	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1106.10	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1124.88	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1143.66	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1162.44	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1181.22	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1200.00	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00

Cumulative travel time = 1513. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111

MAC5-5N3.CX1

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:        MACH^BIG^MUDDY^RIVER
 Design case:            CASE^5^-^PORT^5^-^NORMAL^FLOW
 FILE NAME:              cormix\sim\MAC5-5N3.cx1
 Time of Fortran run:    01/09/20--12:56:44

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     25.76  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .239 F     =       .058 USTAR = .2039E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.80
 D0    =       .203 A0    =       .032 H0    =       .50
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .093       = .9276E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .9276E-01  M0    = .2658E+00  J0    =-.1357E-01  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .18  LM    =      3.18  Lm    =      2.15  Lb    =       .99
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     16.62  R     =     11.97

FLOW CLASSIFICATION
 1111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
```

MAC5-5N3.CX1

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .50      1.0  .100E+04     .10

END OF MOD101: DISCHARGE MODULE
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=    28.47  SIGMAE=       .00
  LE    =       .88  XE    =       .77  YE    =       .00  ZE    =       .93

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .50      1.0  .100E+04     .10
      .77      .00      .93      1.0  .100E+04     .10
      .96      .00     1.03      1.1  .902E+03     .13
     1.17      .00     1.13      1.4  .729E+03     .16
     1.36      .00     1.23      1.6  .617E+03     .18
     1.58      .00     1.32      1.9  .527E+03     .21
     1.80      .00     1.41      2.2  .459E+03     .24
     2.00      .00     1.48      2.4  .410E+03     .26
     2.23      .00     1.56      2.7  .367E+03     .29
     2.45      .00     1.63      3.0  .332E+03     .31
     2.66      .00     1.69      3.3  .306E+03     .33
     2.89      .00     1.76      3.5  .282E+03     .35
     3.12      .00     1.81      3.8  .262E+03     .38
     3.33      .00     1.86      4.1  .246E+03     .39
     3.56      .00     1.90      4.3  .231E+03     .41
```

3.80	.00	1.94	4.6	.219E+03	.43
4.01	.00	1.97	4.8	.209E+03	.45
4.24	.00	2.01	5.0	.199E+03	.47
4.48	.00	2.03	5.2	.191E+03	.48
4.69	.00	2.05	5.4	.184E+03	.49
4.93	.00	2.07	5.6	.177E+03	.51
5.17	.00	2.08	5.8	.172E+03	.52
5.38	.00	2.09	6.0	.167E+03	.53
5.62	.00	2.09	6.2	.163E+03	.54

Maximum jet height has been reached.

5.86	.00	2.09	6.3	.158E+03	.55
6.07	.00	2.09	6.5	.155E+03	.56
6.31	.00	2.08	6.6	.150E+03	.57
6.54	.00	2.07	6.8	.146E+03	.58
6.76	.00	2.05	7.0	.142E+03	.59
7.00	.00	2.03	7.2	.138E+03	.61
7.23	.00	2.01	7.5	.134E+03	.62
7.45	.00	1.98	7.7	.130E+03	.63
7.68	.00	1.95	8.0	.125E+03	.64
7.92	.00	1.92	8.2	.121E+03	.66
8.13	.00	1.89	8.5	.118E+03	.67
8.36	.00	1.85	8.8	.114E+03	.69
8.60	.00	1.81	9.1	.110E+03	.70
8.81	.00	1.77	9.4	.106E+03	.72
9.04	.00	1.72	9.8	.102E+03	.74
9.27	.00	1.67	10.1	.988E+02	.75
9.48	.00	1.62	10.5	.957E+02	.77
9.71	.00	1.57	10.8	.923E+02	.79
9.94	.00	1.51	11.2	.891E+02	.80
10.15	.00	1.46	11.6	.863E+02	.82
10.38	.00	1.40	12.0	.833E+02	.84
10.61	.00	1.34	12.4	.804E+02	.86
10.82	.00	1.29	12.8	.779E+02	.87
11.05	.00	1.22	13.3	.752E+02	.89
11.28	.00	1.16	13.8	.727E+02	.91
11.48	.00	1.10	14.2	.704E+02	.93
11.71	.00	1.03	14.7	.681E+02	.95
11.94	.00	.97	15.1	.660E+02	.97

Cumulative travel time = 16. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
11.94	.00	.97	15.1	.660E+02	.97

MAC5-5N3.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.97	.00	.00	15.1	.660E+02	.00	.00	.00	.00
11.26	.00	.00	15.1	.660E+02	1.40	.71	1.40	.00
11.55	.00	.00	15.1	.660E+02	1.67	1.00	1.67	.00
11.84	.00	.00	15.1	.660E+02	1.83	1.22	1.83	.00
12.13	.00	.00	15.6	.643E+02	1.96	1.41	1.96	.00
12.42	.00	.00	17.5	.572E+02	2.05	1.58	2.05	.00
12.71	.00	.00	20.2	.496E+02	2.12	1.73	2.12	.00
13.00	.00	.00	22.6	.443E+02	2.17	1.87	2.17	.00
13.29	.00	.00	24.3	.412E+02	2.21	2.00	2.21	.00
13.58	.00	.00	25.2	.398E+02	2.23	2.12	2.23	.00
13.87	.00	.00	25.7	.388E+02	2.23	2.23	2.23	.00

Cumulative travel time = 24. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
13.87	.00	.00	25.7	.388E+02	2.23	2.23	2.23	.00
14.87	.00	.00	26.6	.375E+02	2.02	2.56	2.02	.00
15.88	.00	.00	27.4	.365E+02	1.86	2.86	1.86	.00
16.88	.00	.00	28.1	.356E+02	1.73	3.14	1.73	.00
17.88	.00	.00	28.7	.349E+02	1.63	3.42	1.63	.00
18.89	.00	.00	29.2	.342E+02	1.54	3.68	1.54	.00
19.89	.00	.00	29.8	.336E+02	1.46	3.94	1.46	.00
20.89	.00	.00	30.2	.331E+02	1.40	4.18	1.40	.00
21.90	.00	.00	30.7	.326E+02	1.34	4.42	1.34	.00

22.90	.00	.00	31.1	.321E+02	1.30	4.66	1.30	.00
23.90	.00	.00	31.5	.317E+02	1.25	4.88	1.25	.00
24.91	.00	.00	31.9	.313E+02	1.21	5.11	1.21	.00
25.91	.00	.00	32.3	.310E+02	1.18	5.32	1.18	.00
26.91	.00	.00	32.7	.306E+02	1.14	5.54	1.14	.00
27.92	.00	.00	33.0	.303E+02	1.11	5.75	1.11	.00
28.92	.00	.00	33.4	.300E+02	1.09	5.95	1.09	.00
29.92	.00	.00	33.7	.297E+02	1.06	6.15	1.06	.00
30.93	.00	.00	34.0	.294E+02	1.04	6.35	1.04	.00
31.93	.00	.00	34.3	.291E+02	1.02	6.55	1.02	.00
32.93	.00	.00	34.7	.289E+02	1.00	6.74	1.00	.00
33.94	.00	.00	35.0	.286E+02	.98	6.93	.98	.00
34.94	.00	.00	35.3	.284E+02	.96	7.12	.96	.00
35.94	.00	.00	35.6	.281E+02	.94	7.30	.94	.00
36.95	.00	.00	35.9	.279E+02	.93	7.48	.93	.00
37.95	.00	.00	36.2	.276E+02	.91	7.66	.91	.00
38.95	.00	.00	36.5	.274E+02	.90	7.84	.90	.00
39.96	.00	.00	36.8	.272E+02	.89	8.02	.89	.00
40.96	.00	.00	37.1	.270E+02	.88	8.19	.88	.00
41.96	.00	.00	37.4	.268E+02	.87	8.37	.87	.00
42.97	.00	.00	37.7	.266E+02	.86	8.54	.86	.00
43.97	.00	.00	38.0	.263E+02	.85	8.70	.85	.00
44.97	.00	.00	38.3	.261E+02	.84	8.87	.84	.00
45.98	.00	.00	38.6	.259E+02	.83	9.04	.83	.00
46.98	.00	.00	38.8	.257E+02	.82	9.20	.82	.00
47.98	.00	.00	39.1	.255E+02	.81	9.36	.81	.00
48.99	.00	.00	39.4	.253E+02	.80	9.53	.80	.00
49.99	.00	.00	39.8	.252E+02	.80	9.69	.80	.00
50.99	.00	.00	40.1	.250E+02	.79	9.84	.79	.00
52.00	.00	.00	40.4	.248E+02	.78	10.00	.78	.00
53.00	.00	.00	40.7	.246E+02	.78	10.16	.78	.00
54.00	.00	.00	41.0	.244E+02	.77	10.31	.77	.00
55.00	.00	.00	41.3	.242E+02	.76	10.47	.76	.00
56.01	.00	.00	41.6	.240E+02	.76	10.62	.76	.00
57.01	.00	.00	41.9	.239E+02	.75	10.77	.75	.00
58.01	.00	.00	42.2	.237E+02	.75	10.92	.75	.00
59.02	.00	.00	42.6	.235E+02	.75	11.07	.75	.00
60.02	.00	.00	42.9	.233E+02	.74	11.22	.74	.00
61.02	.00	.00	43.2	.231E+02	.74	11.37	.74	.00
62.03	.00	.00	43.6	.230E+02	.73	11.51	.73	.00
63.03	.00	.00	43.9	.228E+02	.73	11.66	.73	.00
64.03	.00	.00	44.2	.226E+02	.73	11.80	.73	.00

Cumulative travel time = 233. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

MAC5-5N3.CX1

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
64.03	11.80	.00	44.2	.226E+02	.73	23.60	.73	.00
64.05	11.80	.00	44.2	.226E+02	.73	23.60	.73	.00
64.07	11.80	.00	44.2	.226E+02	.73	23.60	.73	.00
64.08	11.80	.00	44.3	.226E+02	.73	23.61	.73	.00
64.10	11.80	.00	44.3	.226E+02	.73	23.61	.73	.00
64.11	11.80	.00	44.3	.226E+02	.73	23.61	.73	.00
64.13	11.80	.00	44.3	.226E+02	.73	23.61	.73	.00
64.14	11.80	.00	44.3	.226E+02	.73	23.62	.73	.00
64.16	11.80	.00	44.3	.226E+02	.73	23.62	.73	.00
64.17	11.80	.00	44.3	.226E+02	.73	23.62	.73	.00
64.19	11.80	.00	44.3	.226E+02	.73	23.62	.73	.00
64.20	11.80	.00	44.3	.226E+02	.73	23.62	.73	.00
64.22	11.80	.00	44.3	.226E+02	.73	23.63	.73	.00
64.24	11.80	.00	44.3	.226E+02	.73	23.63	.73	.00
64.25	11.80	.00	44.3	.226E+02	.73	23.63	.73	.00
64.27	11.80	.00	44.3	.226E+02	.73	23.63	.73	.00
64.28	11.80	.00	44.3	.226E+02	.73	23.64	.73	.00
64.30	11.80	.00	44.3	.226E+02	.73	23.64	.73	.00
64.31	11.80	.00	44.3	.226E+02	.73	23.64	.73	.00
64.33	11.80	.00	44.3	.226E+02	.73	23.64	.73	.00
64.34	11.80	.00	44.3	.226E+02	.73	23.64	.73	.00
64.36	11.80	.00	44.3	.226E+02	.73	23.65	.73	.00
64.37	11.80	.00	44.3	.226E+02	.73	23.65	.73	.00
64.39	11.80	.00	44.3	.226E+02	.73	23.65	.73	.00
64.41	11.80	.00	44.3	.226E+02	.73	23.65	.73	.00
64.42	11.80	.00	44.3	.226E+02	.73	23.66	.73	.00
64.44	11.80	.00	44.3	.225E+02	.73	23.66	.73	.00
64.45	11.80	.00	44.4	.225E+02	.73	23.66	.73	.00
64.47	11.80	.00	44.4	.225E+02	.73	23.66	.73	.00
64.48	11.80	.00	44.4	.225E+02	.73	23.66	.73	.00
64.50	11.80	.00	44.4	.225E+02	.73	23.67	.73	.00
64.51	11.80	.00	44.4	.225E+02	.73	23.67	.73	.00
64.53	11.80	.00	44.4	.225E+02	.73	23.67	.73	.00
64.54	11.80	.00	44.4	.225E+02	.73	23.67	.73	.00
64.56	11.80	.00	44.4	.225E+02	.73	23.68	.73	.00
64.58	11.80	.00	44.4	.225E+02	.73	23.68	.73	.00
64.59	11.80	.00	44.4	.225E+02	.73	23.68	.73	.00
64.61	11.80	.00	44.4	.225E+02	.73	23.68	.73	.00
64.62	11.80	.00	44.4	.225E+02	.73	23.68	.73	.00
64.64	11.80	.00	44.4	.225E+02	.73	23.69	.73	.00
64.65	11.80	.00	44.4	.225E+02	.73	23.69	.73	.00
64.67	11.80	.00	44.4	.225E+02	.73	23.69	.73	.00
64.68	11.80	.00	44.4	.225E+02	.73	23.69	.73	.00
64.70	11.80	.00	44.4	.225E+02	.73	23.69	.73	.00
64.71	11.80	.00	44.4	.225E+02	.73	23.70	.73	.00
64.73	11.80	.00	44.4	.225E+02	.73	23.70	.73	.00

64.75	11.80	.00	44.4	.225E+02	.73	23.70	.73	.00
64.76	11.80	.00	44.4	.225E+02	.73	23.70	.73	.00
64.78	11.80	.00	44.4	.225E+02	.73	23.71	.73	.00
64.79	11.80	.00	44.4	.225E+02	.73	23.71	.73	.00
64.81	11.80	.00	44.5	.225E+02	.73	23.71	.73	.00

Cumulative travel time = 236. sec
Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .185E-01 m^2/s
Horizontal diffusivity (initial value) = .463E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
64.81	11.80	.00	44.5	.225E+02	.73	23.71	.73	.00
87.51	11.80	.00	44.6	.224E+02	.73	23.71	.73	.00
110.22	11.80	.00	44.8	.223E+02	.73	23.71	.73	.00
132.92	11.80	.00	45.0	.222E+02	.74	23.71	.74	.00
155.62	11.80	.00	45.2	.221E+02	.74	23.71	.74	.00
178.33	11.80	.00	45.3	.221E+02	.74	23.71	.74	.00
201.03	11.80	.00	45.5	.220E+02	.74	23.71	.74	.00
223.73	11.80	.00	45.7	.219E+02	.75	23.71	.75	.00
246.44	11.80	.00	45.9	.218E+02	.75	23.71	.75	.00
269.14	11.80	.00	46.1	.217E+02	.75	23.71	.75	.00
291.85	11.80	.00	46.3	.216E+02	.76	23.71	.76	.00
314.55	11.80	.00	46.5	.215E+02	.76	23.71	.76	.00
337.25	11.80	.00	46.7	.214E+02	.76	23.71	.76	.00
359.96	11.80	.00	46.8	.213E+02	.77	23.71	.77	.00
382.66	11.80	.00	47.0	.213E+02	.77	23.71	.77	.00
405.37	11.80	.00	47.2	.212E+02	.77	23.71	.77	.00
428.07	11.80	.00	47.4	.211E+02	.78	23.71	.78	.00
450.77	11.80	.00	47.6	.210E+02	.78	23.71	.78	.00
473.48	11.80	.00	47.8	.209E+02	.78	23.71	.78	.00
496.18	11.80	.00	48.0	.208E+02	.79	23.71	.79	.00

MAC5-5N3.CX1

518.88	11.80	.00	48.2	.207E+02	.79	23.71	.79	.00
541.59	11.80	.00	48.5	.206E+02	.79	23.71	.79	.00
564.29	11.80	.00	48.7	.205E+02	.80	23.71	.80	.00
587.00	11.80	.00	48.9	.205E+02	.80	23.71	.80	.00
609.70	11.80	.00	49.1	.204E+02	.80	23.71	.80	.00
632.40	11.80	.00	49.3	.203E+02	.81	23.71	.81	.00
655.11	11.80	.00	49.5	.202E+02	.81	23.71	.81	.00
677.81	11.80	.00	49.7	.201E+02	.81	23.71	.81	.00
700.52	11.80	.00	50.0	.200E+02	.82	23.71	.82	.00
723.22	11.80	.00	50.2	.199E+02	.82	23.71	.82	.00
745.92	11.80	.00	50.4	.198E+02	.82	23.71	.82	.00
768.63	11.80	.00	50.6	.198E+02	.83	23.71	.83	.00
791.33	11.80	.00	50.8	.197E+02	.83	23.71	.83	.00
814.03	11.80	.00	51.1	.196E+02	.83	23.71	.83	.00
836.74	11.80	.00	51.3	.195E+02	.84	23.71	.84	.00
859.44	11.80	.00	51.5	.194E+02	.84	23.71	.84	.00
882.15	11.80	.00	51.8	.193E+02	.85	23.71	.85	.00
904.85	11.80	.00	52.0	.192E+02	.85	23.71	.85	.00
927.55	11.80	.00	52.3	.191E+02	.85	23.71	.85	.00
950.26	11.80	.00	52.5	.190E+02	.86	23.71	.86	.00
972.96	11.80	.00	52.7	.190E+02	.86	23.71	.86	.00
995.67	11.80	.00	53.0	.189E+02	.87	23.71	.87	.00
1018.37	11.80	.00	53.2	.188E+02	.87	23.71	.87	.00
1041.07	11.80	.00	53.5	.187E+02	.87	23.71	.87	.00
1063.78	11.80	.00	53.7	.186E+02	.88	23.71	.88	.00
1086.48	11.80	.00	54.0	.185E+02	.88	23.71	.88	.00
1109.19	11.80	.00	54.3	.184E+02	.89	23.71	.89	.00
1131.89	11.80	.00	54.5	.183E+02	.89	23.71	.89	.00
1154.59	11.80	.00	54.8	.183E+02	.90	23.71	.90	.00
1177.30	11.80	.00	55.0	.182E+02	.90	23.71	.90	.00
1200.00	11.80	.00	55.3	.181E+02	.90	23.71	.90	.00

Cumulative travel time = 4963. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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MAC5-5X1.CX1

CORMIX1_PREDICTION FILE:

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CORNELL MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX1: Subsystem version:

Submerged Single Port Discharges CORMIX_v.3.20_____September_1996

CASE DESCRIPTION

Site name/label: MACH^BIG^MUDDY^RIVER

Design case: CASE^5^-^PORT^5^-^MAXIMUM^FLOW

FILE NAME: cormix\sim\MAC5-5X1.cx1

Time of Fortran run: 01/09/20--13:40:21

ENVIRONMENT PARAMETERS (metric units)

Bounded section

BS = 23.71 AS = 107.64 QA = 84.50 ICHREG= 2

HA = 4.54 HD = 4.54

UA = .785 F = .058 USTAR = .6688E-01

UW = 2.000 UWSTAR= .2198E-02

Uniform density environment

STRCND= U RHOAM = 998.4901

DISCHARGE PARAMETERS (metric units)

BANK = LEFT DISTB = 11.80

D0 = .203 A0 = .032 H0 = .50

THETA = 30.00 SIGMA = .00

U0 = 5.487 Q0 = .178 = .1776E+00

RHO0 = 1013.3900 DRHO0 =-.1490E+02 GP0 =-.1463E+00

C0 = .1000E+04 CUNITS= PPM

IPOLL = 1 KS = .0000E+00 KD = .0000E+00

FLUX VARIABLES (metric units)

Q0 = .1776E+00 M0 = .9744E+00 J0 =-.2599E-01 SIGNJ0= -1.0

Associated length scales (meters)

LQ = .18 LM = 6.08 Lm = 1.26 Lb = .05

Lmp = 99999.00 Lbp = 99999.00

NON-DIMENSIONAL PARAMETERS

FR0 = 31.83 R = 6.98

FLOW CLASSIFICATION

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1 Flow class (CORMIX1) = NH4 1

1 Applicable layer depth HS = 4.54 1

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MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS

C0 = .1000E+04 CUNITS= PPM

```
 NTOX   =  0
 NSTD   =  0
 REGMZ  =  0
 XINT   =   1200.00  XMAX   =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .50      1.0  .100E+04     .10

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     27.38  SIGMAE=       .00
  LE    =       .78  XE    =       .68  YE    =       .00  ZE    =       .87

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .50      1.0  .100E+04     .10
      .68      .00      .87      1.0  .100E+04     .10
     1.36      .00     1.18      1.8  .550E+03     .19
     2.07      .00     1.43      2.9  .350E+03     .27
     2.80      .00     1.62      3.9  .256E+03     .34
     3.54      .00     1.78      4.9  .204E+03     .40
     4.27      .00     1.91      5.9  .171E+03     .44
     5.02      .00     2.02      6.8  .148E+03     .49
     5.77      .00     2.11      7.6  .131E+03     .53
     6.52      .00     2.19      8.4  .119E+03     .56
     7.27      .00     2.26      9.2  .109E+03     .59
     8.01      .00     2.31      9.8  .102E+03     .62
     8.76      .00     2.36     10.5  .953E+02     .64
     9.51      .00     2.40     11.1  .902E+02     .66
    10.27      .00     2.43     11.6  .858E+02     .68
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11.02	.00	2.46	12.2	.822E+02	.70
11.76	.00	2.48	12.6	.792E+02	.72
12.52	.00	2.50	13.1	.765E+02	.73
13.27	.00	2.51	13.5	.743E+02	.75
14.03	.00	2.52	13.8	.723E+02	.76

Maximum jet height has been reached.

14.77	.00	2.52	14.1	.707E+02	.77
15.52	.00	2.52	14.5	.691E+02	.78
16.28	.00	2.51	14.8	.674E+02	.79
17.03	.00	2.50	15.2	.657E+02	.80
17.79	.00	2.48	15.6	.639E+02	.81
18.53	.00	2.47	16.1	.622E+02	.83
19.28	.00	2.44	16.6	.604E+02	.84
20.04	.00	2.42	17.1	.586E+02	.86
20.79	.00	2.39	17.6	.568E+02	.87
21.54	.00	2.36	18.2	.550E+02	.89
22.28	.00	2.33	18.7	.533E+02	.90
23.04	.00	2.29	19.4	.517E+02	.92
23.79	.00	2.25	20.0	.500E+02	.93
24.55	.00	2.21	20.6	.484E+02	.95
25.30	.00	2.17	21.3	.469E+02	.97
26.04	.00	2.13	22.0	.454E+02	.99
26.79	.00	2.08	22.7	.440E+02	1.00
27.55	.00	2.03	23.5	.426E+02	1.02
28.30	.00	1.98	24.2	.413E+02	1.04
29.04	.00	1.93	25.0	.400E+02	1.06
29.79	.00	1.88	25.8	.388E+02	1.08
30.54	.00	1.83	26.6	.376E+02	1.09
31.30	.00	1.78	27.4	.364E+02	1.11
32.05	.00	1.73	28.3	.354E+02	1.13
32.79	.00	1.67	29.1	.343E+02	1.15
33.54	.00	1.62	30.0	.333E+02	1.17
34.29	.00	1.56	30.9	.324E+02	1.19
35.05	.00	1.51	31.8	.315E+02	1.21
35.80	.00	1.45	32.7	.306E+02	1.22
36.54	.00	1.39	33.6	.297E+02	1.24
37.29	.00	1.34	34.6	.289E+02	1.26
38.04	.00	1.28	35.5	.282E+02	1.28

Cumulative travel time = 32. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
38.04	.00	1.28	35.5	.282E+02	1.28

MAC5-5X1.CX1

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
36.76	.00	.00	35.5	.282E+02	.00	.00	.00	.00
37.15	.00	.00	35.5	.282E+02	1.64	.83	1.64	.00
37.53	.00	.00	35.5	.282E+02	1.95	1.17	1.95	.00
37.92	.00	.00	35.5	.282E+02	2.14	1.43	2.14	.00
38.30	.00	.00	36.5	.274E+02	2.29	1.65	2.29	.00
38.68	.00	.00	41.0	.244E+02	2.40	1.85	2.40	.00
39.07	.00	.00	47.2	.212E+02	2.48	2.02	2.48	.00
39.45	.00	.00	52.9	.189E+02	2.54	2.19	2.54	.00
39.83	.00	.00	56.9	.176E+02	2.58	2.34	2.58	.00
40.22	.00	.00	59.0	.170E+02	2.60	2.48	2.60	.00
40.60	.00	.00	60.4	.166E+02	2.61	2.61	2.61	.00

Cumulative travel time = 35. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
40.60	.00	.00	60.4	.166E+02	2.61	2.61	2.61	.00
41.01	.00	.00	60.6	.165E+02	2.60	2.64	2.60	.00
41.42	.00	.00	60.9	.164E+02	2.58	2.67	2.58	.00
41.82	.00	.00	61.2	.163E+02	2.57	2.70	2.57	.00
42.23	.00	.00	61.5	.162E+02	2.55	2.73	2.55	.00
42.63	.00	.00	61.9	.162E+02	2.54	2.76	2.54	.00
43.04	.00	.00	62.2	.161E+02	2.53	2.78	2.53	.00
43.45	.00	.00	62.5	.160E+02	2.51	2.81	2.51	.00
43.85	.00	.00	62.8	.159E+02	2.50	2.84	2.50	.00

44.26	.00	.00	63.1	.159E+02	2.49	2.87	2.49	.00
44.66	.00	.00	63.4	.158E+02	2.48	2.90	2.48	.00
45.07	.00	.00	63.7	.157E+02	2.46	2.92	2.46	.00
45.48	.00	.00	64.0	.156E+02	2.45	2.95	2.45	.00
45.88	.00	.00	64.3	.155E+02	2.44	2.98	2.44	.00
46.29	.00	.00	64.6	.155E+02	2.43	3.01	2.43	.00
46.70	.00	.00	65.0	.154E+02	2.42	3.03	2.42	.00
47.10	.00	.00	65.3	.153E+02	2.41	3.06	2.41	.00
47.51	.00	.00	65.6	.152E+02	2.40	3.09	2.40	.00
47.91	.00	.00	65.9	.152E+02	2.40	3.11	2.40	.00
48.32	.00	.00	66.2	.151E+02	2.39	3.14	2.39	.00
48.73	.00	.00	66.6	.150E+02	2.38	3.17	2.38	.00
49.13	.00	.00	66.9	.149E+02	2.37	3.19	2.37	.00
49.54	.00	.00	67.2	.149E+02	2.36	3.22	2.36	.00
49.95	.00	.00	67.6	.148E+02	2.36	3.24	2.36	.00
50.35	.00	.00	67.9	.147E+02	2.35	3.27	2.35	.00
50.76	.00	.00	68.3	.147E+02	2.34	3.30	2.34	.00
51.16	.00	.00	68.6	.146E+02	2.34	3.32	2.34	.00
51.57	.00	.00	68.9	.145E+02	2.33	3.35	2.33	.00
51.98	.00	.00	69.3	.144E+02	2.32	3.37	2.32	.00
52.38	.00	.00	69.6	.144E+02	2.32	3.40	2.32	.00
52.79	.00	.00	70.0	.143E+02	2.31	3.42	2.31	.00
53.20	.00	.00	70.3	.142E+02	2.31	3.45	2.31	.00
53.60	.00	.00	70.7	.141E+02	2.30	3.47	2.30	.00
54.01	.00	.00	71.1	.141E+02	2.30	3.50	2.30	.00
54.41	.00	.00	71.4	.140E+02	2.29	3.52	2.29	.00
54.82	.00	.00	71.8	.139E+02	2.29	3.55	2.29	.00
55.23	.00	.00	72.1	.139E+02	2.28	3.57	2.28	.00
55.63	.00	.00	72.5	.138E+02	2.28	3.60	2.28	.00
56.04	.00	.00	72.9	.137E+02	2.27	3.62	2.27	.00
56.45	.00	.00	73.3	.137E+02	2.27	3.65	2.27	.00
56.85	.00	.00	73.6	.136E+02	2.27	3.67	2.27	.00
57.26	.00	.00	74.0	.135E+02	2.26	3.70	2.26	.00
57.66	.00	.00	74.4	.134E+02	2.26	3.72	2.26	.00
58.07	.00	.00	74.8	.134E+02	2.26	3.75	2.26	.00
58.48	.00	.00	75.2	.133E+02	2.26	3.77	2.26	.00
58.88	.00	.00	75.6	.132E+02	2.25	3.79	2.25	.00
59.29	.00	.00	76.0	.132E+02	2.25	3.82	2.25	.00
59.69	.00	.00	76.4	.131E+02	2.25	3.84	2.25	.00
60.10	.00	.00	76.8	.130E+02	2.25	3.87	2.25	.00
60.51	.00	.00	77.2	.130E+02	2.24	3.89	2.24	.00
60.91	.00	.00	77.6	.129E+02	2.24	3.91	2.24	.00

Cumulative travel time = 61. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

MAC5-5X1.CX1

Vertical diffusivity (initial value) = .607E-01 m^2/s
Horizontal diffusivity (initial value) = .152E+00 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
60.91	.00	.00	77.6	.129E+02	2.24	3.91	2.24	.00
65.00	.00	.00	85.2	.117E+02	2.28	4.22	2.28	.00
69.09	.00	.00	92.8	.108E+02	2.33	4.50	2.33	.00
73.17	.00	.00	100.5	.995E+01	2.38	4.77	2.38	.00
77.26	.00	.00	108.2	.924E+01	2.44	5.02	2.44	.00
81.35	.00	.00	116.1	.861E+01	2.49	5.26	2.49	.00
85.43	.00	.00	124.1	.805E+01	2.56	5.49	2.56	.00
89.52	.00	.00	132.4	.755E+01	2.62	5.72	2.62	.00
93.61	.00	.00	140.8	.710E+01	2.69	5.93	2.69	.00
97.69	.00	.00	149.4	.669E+01	2.75	6.13	2.75	.00
101.78	.00	.00	158.2	.632E+01	2.83	6.33	2.83	.00
105.86	.00	.00	167.3	.598E+01	2.90	6.53	2.90	.00
109.95	.00	.00	176.6	.566E+01	2.98	6.71	2.98	.00
114.04	.00	.00	186.1	.537E+01	3.05	6.90	3.05	.00
118.12	.00	.00	195.8	.511E+01	3.13	7.07	3.13	.00
122.21	.00	.00	205.7	.486E+01	3.21	7.25	3.21	.00
126.30	.00	.00	215.8	.463E+01	3.29	7.41	3.29	.00
130.38	.00	.00	226.1	.442E+01	3.37	7.58	3.37	.00
134.47	.00	.00	236.6	.423E+01	3.46	7.74	3.46	.00
138.56	.00	.00	247.2	.404E+01	3.54	7.90	3.54	.00
142.64	.00	.00	258.1	.388E+01	3.62	8.06	3.62	.00
146.73	.00	.00	269.0	.372E+01	3.71	8.21	3.71	.00
150.82	.00	.00	280.2	.357E+01	3.79	8.36	3.79	.00
154.90	.00	.00	291.5	.343E+01	3.88	8.50	3.88	.00
158.99	.00	.00	302.9	.330E+01	3.96	8.65	3.96	.00
163.07	.00	.00	314.4	.318E+01	4.05	8.79	4.05	.00
167.16	.00	.00	326.1	.307E+01	4.13	8.93	4.13	.00
171.25	.00	.00	337.8	.296E+01	4.21	9.07	4.21	.00
175.33	.00	.00	349.7	.286E+01	4.30	9.20	4.30	.00
179.42	.00	.00	361.7	.276E+01	4.38	9.34	4.38	.00
183.51	.00	.00	373.7	.268E+01	4.46	9.47	4.46	.00

Plume interacts with SURFACE.

MAC5-5X1.CX1

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

187.59	.00	.00	385.3	.260E+01	4.54	9.60	4.54	.00
191.68	.00	.00	390.4	.256E+01	4.54	9.73	4.54	.00
195.77	.00	.00	395.5	.253E+01	4.54	9.85	4.54	.00
199.85	.00	.00	400.5	.250E+01	4.54	9.98	4.54	.00
203.94	.00	.00	405.5	.247E+01	4.54	10.10	4.54	.00
208.03	.00	.00	410.4	.244E+01	4.54	10.22	4.54	.00
212.11	.00	.00	415.2	.241E+01	4.54	10.35	4.54	.00
216.20	.00	.00	420.0	.238E+01	4.54	10.46	4.54	.00
220.28	.00	.00	424.7	.235E+01	4.54	10.58	4.54	.00
224.37	.00	.00	429.4	.233E+01	4.54	10.70	4.54	.00
228.46	.00	.00	434.0	.230E+01	4.54	10.81	4.54	.00
232.54	.00	.00	438.6	.228E+01	4.54	10.93	4.54	.00
236.63	.00	.00	443.1	.226E+01	4.54	11.04	4.54	.00
240.72	.00	.00	447.6	.223E+01	4.54	11.15	4.54	.00
244.80	.00	.00	452.0	.221E+01	4.54	11.26	4.54	.00
248.89	.00	.00	456.4	.219E+01	4.54	11.37	4.54	.00
252.98	.00	.00	460.8	.217E+01	4.54	11.48	4.54	.00
257.06	.00	.00	465.1	.215E+01	4.54	11.59	4.54	.00
261.15	.00	.00	469.4	.213E+01	4.54	11.69	4.54	.00
265.24	.00	.00	473.6	.211E+01	4.54	11.80	4.54	.00

Cumulative travel time = 321. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
265.24	11.80	.00	473.6	.211E+01	4.54	23.60	4.54	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 273.82 m.

283.93	11.80	.00	478.4	.209E+01	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

302.63	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
321.32	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
340.02	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
358.71	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
377.41	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
396.10	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
414.80	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
433.49	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
452.19	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
470.88	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
489.58	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
508.27	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
526.97	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00

545.66	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
564.36	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
583.06	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
601.75	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
620.45	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
639.14	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
657.84	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
676.53	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
695.23	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
713.92	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
732.62	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
751.31	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
770.01	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
788.70	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
807.40	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
826.09	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
844.79	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
863.49	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
882.18	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
900.88	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
919.57	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
938.27	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
956.96	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
975.66	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
994.35	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1013.05	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1031.74	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1050.44	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1069.13	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1087.83	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1106.52	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1125.22	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1143.91	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1162.61	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1181.31	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1200.00	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00

Cumulative travel time = 1509. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

11111111111111111111111111111111111111111111111111111111111111111111111111111111

Run	3.3:1	B kw:dT4	34:1	BH kw:dT4
Mac 1-1N1	1.11	.14	10.74	.55
Mac 1-1X1	1.15	.15	14.3	.64
Mac 2-1N1	1.04	.13	12.31	.48
Mac 2-1X1	1.37	.17	13.02	.73
Mac 3-1N1	1.11	.14	10.74	.55
Mac 3-1X1	1.37	.17	13.02	.73
Mac 3-3N1	1.42	.18	12.10	1.1
Mac 3-3X1	1.51	.19	16.02	.96
Mac 4-1N1	1.11	.14	10.74	.55
Mac 4-1X1	1.09	.14	13.81	.67
Mac 4-3N1	1.42	.18	12.1	1.1
Mac 4-3X1	1.63	.21	16.97	.88
Mac 4-4N1	2.09	.260	13.75	1.28
Mac 4-4X1	2.33	.30	22.85	1.33
Mac 5-1N1	1.03	.13	10.07	.60
Mac 5-1X1	.95	.12	18.67	.47
Mac 5-3N1	1.33	.17	11.12	1.17
Mac 5-3X1	1.73	.20	23.71	.64
Mac 5-4N1	1.97	.25	14.27	2.24
Mac 5-4X1	1.89	.23	30.64	.94
Mac 5-5N3	2.666	.33	30.93	6.35
Mac 5-5X1	2.80	.34	37.29	1.26

STATE OF ILLINOIS
ENVIRONMENTAL PROTECTION AGENCY

IL 532-0357
ADM 39
054-002

R01566

Subject Dilution needed for $C_E = 5,000$

Data

Reviewed by Date

$$C_U Q_U + C_E Q_E = (Q_U + Q_E) C_D$$

C_U @ Rend Lake = 30.1 mg/L

C_U = 161.8 mg/L — Sugar Comp Taken into acct.

Solve for Q_U

$$Q_U = \frac{Q_E (C_E - C_D)}{(C_D - C_U)}$$

$Q_E = 1$
$C_U = 161.8$
$C_D = 500$
$C_E = 5000$

$$Q_U = \frac{(5000 - 500)}{(500 - 161.8)}$$

$Q_U = 13.3$

13.3 : 1

	length	½ width
Mac 5 - 5N3	11.05 m	0.89
Mac 5 - 5X1	13.27 m	.75

Max length = 13.27 m = 46 ft

Williamson Energy, LLC
PO Box 99
Johnston City, IL 62951
Office: 618-983-3020 Fax: 618-983-3017

RECEIVED
JAN 21 2020
IEPA
BOW/WPC/PERMIT SECTION

January 17, 2020

Mr. Darin LeCrone
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY
1021 North Grand Avenue East
Springfield, IL 62794-9276

Re: Williamson Energy, LLC – Supplemental information concerning the Anti-Degradation Document for Pond Creek Mine, Big Muddy Flood Analysis, and Modeling of Big Muddy River Chloride dispersion downstream of the proposed mixing zone.
NPDES Permit IL0077666

Dear Mr. LeCrone:

Please find attached two (2) copies of the Supplemental information concerning the NPDES Renewal for Permit IL 0077666 . One copy of this submittal has also been submitted to the permit manager at the IEPA Office in Marion.

- Alliance Consulting, Inc – Benthic Macroinvertebrate Community Survey of the Big Muddy River
- Illinois Natural History Survey – Fresh Water Mussels of the Big Muddy River
- Aquaeter – Update Cormix Model Results
- Potesta - Opinion of the Ecological Effects of Williamson Energy's Renewal of NPDES Permit IL0077666
- Big Muddy River TMDL Report 2004
- Stage 3 TMDL Report Upper Big Muddy Watershed 2018
- IDNR, Division of Fisheries Resources - Big Muddy Fish Data
- Supplemental Water Data from Williaamson Energy, LLC

We appreciate your assistance with the matter. If you have any questions or require additional information, please contact me at (618) 969-8259.

Respectfully submitted,

WILLIAMSON ENERGY, LLC

James Plumley

James Plumley, P.E.

Alliance Consulting, Inc.
Engineers • Constructors • Scientists

BENTHIC MACROINVERTEBRATE COMMUNITY SURVEY OF THE BIG MUDDY RIVER

WILLIAMSON ENERGY, LLC DIFFUSER LOCATION

Prepared for

WILLIAMSON ENERGY, LLC
WILLIAMSON COUNTY, ILLINOIS

ALLIANCE PROJECT NO. B16-454-1413
DECEMBER 2019

Charleston, WV

928 Cross Lanes Drive, Suite 300
Charleston, WV 25313
Telephone: (681) 217-2090
Fax: (681) 217-2092

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124 Philpott Lane
Beaver, WV 25813-9502
Telephone: (304) 255-0491
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3 Four Coins Drive, Ste. 100
Canonsburg, PA 15317
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Fax: (724) 745-3631

BENTHIC MACROINVERTEBRATE COMMUNITY SURVEY OF THE BIG MUDDY RIVER

WILLIAMSON ENERGY, LLC
DIFFUSER LOCATION

Prepared for

WILLIAMSON ENERGY, LLC
WILLIAMSON COUNTY, ILLINOIS

ALLIANCE PROJECT NO. B16-454-1413
DECEMBER 2019



BENTHIC MACROINVERTEBRATE COMMUNITY SURVEY OF THE BIG MUDDY RIVER WILLIAMSON ENERGY, LLC DIFFUSER LOCATION WILLIAMSON COUNTY, ILLINOIS

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Appendix B – Habitat Mapping Photographs
Appendix C – Summary of Macroinvertebrate Community Sampled
Appendix D – Summary of Macroinvertebrate Metric Results

TABLES

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Table 2 – Summary of Benthic Metric Results

FIGURES

Drawing No. B16-454-A3 – Habitat Assessment Map
Drawing No. B16-454-A4 – Sampling Location Map

BENTHIC MACROINVERTEBRATE COMMUNITY SURVEY OF THE BIG MUDDY RIVER WILLIAMSON ENERGY, LLC DIFFUSER LOCATION WILLIAMSON COUNTY, ILLINOIS

1.0 INTRODUCTION

Alliance Consulting, Inc. (Alliance) was contracted by Williamson Energy (Williamson) to perform a benthic macroinvertebrate survey for a proposed diffuser location in Franklin County, Illinois.

The benthic survey was performed by Alliance on November 20, 2019. The survey was completed following the protocols set forth by the U.S. Environmental Protection Agency (USEPA), Illinois Environmental Protection Agency (Illinois EPA), and the Illinois Department of Natural Resources (IDNR).

The purpose of the survey was to obtain data on the condition and composition of the aquatic macroinvertebrate communities present in the Big Muddy River downstream of the project area. This data will be used to help assess the impacts of the proposed project on the aquatic community.

2.0 SITE LOCATION

The sampling site is located on the Big Muddy River approximately 1.2 miles southeast of Ziegler, Illinois and approximately 0.77 miles downstream of the proposed diffuser location (37.524392°N, -89.23009°W).

The project area is located within the Central Lowland Physiographic Province and Interior River valleys and Hills ecoregion. The topography of the region is characterized by low lying flatland (typically agricultural) to gently rolling hills. The geology of the area is heavily influenced from glaciation.

The land cover attributes of the sample site are primarily composed of agricultural cropland and bottomland forest with heavily forested, but often narrow, riparian buffer zones.

3.0 METHODS

All work performed by Alliance to complete the survey of the benthic communities generally followed the protocols set forth by the USEPA, and the Illinois EPA, benthics were collected in accordance with the conditions of Illinois DNR 2019 Scientific Collecting Permit (No. A18.5984) (Appendix A).

3.1 Stream Site Selection

Using topographic maps, aerial photographs, and field reconnaissance of the project site,



Alliance attempted to identify areas to use as sample reaches for the survey in accordance with established wadeable collection methods provided by the USEPA (1999) and the Illinois EPA (2006) for sampling benthic macroinvertebrate communities. Alliance personnel walked the entire length of the Big Muddy River from the sampling location to the water diffuser location and evaluated the potential stream habitat to obtain a benthic sample according to the wadeable collection protocol. However, it was determined that this was not feasible due to lack of preferred habitat (riffles and/or runs) and the inaccessibility of the river due to steep banks and/or depth of the river to reach snags or submerged aquatic vegetation (Appendix B). The entire reach of the stream in the project area was determined to be 100% pool with no available riffle, run, or glide habitat, and the depth of the river made it far too deep for wadeable collection methods.

3.2 Stream Habitat Assessment

Upon evaluation of the project reach it was deemed that traditional methods of habitat assessment for wadable streams were not applicable based on the physical conditions of the survey area. A total of 32 photographs were taken along the stream reach for documentation of the stream conditions at the time of sampling (Figures, Drawing No. B16-454-A3). The substrate found within the reach consisted primarily of fine grained clay, silt, and sandy sediments. Additionally, large portions of the channel exhibited no substantial bedload material and was primarily hard packed clay substrate commonly found within streams in southern Illinois.

3.3 Benthic Macroinvertebrate Sampling

Alliance was requested to sample benthic macroinvertebrates downstream of the project area within the Big Muddy River (BMR). Benthic macroinvertebrates were sampled using an Ekman Dredge dropped from an abandoned railroad bridge at the sampling location. The dredge was dropped 20 times from multiple points on the upstream and downstream side of the bridge to best represent the sampling reach due to lack of preferred habitat and inaccessibility issues, which prevented Alliance personnel from collecting a sample in a more traditional manner.

Following field preservation of benthic macroinvertebrates, individual specimens were sorted, preserved with 95 percent denatured ethanol, and were identified to the lowest practical level (to family level in most cases) by Alliance personnel located in Beaver, West Virginia.

The following are benthic macroinvertebrate community metrics used to analyze the composition of the benthic community sampled in this study:

Number of Coleopteran Taxa: The number of different taxa identified belonging to the Order Coleoptera (beetles). This metric generally decreases with increasing impairment.

Number of Ephemeropteran Taxa: The number of different taxa identified belonging to the order Ephemeroptera (mayflies). This metric generally decreases with increasing impairment.

Number of Intolerant Taxa: The total number of different taxa determined to be sensitive to degradation according to the IEPA. This metric should decrease with increasing degradation.

Percent Individuals as Scrapers: The overall percentage of individual macroinvertebrates within the subsample belonging to the Scraper functional feeding group. This metric generally decreases with increasing impairment.

Shannon-Wiener Diversity Index: An index that measures the diversity of a community by taking into account the number of taxa present (richness) and taxa evenness (McCune and Grace, 2002). Evenness is essentially how equal in abundance individuals of different taxa are to each other. A healthy community should have a high Shannon-Wiener Diversity Index value.

Taxa Richness: Indicative of community health through a measurement of the number of taxa present. Typically increases with increasing water quality and habitat quality. Majority of taxa should come from pollution sensitive groups, with fewer from facultative and tolerant groups.

Percent Contribution of Ephemeroptera, Plecoptera, and Trichoptera (EPT): Measures community health considering a community in good health should have a high percent contribution from the EPT groups as they are often pollution sensitive.

Macroinvertebrate Index of Biotic Integrity (mIBI): An indicator of stream ecosystem health and impairment. The index combines seven metrics (Macroinvertebrate Biotic Index, Total Taxa Richness, Number of Ephemeropteran Taxa, % EPT, Number of Coleopteran Taxa, Number of Intolerant Taxa, and % Scaper) that collectively represent the overall health and integrity of a stream ecosystem and its benthic macro-invertebrate community. The following is a list of the mIBI ratings based on score:

Macroinvertebrate IBI (mIBI) Quality Categories

Lower Boundary	Upper Boundary	Narrative Description
73	100	Exceptional
41.8	72.9	Good
20.9	41.7	Fair
0.0	20.8	Poor

Macroinvertebrate Biotic Index: Indicates presence/absence of pollution (specifically organic pollution) by summarizing the abundance of a taxon multiplied by its tolerance value, and divided by the total number of organisms in the sample (Hilsenhoff, 1977). The biotic index is based on a scale from 0 – 10, with 0 being the best possible score (no pollution) and 10 being the worst possible score (high pollution).

Macroinvertebrate Biotic Index (MBI)

Limits	Water Quality Narrative Description
< 6.0	Good
6.0 to 7.5	Fair
7.6 to 8.9	Poor
≥ 9.0	Very Poor

Alliance reviewed the relative abundance of pollution tolerant species as a measure of the general health of the benthic community. Taxa such as Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), collectively referred to as EPT, are often pollution sensitive, whereas taxa such as *Chironomidae* (midges) have a relatively high tolerance for pollution. Skewed populations of specific groups provide insight into the existence of environmental stress factors.

4.0 RESULTS

4.1 Biological Monitoring Survey

The surveys were performed by Alliance on November 20th, 2019 at the established monitoring station on the Big Muddy River (Figures, Drawing No. B16-454-A4). Data collected includes aquatic organism community data and associated metrics.

4.2 Station Big Muddy River

The biological monitoring Station BMR is located approximately 0.77 miles directly downstream of the proposed diffuser location on the Big Muddy River (Figures, Drawing No. B16-454-A4).

4.2.1 Benthics for Big Muddy River

In total 274 individuals, representing 10 taxa were identified during the benthic survey (Table 1). A diversity score of 0.9 (Shannon-Wiener Diversity Index) (Table 2). *Chironmidae* made up 76% of the sample with 209 individuals. A low percent EPT score of 12.04% was recorded showing a lack of sensitive organisms. The mIBI scored 23.8, which is a rating of fair and 80.7% of the sample was made up of tolerant taxa. The metrics reflect a stream with poor habitat quality, low biodiversity, and a struggling benthic macroinvertebrate community.

5.0 CONCLUSIONS

Concerning the benthic macroinvertebrate community, Alliance reviewed several metrics and community characteristics which evaluate the overall health of the macroinvertebrate community. Metrics such as percent tolerant taxa, EPT taxa richness, and the Shannon-Wiener Diversity index are often good indicators of aquatic life health.

The sampled site showed a tolerant taxa percentage of 80.7%. The station had a low percentage of EPT taxa collected at 12.04%. *Chironomidae* dominated the sample at 76% which would be indicative of a more pollutant tolerant benthic community. The Shannon-Wiener Diversity Index scores the site at 0.90 showing a low diversity of organisms. The mIBI scored at 23.8 which indicates a benthic community in fair health.

Metrics recorded based on the samples collected reflect a stream with poor habitat quality, low biodiversity, and a struggling benthic macroinvertebrate community. Some factors likely



contributing to impairment are the lack of heterogeneity in stream habitat (i.e. very little riffle/run habitat), bank instability and substrate composition.

If you have any questions or require clarification, please do not hesitate to call.

Respectfully submitted,

ALLIANCE CONSULTING, INC.

Alex Patterson
Staff Scientist

Braden A. Hoffman
Senior Project Manager

AP/BAH:kjs

File: \\Aci-zeus\projects\Projects\Williamson Energy (1413)\2016\B16-454-1413\Benthic Survey\2019\benthic survey.doc

6.0 LITERATURE CITED

Hilsenhoff, W.L. 1977. Using a Biotic Index to Evaluate Water Quality/Streams. Wisconsin Department of Natural Resources Technical Bulletin No. 100. Madison, Wisconsin.

McCune, B., Grace, J.B., and D.L. Urban. 2002. Analysis of Ecological Communities. MjM Software Design. Gleneden Beach, Oregon.

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Illinois Department of Natural Resources (IDNR). 2015. Scientific Collecting Permit Standard Conditions for Environmental Assessments on Wadeable Streams.

Illinois Department of Natural Resources (IDNR) IBR Calculator. Metric and Total IBI Score. [Web]. 2014. http://dnr.illinois.gov/IBICalculation/ResultsForm.aspx#SampleSummary

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APPENDIX A

COLLECTION PERMIT

R01578

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

Authorization is hereby granted, under 520 ILCS 5/3.22 and 515 ILCS 5/20-100 of the Illinois Compiled Statutes and 17 ILL. Adm. Code 520 to:

Last Name: **Patterson** First Name: **Alex** Permit Number: **A19.5984**

Issued: **3/7/2019** **Expires: 12/31/2019**

Business Name: Alliance Consulting, Inc.

Street Address: 124 Philpott Lane

City: Beaver State: WV Zip Code: 25813

for strictly scientific, educational or zoological purposes, to take the Illinois fauna identified below subject to the following provisions:

May legally capture, by scientifically accepted methods, only the specific aquatic life species listed on the accompanying Illinois Department of Natural Resources (IDNR) scientific permit application/project proposal (on file in Springfield, IL) strictly for scientific, educational, and/or zoological purposes (except endangered and threatened species). After data has been humanely collected from these species, all animals shall be released unharmed at or near the original site of capture. Deceased animals and/or animal parts must be buried or given to a public or state scientific educational or zoological institution. A federal permit is required for all projects involving federally regulated species. If endangered and threatened species are to be taken, the IDNR Division of Natural Heritage, Endangered Species Coordinator must be notified and must approve in writing all project related activities of the permit application.
Possession/Transportation of injurious aquatic life species requires appropriate permits in addition to the previously stated. The IDNR Aquaculture Specialist can be contacted to request and seek approval of all project activities of the permit applicant prior to activities being initiated. If such species are encountered as part of previously authorized projects, they may be kept for deposition into state, scientific, educational, or zoological institutions, if appropriate precautions are taken to further restrict potential release into the environment AND immediate reporting of escape to dnr.aquaculture@illinois.gov . (All aquatic life may be immediately returned unharmed from where they were taken. 515 ILCS 5/10-100.)
Authorization: Statewide, exclusive of nature preserves, and IDNR owned and managed properties.
Individuals authorized to work under direction of applicant include: Braden Hoffman, Bethany Wolfe, Jennifer Arp-Bazzie, Brandon Alderman, Blake Davis, Bo Wolfe

I agree to the following provisions and terms of this Scientific Permit.

Permittee's Signature: _____ (Permit not valid unless signed)

Approved By: _____ Office of Resource Conservation

Date: 3/8/19

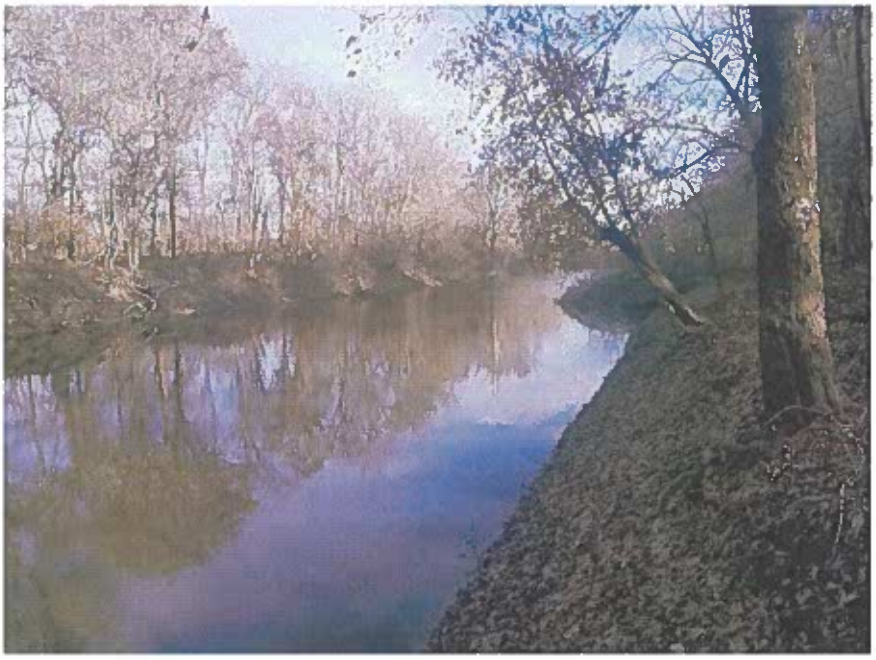
TERMS FOR SCIENTIFIC PERMIT

1. This permit is valid only for the approved methods, locations and activities stated on the permit.
2. All permitted activities shall be performed by or under the direct supervision of the permittee. Permittee must be present with persons involved in actual taking of fauna.
3. Under no circumstances shall a scientific permit be used in lieu of sport or commercial licenses.
4. This permit is valid only for species not listed as Illinois Threatened or Endangered (https://www.dnr.illinois.gov/conservation/NaturalHeritage/Pages/EndangeredandThreatenedSpecies.aspx). If a Threatened or Endangered species is incidentally captured, the specimen must be released and the occurrence must be reported to tara.kieninger@illinois.gov within 5 business days.
5. This permit does not allow the privilege of trespass. Landowner permission is required. Activities on Department sites are not permitted without the prior approval of the Site Superintendent. Activities on Illinois Nature Preserves and Land and Water Reserves must have prior approval from the Illinois Nature Preserve Commission.
6. Permittee must carry this permit at all times when taking specimens and be presented, upon request, to Department personnel.
7. Fauna taken and/or salvaged and rehabilitated must be released to the wild or permanently donated to a public or state scientific educational or zoological institution
8. This permit does not supersede Federal permits, which may be necessary for the permitted work.
9. All gear left unattended must be tagged bearing name and scientific permit number of permittee.
10. Use of rotenone or any other toxic materials for taking of fauna must have written approval from the Department prior to using such materials, and may need a variance from the Illinois Environmental Protection Agency.
11. An annual report must be submitted to the Department by January 31 of each year.
12. This permit may be revoked or suspended if the Department finds that a permittee has falsified information on the application, failed to comply with the provisions of this permit, or violated state or federal laws.

The Department of Natural Resources is an equal opportunity employer.

APPENDIX B

HABITAT MAPPING PHOTOGRAPHS



1. BM-1, upstream



2. BM-1, habitat



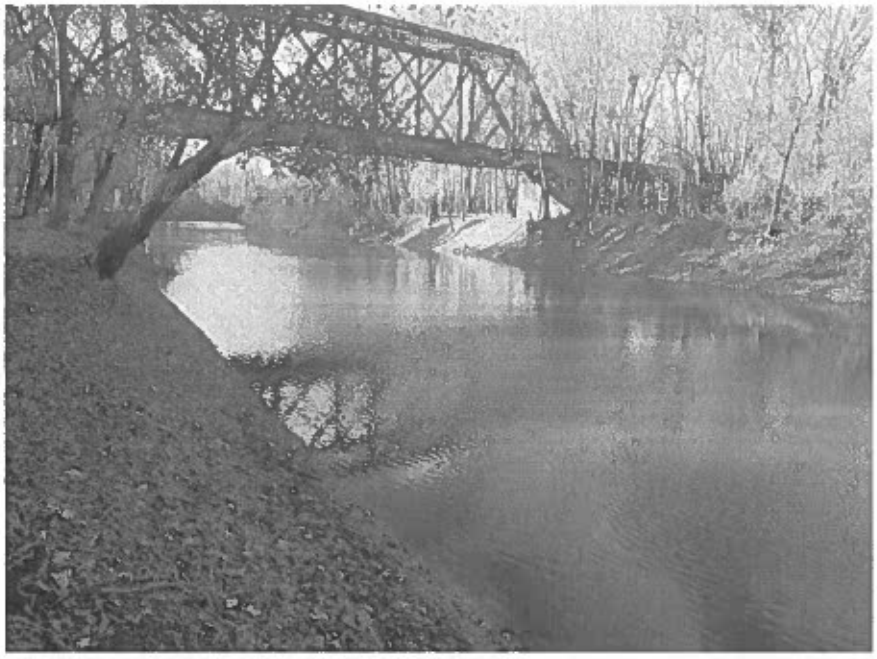
3. BM-1, downstream



4. BM-2, upstream



5. BM-2, habitat



6. BM-2, downstream



7. BM-3, upstream



8. BM-3, habitat



9. BM-3, downstream



10. BM-4, upstream



11. BM-4, habitat



12. BM-4, downstream



13. BM-5, upstream



14. BM-5, habitat



15. BM-5, downstream



16. BM-6, upstream



17. BM-6, habitat



18. BM-6, downstream



19. BM-7, upstream



20. BM-7, habitat



21. BM-7, downstream



22. BM-8, upstream



23. BM-8, habitat



24. BM-8, downstream



25. BM-9, upstream



26. BM-9, habitat



27. BM-9, downstream



28. BM-10, upstream



29. BM-10, habitat



30. BM-10, downstream



31. BM-11, upstream



32. BM-11, habitat



33. BM-11, downstream



34. BM-12, upstream



35. BM-12, habitat



36. BM-12, downstream



37. BM-13, upstream



38. BM-13, habitat



39. BM-13, downstream



40. BM-14, upstream



41. BM-14, habitat



42. BM-14, downstream



43. BM-15, upstream



44. BM-15, habitat



45. BM-15, downstream



46. BM-16, upstream



47. BM-16, habitat



48. BM-16, downstream



49. BM-17, upstream



50. BM-17, habitat



51. BM-17, downstream



52. BM-18, upstream



53. BM-18, habitat



54. BM-18, downstream



55. BM-19, upstream



56. BM-19, habitat



57. BM-19, downstream



58. BM-20, upstream



59. BM-20, habitat



60. BM-20, downstream



61. BM-21, upstream



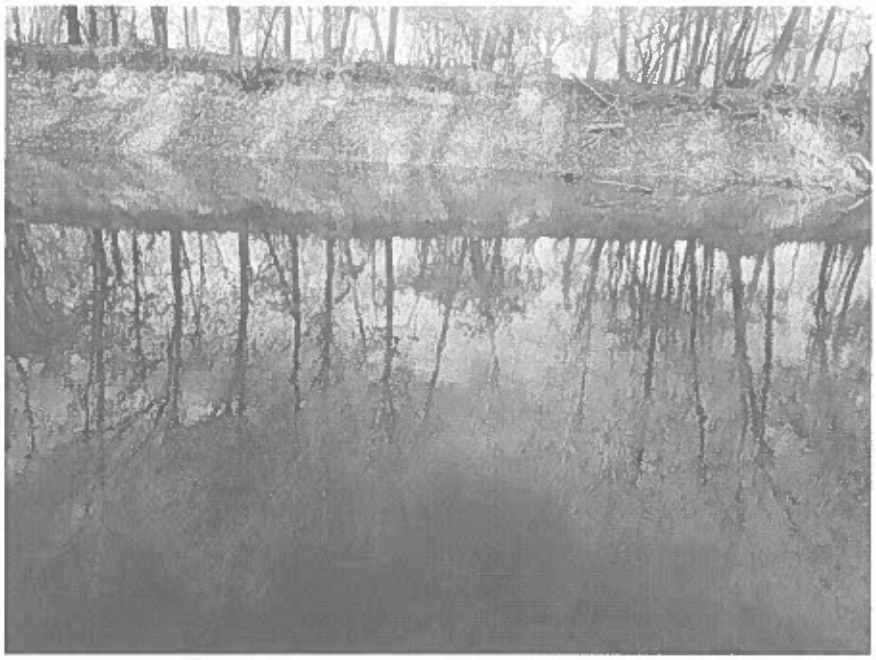
62. BM-21, habitat



63. BM-21, downstream



64. BM-22, upstream



65. BM-22, habitat



66. BM-22, downstream



67. BM-23, upstream



68. BM-23, habitat



69. BM-23, downstream



70. BM-24, upstream



71. BM-24, habitat



72. BM-24, downstream



73. BM-25, upstream



74. BM-25, habitat



75. BM-25, downstream



76. BM-26, upstream



77. BM-26, habitat



78. BM-26, downstream



79. BM-27, upstream



80. BM-27, habitat



81. BM-27, downstream



82. BM-28, upstream



83. BM-28, habitat



84. BM-28, downstream



85. BM-29, upstream



86. BM-29, habitat



87. BM-29, downstream



88. BM-30, upstream



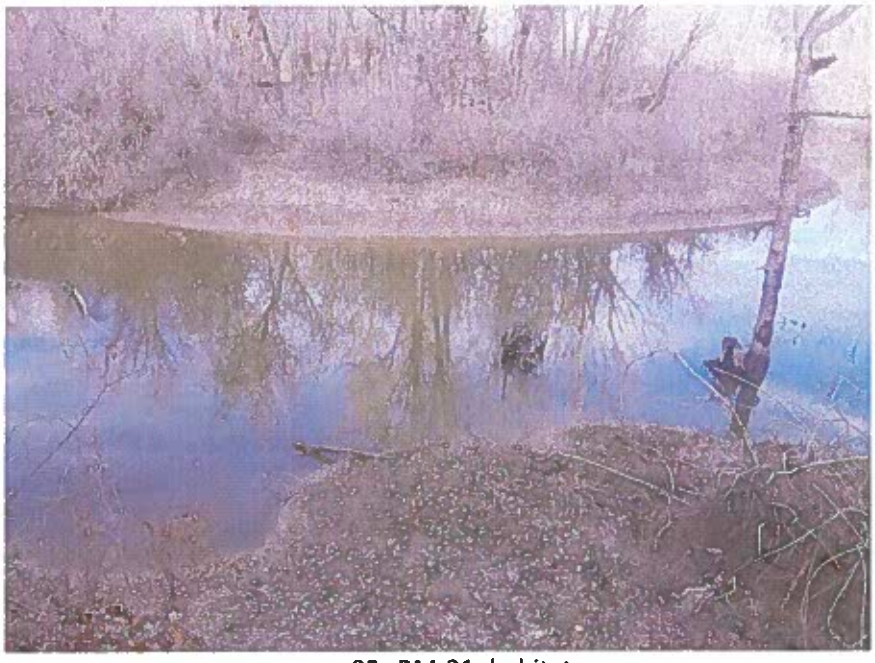
89. BM-30, habitat



90. BM-30, downstream



91. BM-31, upstream



92. BM-31, habitat



93. BM-31, downstream



94. BM-32, upstream



95. BM-32, habitat



96. BM-32, downstream

APPENDIX C

SUMMARY OF MACROINVERTEBRATE COMMUNITY SAMPLED

Alliance Consulting, Inc.

Engineers · Constructors · Scientists

Benthic Macroinvertebrate Sampling

Field Sampling	
Stream Name	Big Muddy River
Site/Station ID	**BM-1**
Project #	B16-454-1413
Method Used	1 m² kick
Date Collected	11/20/2019
Sample Collector(s)	Daniel Brady; Jeff Rabbitt
Sample Deliverer(s)	Daniel Brady

Laboratory Analysis	
Total # of Grids	100
# of Grids Picked	100
Total # of Ind.	274
Method Used	300 count subsample
Sample picker(s)	Daniel Brady
Date Picked	12/04/2019
Sample Identifier(s)	Daniel Brady
Date Identified	12/04/2019

Chain of Custody	
Collector(s)	Daniel Brady
	Jeff Rabbitt
Deliverer(s)	Daniel Brady
Picker(s)	Daniel Brady
Identifier(s)	Daniel Brady
Analyzer(s)	Daniel Brady

Order	Family	Count
Amphipoda	Gammaridae	1
Coleoptera	Psephenidae	1
Diptera	Ceratopogonidae	18
	Chironomidae	209
Ephemeroptera	Ephemeridae	30
Isopoda	Asellidae	7
Trichoptera	Hydropsychidae	1
	Leptoceridae	1
	Philopotamidae	1
Unionida	Unionidae	5
Total # of Individuals		**274**

APPENDIX D

SUMMARY OF MACROINVERTEBRATE METRIC RESULTS

TABLES

Table 1: BENTHIC RESULTS DATA				
Taxon	**Feeding Group**	**Tolerance Value**	**Tolerance Level**	**Sampling Station BM-1**
Amphipoda				
Gammaridae-Gammarus	omnivore	4	Facultative	1
Bivalvia				
Unionidae-ND	filter/collector	8	Tolerant	5
Coleoptera				
Psephenidae-ND	scraper	4	Facultative	1
Diptera				
Ceratopogonidae-ND	predator	5.7	Facultative	18
Chironomidae-ND	gatherer/collector	6	Tolerant	209
Ephemeroptera				
Ephemeridae-Ephemera	gatherer/collector	3.1	Facultative	30
Isopoda				
Asellidae-Asellus	gatherer/collector	9.4	Tolerant	7
Trichoptera				
Hydropsychidae-ND	filterer/collector	4	Facultative	1
Leptoceridae-ND	gatherer/collector	4	Facultative	1
Philopotamidae-ND	filterer/collector	3	Sensitive	1
			Totals	274

R01632

Table 2

Summary of Benthic Metric Results	
Metric	**Station**
	BM
Total Individuals	274
Total Taxa	10
Sensitive Individuals	1
% Sensitive Individuals	0.4%
# Sensitive Taxa	1
Facultative Individuals	52
% Facultative Individuals	19.0%
# Facultative Taxa	5
Tolerant Individuals	221
% Tolerant Individuals	80.7%
# Tolerant Taxa	3
No. of Coleoptera Taxa	1
No. of Ephemeroptera Taxa	1
No. of Intolerant Taxa	1
% Scrapers	0.36
% EPT	12.04
Shannon-Wiener Diversity Index	0.90
Macroinvertebrate Biotic Index (MBI)	5.73
Macroinvertebrate Index of Biotic Integrity (MIBI)	23.80
mIBI Rating	Fair

FIGURES



Legend

PHOTO LOCATIONS

SCALE

0 250 500 1,000 1,500 Feet

1 inch = 500 feet

Alliance Consulting, Inc.
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124 PHILPOTT LANE
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HABITAT ASSESSMENT MAP

WILLIAMSON ENERGY, LLC
DIFFUSSER LOCATION
PREPARED FOR
WILLIAMSON ENERGY, LLC
P.O. BOX 357
JOHNSTON CITY, IL 62951

DRAWN BY	BAH	12-11-19
CHECKED BY	BAH	12-11-19
APPROVED BY		

DRAWING NUMBER
B16-454-A3

R010935



SCALE

0 250 500 1,000 1,500 Feet

1 inch = 500 feet

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SAMPLING LOCATION MAP

WILLIAMSON ENERGY, LLC

DIFFUSSER LOCATION

PREPARED FOR

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DRAWN BY	BAH	12-11-19
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ILLINOIS NATURAL
HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

Freshwater Mussels of the Big Muddy River

Diane K. Shasteen, Alison L. Price, Sarah A. Bales

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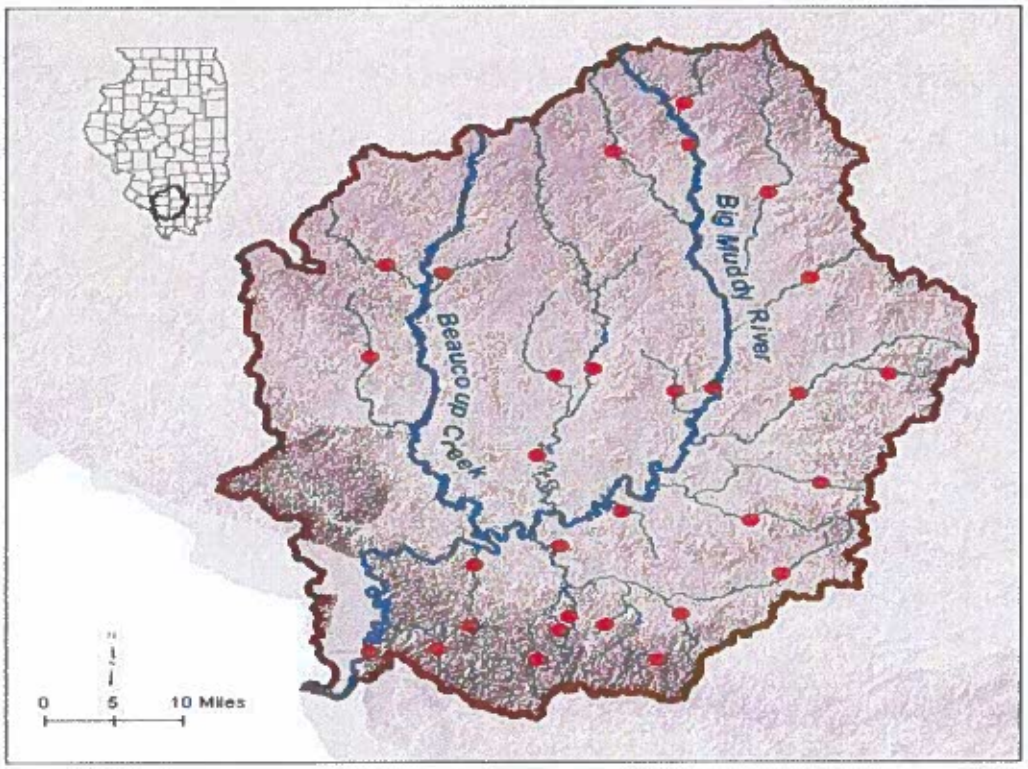
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R01638

Freshwater Mussels of the Big Muddy River



2012

Illinois Natural History Survey, Prairie Research Institute, University of Illinois
Illinois Department of Natural Resources

Diane Shasteen, Alison Price, Sarah Bales

Preface

While broad geographic information is available on the distribution and abundance of mussels in Illinois, systematically collected mussel-community data sets required to integrate mussels into aquatic community assessments do not exist. In 2009, a project funded by a US Fish and Wildlife Service State Wildlife Grant was undertaken to survey and assess the freshwater mussel populations at wadeable sites from 33 stream basins in conjunction with the Illinois Department of Natural Resources (IDNR)/Illinois Environmental Protection Agency (IEPA) basin surveys. Inclusion of mussels into these basin surveys contributes to the comprehensive basin monitoring programs that include water and sediment chemistry, instream habitat, macroinvertebrate, and fish, which reflect a broad spectrum of abiotic and biotic stream resources. These mussel surveys will provide reliable and repeatable techniques for assessing the freshwater mussel community in sampled streams. These surveys also provide data for future monitoring of freshwater mussel populations on a local, regional, and watershed basis.

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Introduction

Freshwater mussel populations have been declining for decades and are among the most seriously impacted aquatic animals worldwide (Bogan 1993, Williams et al. 1993). It is estimated that nearly 70% of the approximately 300 North American mussel taxa are extinct, federally-listed as endangered or threatened, or in need of conservation status (Williams et al. 1993, Strayer et al. 2004). In Illinois, 25 of the 62 extant species (44%) are listed as threatened or endangered (Illinois Endangered Species Protection Board 2011). While broad geographic information is available on the distribution and abundance of mussels in Illinois, systematically collected mussel-community data sets required to integrate mussels into aquatic community assessments do not exist. Sampling of mussels has been very sporadic and limited in the Big Muddy River basin and no known reports pertaining to mussel communities of the basin have been published. This report summarizes the mussel survey conducted in the Big Muddy River basin in 2009-2010 in conjunction with IDNR and IEPA basin surveys.

The Big Muddy River basin drains 3798 km^2 (2360 mi^2) in the southern part of Illinois and contains principal tributaries of Casey Fork, Middle Fork Big Muddy, Beaucoup Creek, Little Muddy River, and Crab Orchard Creek (Page et al. 1992). Originating near Cravat in Jefferson County, the Big Muddy River basin drains through the counties of Jefferson, Washington, Perry, Franklin, Williamson, and Jackson. The river mainstem forms the Jackson /Union county line and joins the Mississippi River south of Grand Tower (Figure 1). The Big Muddy River basin flows through four natural divisions, including the Lower Mississippi River Bottomlands, Ozark, Shawnee Hills, and Southern Till Plain (Schwegman 1973). The Southern Till Plain comprises the majority of the basin which is characterized by hilly upland topography and a broad flood plain (Forbes and Richardson 1908).

Land-use and Instream Habitat

In the Big Muddy River basin, land use varies slightly by county with approximately 50 to 75% of the area in agriculture. Forested lands account for 8 to nearly 25% of the landscape with the larger forested areas being located in Jackson and Williamson counties (IDA 2000). Three of the largest cities in southern Illinois with populations between 15,000 and 28,000 (Marion, Mt. Vernon, and Carbondale) are also located in this basin (IEPA 1996, US Census Bureau 2010). In 1965, the Big Muddy River was dammed near Benton and thus Rend Lake, the second largest inland impoundment in the state, was created (Page et al. 1992, USACE 2005). This reservoir provides over 15 million gallons of water per day to approximately 300,000 people in over 60 communities throughout the basin. It is also used extensively for recreational activities including boating, fishing, waterfowl hunting and camping (USACE 2005). These recreational activities are also popular in the Shawnee National Forest, Giant City State Park, Lake Kinkaid and Murphysboro, Crab Orchard National Wildlife Refuge, and LaRue Pine Hills Ecological Area,

which are all located within the Big Muddy River basin. In the southwestern part of this basin, especially near the Murphysboro area, strip mining for coal was prevalent during the early 20th century and pollution from the remaining spoil banks continues to be a problem in the basin (Page et al. 1992).

During glacial activity in the region, the Mississippi River exceeded its sediment transporting capacity thus closing off the mouths of its tributary streams, including the Big Muddy River. The Big Muddy River temporarily formed a lake; once the natural process of removing sediment returned to the Mississippi River a deeper channel emerged. As the Big Muddy River drained, soils typical of a lake bed were left behind (LeTellier 1971). Today, the soils of the Big Muddy basin consist of impervious clays, silt and fine sand. The substrates in all of the streams of this basin were dominated by some combination of sand, silt, and clay. Excessive siltation along with large woody debris was common at many sites within the basin (Figure 2 and 3). Most of the sites in the basin had wadeable water depths; however sampling sites were limited on the mainstem of the Big Muddy and on Beaucoup Creek due to non-wadeable water depths (e.g., depth>1m).

Methods

During the 2009/2010 surveys, freshwater mussel data were collected at 30 sites: 3 mainstem and 27 tributary sites in the Big Muddy River basin (Figure 1, Table 1). Locations of sampling sites are listed in Table 1 along with information regarding IDNR/IEPA sampling at the site. In most cases, mussel survey locations were the same as IDNR/IEPA sites.

Live mussels and shells were collected at each sample site to assess past and current freshwater mussel occurrences. Live mussels were surveyed by hand grabbing and visual detection (e.g. trails, siphons, exposed shell) when water conditions permitted. Efforts were made to cover all available habitat types present at a site including riffles, pools, slack water, and areas of differing substrates. A four-hour timed search method was implemented at each site. Live mussels were held in the stream until processing.

Following the timed search, all live mussels and shells were identified to species and recorded (Table 2). For each live individual, shell length (mm), gender, and an estimate of the number of growth rings were recorded. Shell material was classified as recent dead (periostracum present, nacre pearly, and soft tissue may be present) or relict (periostracum eroded, nacre faded, shell chalky) based on condition of the best shell found. A species was considered extant at a site if it was represented by live or recently dead shell material (Szafoni 2001). The nomenclature employed in this report (Appendix 1) follows Turgeon et al. (1998) except for recent taxonomic changes to the gender ending of lilliput (*Toxolasma parvum*), which follows Williams et al. (2008). Voucher specimens were retained and deposited in the Illinois Natural History Survey

Mollusk Collection. All non-vouchered live mussels were returned to the stream reach where they were collected.

Parameters recorded included extant and total species richness, presence of rare or listed species, and individuals collected, expressed as catch-per-unit-effort (CPUE; Table 2). A population was considered to indicate recent recruitment if individuals less than 30 mm in length or with 3 or fewer growth rings were recorded. Finally, mussel resources were classified as Unique, Highly Valued, Moderate, Limited, or Restricted (Table 2) based on the above parameters (Table 3) and following criteria outlined in Table 4 (Szafoni 2001).

Results

Species Richness

A total of 19 species of freshwater mussels were observed in the Big Muddy River basin, all of which were collected live (Table 2). Across all sites, the number of live species collected, the number of extant species collected (live + dead), and the total number of species collected (live + dead + relict) ranged from 0 to 13. The giant floater (*Pyganodon grandis*) had the most occurrences across sites sampled with live mussels present (11 of 30 sites; 37%; Figure 4). The lilliput (*Toxolasma parvum*), paper pondshell (*Utterbackia imbecillis*), pondhorn (*Uniomerus tetralasmus*) and white heelsplitter (*Lasmigona complanata*) were other commonly occurring species (Figure 4), occupying 17% of these sites. Site 6, the Big Muddy River near Benton, had the greatest species richness with 12 live species.

Abundance and Recruitment

A total of 358 individuals were collected across 30 sites. The number of live specimens collected at a given site ranged from 0 to 133, with an average of 16 mussels per site where live mussels were collected (22 of 30 sites; Table 2). A total of 120 collector-hours were spent sampling with an average of three mussels collected per hour. Nine sites yielded more than 10 live individuals and 2 of the 9 sites (sites 6 and 15) yielded more than 45 live individuals. The most common species collected in the Big Muddy basin were giant floater (*n*=131), mapleleaf (*Quadrula quadrula*; n=37), white heelsplitter (n=34), lilliput (n=24), and pink papershell (*Potamilus ohiensis;* n=20), which together comprised approximately 70% of the individuals collected.

Recruitment for each species was determined by the presence of individuals less than 30mm or with 3 or fewer growth rings. Smaller (i.e., younger) mussels are harder to locate by hand grab methods and large sample sizes can be needed to accurately assess population reproduction. However, a small sample size can provide evidence of recruitment if it includes individuals that are small or possess few growth rings. Alternatively, a sample consisting of very large (for the species) individuals with numerous growth rings suggests a senescent population.

Recruitment at individual sites ranged from none observed to high across the basin. Recruitment levels, referred to in Table 3 as Reproduction Factor, varied from one to five, and three of the sites in the Big Muddy River basin exhibited high to very high recruitment. Recruitment was over 50% at site 7, Andy Creek, and 30 to 50% at sites 1 and 9, Snow Creek and Middle Fork Big Muddy (Figure 5). Sites 2 and 29, Big Muddy River and Cedar Creek, exhibited recruitment from 1 to 30% of species collected. Recruitment may be occurring at site 30, Big Muddy mainstem, where dead shells of nearly all species collected were less than 3 years of age. All other sites in the Big Muddy River basin (24 of 30) exhibited no observed recruitment during this survey.

Mussel Community Classification

Based on the data collected in the 2009/2010 basin surveys, nearly 75% of the sites in the Big Muddy River basin have Restricted or Limited mussel communities using the current MCI classification system (Table 4, Figure 5). No sites are ranked as Unique or Highly Valued in the basin. Eight sites (sites 1, 2, 6, 7, 9, 15, 23, and 29) in the Big Muddy River basin were ranked as Moderate mussel resources.

Noteworthy Finds

According to historical records, 25 species are known from the Big Muddy River basin (Tiemann et al. 2007). All 19 species found during this survey had been recorded in the basin historically. However, three of these species had not been recorded live since 1969; these species included Wabash pigtoe (*Fusconaia flava*), pondmussel (*Ligumia subrostrata*), and deertoe (*Truncilla truncata*). Historic species not detected during this survey include creeper (*Strophitus undulatus*), spike (*Elliptio dilatata*), pimpleback (*Quadrula pustulosa*), plain pocketbook (*Lampsilis cardium*), pink heelsplitter (*Potamilus alatus*), and fawnsfoot (*Truncilla donaciformis*).

A possible range expansion may be occurring with the Louisiana fatmucket (*Lampsilis hydiana)* which occurs in the upper Arkansas, White and St. Francis rivers and in Louisiana and East Texas (NatureServe 2011). Specimens collected during this survey were classified as *Lampsilis siliquoidea* (*hydiana*) due to morphological features that resemble the Louisiana fatmucket (pers. comm. Kevin Cummings). Additional genetic testing would need to be conducted to correctly determine which species, *Lampsilis siliquoidea* or *Lampsilis hydiana*, exists in the Big Muddy basin.

Discussion

Our survey documented 19 species from the Big Muddy River basin, all were recorded live. No new species were found that had previously been undetected and six species previously detected were not found during our survey. Of these six species, only the plain pocketbook has

been documented as live in the basin. This species was found at three tributaries in the late 1990's to early 2000's; however these streams were not sampled during our survey. These sites would need to be surveyed to determine if this species is still present in the basin. Of the remaining five species not collected, deertoe and creeper have been documented only by relict shell, and the pink heelsplitter, pimpleback, and spike have not been documented since the late 1800's, early 1900's. All of these species were collected from the Big Muddy mainstem. These particular species, except for spike, are widespread and common throughout most of Illinois (Cummings and Mayer 1992) and all of these species are known from other major Mississippi River tributaries including the Rock, Illinois, and Kaskaskia Rivers (INHS Mollusk Collection Database). Sampling the mainstem of the Big Muddy was hindered by non-wadeable water depths; therefore additional sampling by alternative means would need to be conducted to determine if these species have indeed been extirpated from the basin.

Recruitment

Data collected during this survey indicate that very recent recruitment may not be occurring at most (25 of 30) sites in the Big Muddy basin. Only 3 of the 30 sites exhibited high to very high recruitment and 2 other sites had moderate recruitment noted. This finding suggests that most mussel communities of the Big Muddy may not be viable and self-maintaining. Although very few mussels collected during this basin survey fell into the category of 3 age rings or younger, many of them ranged from 4 to 10 years of age. This would indicate that the populations observed in most streams are within the age range thought to be reproductively active (Haag and Staton 2003). Therefore, we cannot conclusively state that the mussel communities of this system are void of recruitment. Recruitment may also be occurring on the Big Muddy mainstem near the Mississippi as nearly all of the dead shells found at site 30 were less than 3 years of age. Sampling methods to target juvenile mussels would be necessary to better assess the reproductive status of these populations.

Mussel community of the Big Muddy River basin

There is limited mussel community information relating to this basin from past surveys and reports. Nearly 90% of the sites sampled had no historical data available (Table 2), and there is no known intensive survey for mussels in this basin. Our surveys documented the existence of 19 species in the Big Muddy River basin from which 25 species were known historically. Additionally, our surveys found that all 19 species were represented by live individuals. Five of the six species not collected during this survey are represented by either relict shell or pre-1930 collections.

Other major Mississippi tributaries such as the Kaskaskia, Rock, and Illinois Rivers have a larger mussel fauna base according to historical records and recent surveys. Historically, these basins

contained 43, 47, and 49 species, respectively, while the Big Muddy has only 25 recorded species (Tiemann et al. 2007). Several theories could be offered on the disparity of species in this basin including the inability to conduct wadeable surveys, challenging diving conditions, lack of river access by vehicle, or the lack of suitable substrate composition for varying species. Substrates such as gravel, cobble, and boulder are practically nonexistent in the Big Muddy basin. As mentioned in the introduction, the substrate of the Big Muddy is predominately impervious clay, silt, and sand. The Big Muddy basin provides suitable substrates for many mussel species such as the giant floater, white heelsplitter, and other Anodontines. However, many species that occur in the other major Mississippi tributaries such as mucket (*Actinonaias ligamentina*), black sandshell (*Ligumia recta*), and threehorn wartyback (*Obliquaria reflexa*) prefer a mixture of substrate types including gravel, sand, and cobble (Cummings and Mayer 1992). Sedimentation and siltation of the streams in this basin may be another factor influencing the lack of these species. These factors are listed as impairments for aquatic life for many mainstem sites on the Big Muddy and several tributaries within the basin (IEPA 2010). With the lack of coarser substrates from the basin both today and historically, it may be safe to assume that many of these species have never existed in the basin. However, this statement cannot be made conclusively, due to a lack in historical information.

Living up to its name, sampling in the Big Muddy basin is challenging at best due to water depths (Big) and high turbidity (Muddy). The Big Muddy mainstem and many of its larger tributaries, such as Beaucoup and Drury Creeks, are not easily surveyed for freshwater mussels, thus it is difficult to accurately determine species richness of the basin. It is possible that the Big Muddy River provides a haven for the recruitment of many mussel species, based on the dead shells less than 3 years of age found at site 30, the nature of its substrates, and the river's connection with the Mississippi River. We are unable to conclusively state that the Big Muddy is serving as a source population for mussel species because of the lack of historical data and difficulty in sampling the basin. Additional sampling, either diving or boating to shallow areas on the lower portion of the mainstem and larger tributaries, would be needed to adequately determine the mussel fauna of this basin.

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Table1. 2009/2010 Big Muddy River Intensive Basin Survey. Types of samples include MU-mussel sampling, BE-boat electrofishing, ES-electric fish seine, SH-fish seine hauls, FF-fish flesh contaminate, H-habitat, M-macroinvertebrate, S-sediment, W-water chemistry. *Drury Creek Survey not completed due to water depth >3m.

Site Number	IEPA Code	Stream	Types of Samples	County	Location	Watershed Area (km^2)
1	NL-01	Snow Creek	MU, ES,H,M,S,W	Jefferson	6 mi NW Mt Vernon; Rd 1850N	49.60
2	N-05	Big Muddy River	MU, ES,H,M,S	Jefferson	1.5 mi NE Woodlawn Co Rd; 1450N	154.04
3	NK-02	Rayse Creek	MU	Jefferson	3.7 mi W Woodlawn; Rd 1400N	119.89
4	NJ-26	Casey Fork	MU	Jefferson	SE Mt Vernon; DNS Rt 142	196.87
5	NI-01	Gun Creek	MU, ES,H,M,S,W	Jefferson	3.3 mi E Ina	35.62
6	N-06	Big Muddy River	MU, BE,H,M,S,W	Franklin	Rt 14 Br; 3 mi W Benton	1287.86
7	NZN-15	Andy Creek	MU, ES,H,M,S,W	Franklin	Satch Road; 1.6 mi NE of Christopher	33.54
8	NHG-01	Akin Creek	MU, ES,H,M,S,W	Franklin	N Botail Road; 8.8 mi E of Benton	21.98
9	NH-23	Middle Fork	MU, BE,H,M,S	Franklin	2.2 mi SE Bent; Us Rt 34	329.47
10	NG-05	Pond Creek	MU, SH,H,M,S,W	Williamson	Liberty School Rd; 4.7 mi SE of West Frankfort	31.84
11	NGA-02	Lake Creek	MU, ES,H,M,S,W	Williamson	Co Rd 1200E; 0.3 mi S Johnston City	40.90
12	NF-01	Hurricane Creek	MU, ES,H,M,S,W	Williamson	4 mi WNW Herrin	60.67
13	NE-04	Little Muddy River	MU	Perry	Rt 14 Br; 2 mi E Old Duquoin	426.62
14	NEB-02	Reese Creek	MU, ES,H,M,S,W	Perry	2 mi E Duquoin on Park St	60.79
15	NE-05	Little Muddy River	MU, BE,H,M,S,W	Jackson	1.3 mi E of Elkville	684.39
16	ND-04	Crab Orchard Creek	MU, ES,H,M,S,W	Williamson	Rt 13 Br; E edge of Marion	82.52
17	NDJ-01	Wolf Creek	MU, ES,H,M,S,W	Williamson	E Rt 148; old railroad	44.74
18	NDD-03	Grassy Creek	MU, ES,H,M,S,W	Williamson	At Wolf Creek Rd	14.84
19	NDDA-01	Little Grassy	MU, ES,H,M,S,W	Williamson	6 mi SSW Carterville	47.11
20	NDC-99*	Drury Creek	ES,H,M,S,W	Jackson	0.2 mi US Makanda business dist	47.29
21	NDCB-01	Indian Creek	MU, ES,H,M,S,W	Jackson	2.5 mi NE Makanda	14.01
22	NDCA-01	Sycamore Creek	MU, ES,H,M,S,W	Jackson	2 mi E of Boskydell	5.27
23	ND-01	Crab Orchard Creek	MU, BE,H,M,S,W	Jackson	4 mi NE Carbondale	693.93
24	NCK-02	Swanwick Creek	MU, ES,H,M,S,W	Perry	Misty Road; 5.8 mi NW of Pinckneyville	117.41
25	NCI-01	Little Beaucoup Creek	MU, ES,H,M,S,W	Perry	6 mi NNE Pinckneyville	46.96
26	NCDB-01	Little Galum Creek	MU, SH,H,M,S,W	Perry	Galum Cr Rd; 0.5 mi N Pyramid St	30.47
27	NZL-01	Mud Creek	MU, ES,H,M,S,W	Jackson	West Lake Road; 2.1 mi SE of Muphysboro	25.54
28	NAC-02	Cave Creek	MU, ES,H,M,S,W	Jackson	Jerusalem Hill Road; 0.2 mi W of Ponoma	15.24
29	NA-03	Cedar Creek	MU, ES,H,M,S	Jackson	1 mi S Brewer School on Dutch Ridge	80.38
30	N-99	Big Muddy River	MU, BE,H,M,S	Jackson	5 mi E Grandtower at Rattlesnake Ferry	6064.97

R01648

Table 2. Mussel data for sites sampled during 2009/2010 surveys (Table 1). Numbers in columns are live individuals collected; "D" and "R" indicates dead or relict shells collected. Shaded boxes are historic collections at the specific site location obtained from the INHS Mollusk Collection records. Species in bold are federally or state-listed species or species in Greatest Need of Conservation by IL DNR. Proportion of total is number of individuals of a species divided by total number of individuals at all sites. Extant species is live + dead shell and total species is live + dead + relict shell. NDA represents no historical data available. MCI scores and Resource Classification are based on values in Tables 3 and 4 (R= Restricted, L= Limited, M= Moderate, HV= Highly Valued, and U= Unique).
*Includes *Strophitus undulatus*, *Elliptio dilatata*, *Quadrula pustulosa*, *Lampsilis cardium*, *Potamilus alatus*, and *Truncilla donaciformis*, historical species not collected during this survey.

	Site Number																						Proportion of Total
	1	2	3	5	6	7	9	11	13	14	15	16	17	19	23	24	25	26	27	28	29	30	
Anodontinae																							
Anodonta suborbiculata					1		2				D												1%
Arcidens confragosus											4				D							D	1%
Lasmigona complanata					19					1	9				1						4		9%
Pyganodon grandis		12	1	R	30		23	2	2	21	19	R	D	12	D	D			1		8	D	37%
Strophitus undulatus																							0%
Utterbackia imbecillis	1	1			D		3				1										2	D	2%
Ambleminae																							
Amblema plicata		1			4				1		3												3%
Elliptio dilatata																							0%
Fusconaia flava					1																		0%
Megalonaias nervosa					16										1								5%
Quadrula pustulosa																							0%
Quadrula quadrula					26				2		6				3								10%
Tritogonia verrucosa					1																		0%
Uniomerus tetralasmus	1	R				2				1							2	D	R	1			2%
Lampsilinae																							
Lampsilis cardium																							0%
Lampsilis siliquoidea (hydiana)		3														D							1%
Lampsilis teres					4						4				1						5		4%
Leptodea fragilis					8				1	1	D				1							D	3%
Ligumia subrostrata	4	4	2									R		4									4%
Potamilus alatus																							0%
Potamilus ohiensis					19						1											D	6%
Toxolasma parvum	16	3	3											1							1		7%
Toxolasma texasiensis	1	5	D			4	D			D													3%
Truncilla donaciformis																							0%
Truncilla truncata					4										6								3%
																							Total
Individuals	23	29	6	0	133	6	28	2	6	24	47	0	0	17	13	0	2	0	1	1	20	0	358
Live Species	5	7	3	0	12	2	3	1	4	4	8	0	0	3	6	0	1	0	1	1	5	0	19
Extant Species	5	7	4	0	13	2	4	1	4	5	10	0	1	3	8	2	1	1	1	1	5	5	19
Total Species	5	9	4	1	13	2	4	1	4	5	10	2	1	3	8	2	1	1	2	1	5	5	19
Historical Species	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	2	NDA	NDA	NDA	1	NDA	NDA	1	6	25*
Catch per unit effort (CPUE)	5.76	7.02	1.50	0.00	33.33	1.50	6.97	0.50	1.50	6.00	11.78	0.00	0.00	4.25	3.25	0.00	0.50	0.00	0.25	0.25	5.00	0.00	
Mussel Community Index (MCI)	10	10	7	0	11	10	10	4	7	7	10	0	0	6	8	0	4	0	4	4	9	0	
Resource Classification	M	M	L	R	M	M	M	R	L	L	M	R	R	L	M	R	R	R	R	R	M	R	

R01649

Table 3. Mussel Community Index (MCI) parameters and scores.

Extant species in sample	Species Richness
0	1
1-3	2
4-6	3
7-9	4
10+	5

Catch per Unit Effort (CPUE)	Abundance (AB) Factor
0	0
1-10	2
>10-30	3
>30-60	4
>60	5

% live species with recent recruitment	Reproduction Factor
0	1
1-30	3
>30-50	4
>50	5

# of Intolerant species	Intolerant species Factor
0	1
1	3
2+	5

Table 4. Freshwater mussel resource categories based on species richness, abundance, and population structure. MCI = Mussel Community Index Score

Unique Resource MCI ≥ 16	Very high species richness (10 + species) &/or abundance (CPUE > 80); intolerant species typically present; recruitment noted for most species
Highly Valued Resource MCI = 12- 15	High species richness (7-9 species) &/or abundance (CPUE 51-80); intolerant species likely present; recruitment noted for several species
Moderate Resource MCI = 8 - 11	Moderate species richness (4-6 species) &/or abundance (CPUE 11-50) typical for stream of given location and order; intolerant species likely not present; recruitment noted for a few species
Limited Resource MCI = 5 - 7	Low species richness (1-3 species) &/or abundance (CPUE 1-10); lack of intolerant species; no evidence of recent recruitment (all individuals old or large for the species)
Restricted Resource MCI = 0 - 4	No live mussels present; only weathered dead, sub-fossil, or no shell material found

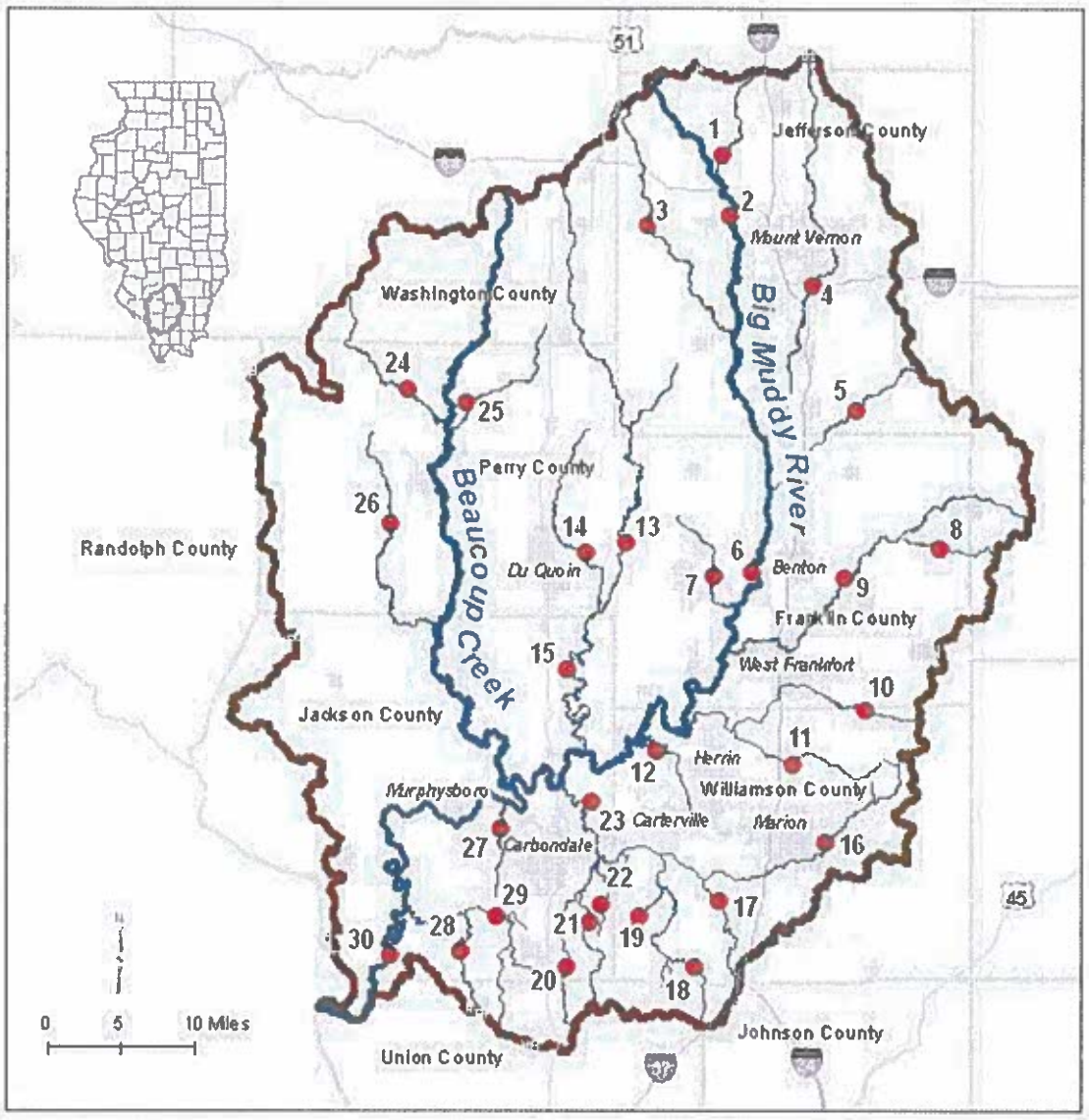


Figure 1. Sites sampled in the Upper and Lower Big Muddy River basin during 2009. Site codes referenced in Table 1.

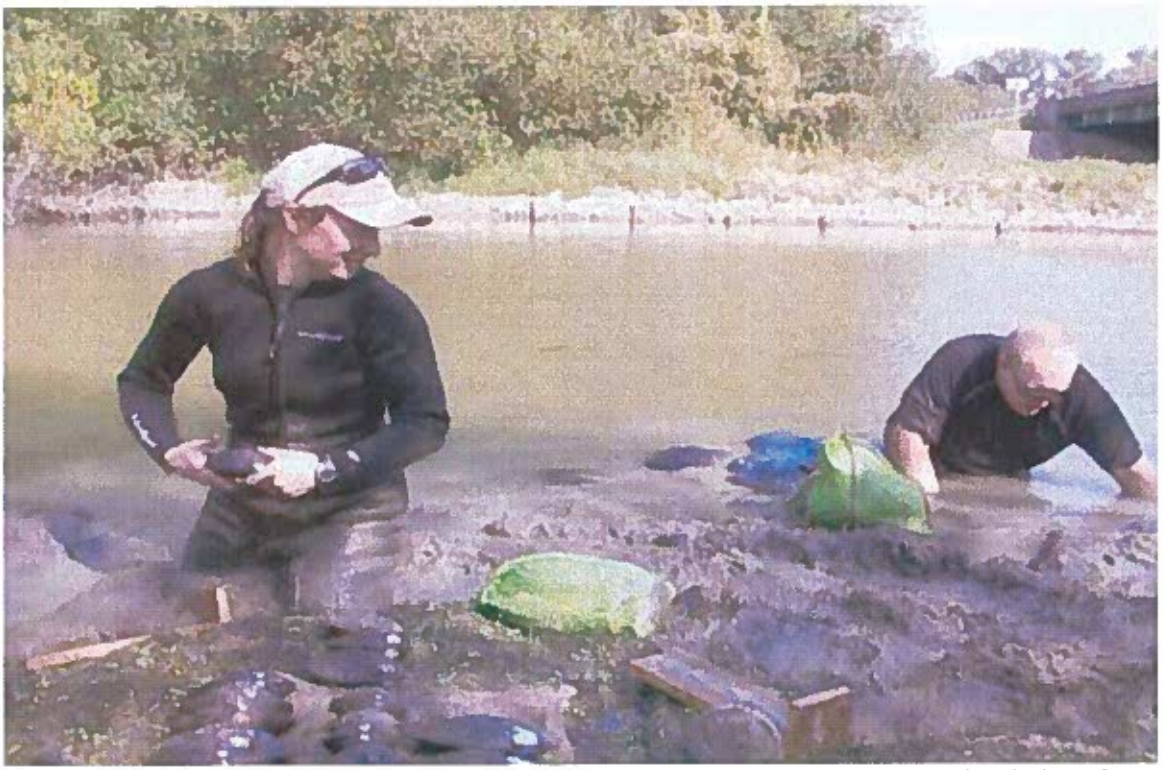


Figure 2. Big Muddy near Benton, Illinois (Site 6). Note excessive sedimentation and turbidity of river. Alison Price and A. J. Berger measuring mussels sunk up to thighs and waist in silt.



Figure 3. Casey Fork near Mt. Vernon, Illinois (Site 4). Note large woody debris in stream, silt/clay banks, and turbidity of river.

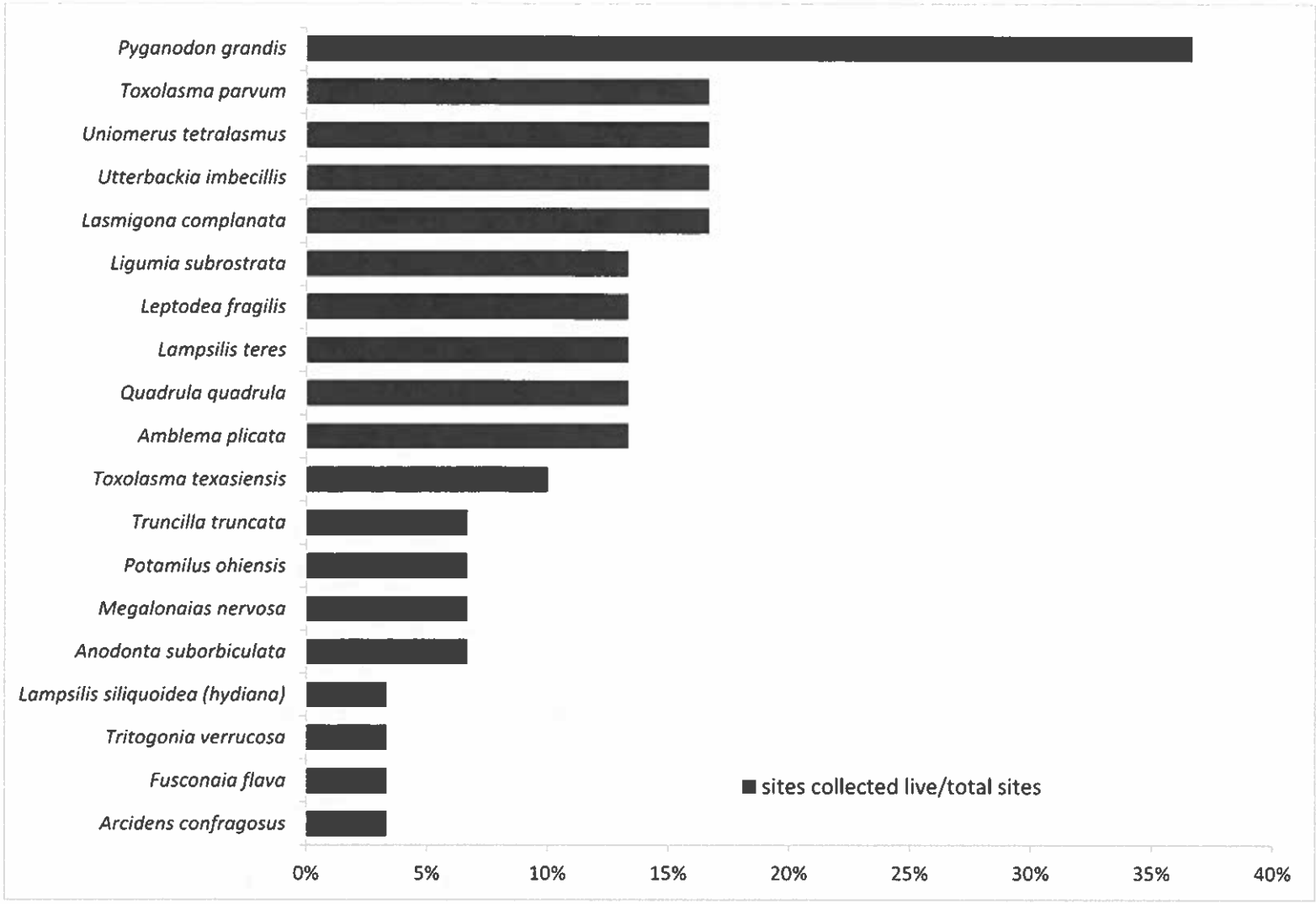


Figure 4. Number of sites where a species was collected live compared to the number of total sites sampled (30 total sites).

R01653

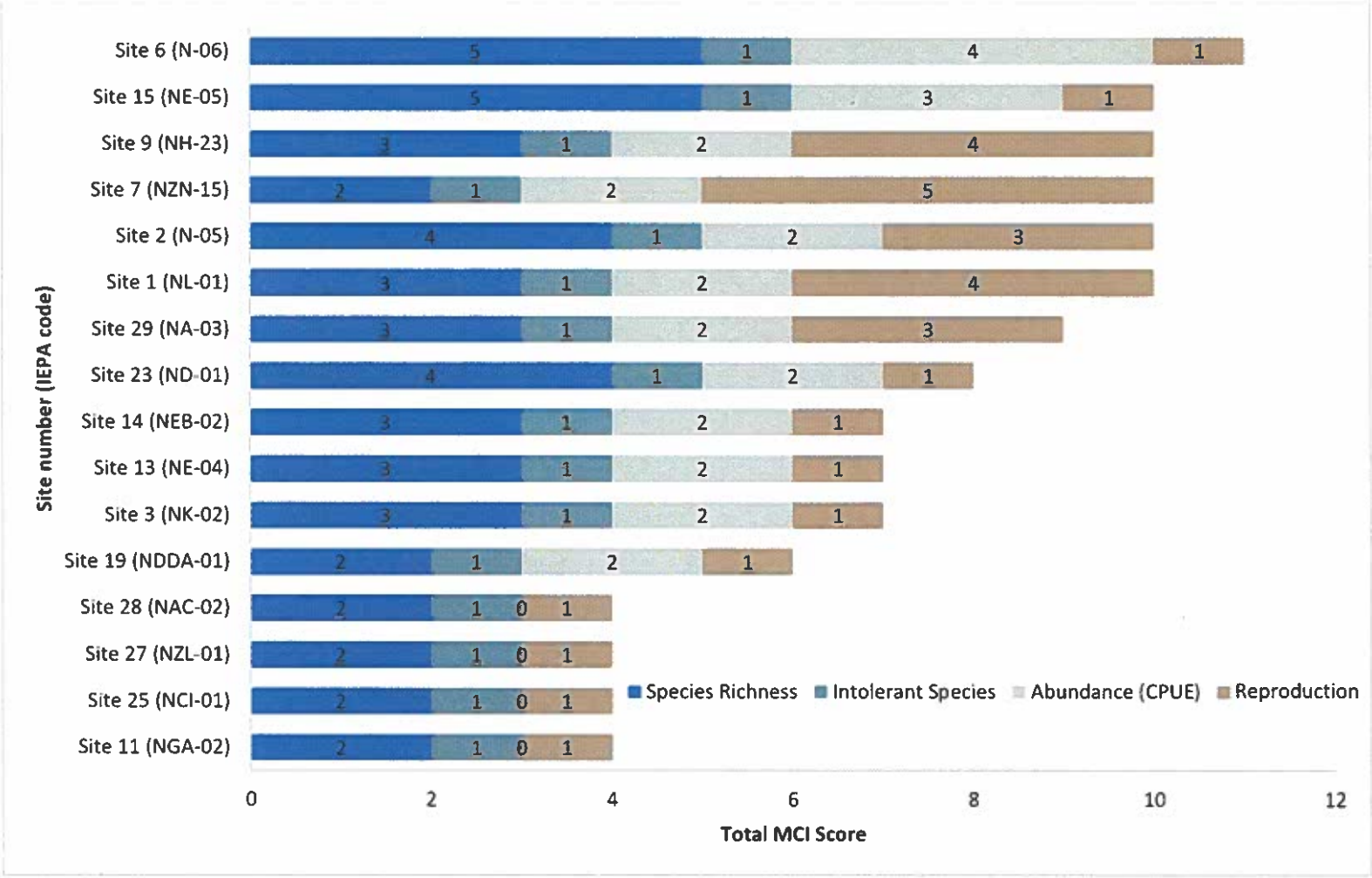


Figure 5. Comparison of Mussel Community Index (MCI) and MCI component scores for Big Muddy River basin sites based on factor values from Table 3.

R01654

Appendix 1. Scientific and common names of species. ST= state threatened.

Scientific Name	Common Name	Status
	Subfamily Anodontinae	
Anodonta suborbiculata	flat floater	
Arcidens confragosus	rock pocketbook	
Lasmigona complanata	white heelsplitter	
Pyganodon grandis	giant floater	
Strophitus undulatus	creeper	
Utterbackia imbecillis	paper pondshell	
	Subfamily Ambleminae	
Amblema plicata	threeridge	
Elliptio dilatata	spike	ST
Fusconaia flava	Wabash pigtoe	
Megalonaias nervosa	washboard	
Quadrula pustulosa	pimpleback	
Quadrula quadrula	mapleleaf	
Tritogonia verrucosa	pistolgrip	
Uniomerus tetralasmus	pondhorn	
	Subfamily Lampsilinae	
Lampsilis cardium	plain pocketbook	
Lampsilis siliquoidea hydiana	Louisiana fatmucket	
Lampsilis teres	yellow sandshell	
Leptodea fragilis	fragile papershell	
Ligumia subrostrata	pondmussel	
Potamilus alatus	pink heelsplitter	
Potamilus ohiensis	pink papershell	
Toxolasma parvum	lilliput	
Toxolasma texasiensis	Texas lilliput	
Truncilla donaciformis	fawnsfoot	
Truncilla truncata	deertoe	

AquAeTer

optimizing
resources | water, air, earth

MEMORANDUM

TO: **James Plumley**
CC: Clayton Cross
FROM: John Michael Corn, P.E. (TN)
DATE: January 17, 2020
JOB NO.: 192590
RE: **Updated CORMIX Model Results**

AquAeTer previously submitted a mixing zone report detailing the conceptual diffuser design for the proposed diffuser on the Big Muddy River. At that time, we utilized the data available to us from the USGS Plumfield gage for the channel geometry. An additional consideration for the diffuser design was the amount of debris carried by the River. During one of our reconnaissance trips on the stream, we could not access the current location from the USGS gage site due to a log jam. For that reason, we wanted to keep the ports as low as possible to reduce the possibilities of log strikes, both from the standpoint of reducing the risk of damage to the ports and to reduce the risk of log jams forming at the diffuser.

Prior to the Public Comment Period, Mr. Scott Thwaite of the Illinois Environmental Protection Agency (IEPA) requested that we revise the modeling to reduce bottom attachment.

MODEL RESULTS

The model results are shown in Table 1. The changes made to the model will be discussed in further detail in the section following this one. For most cases, Case 1 maximum flow being the exception, the distances required to achieve the necessary dispersion of 34.0:1 were shorter than those reported in the Mixing Zone Report. The Case 1 maximum flow scenario required approximately ten feet further downstream to meet 34:1. For all cases, the cross-sectional area of the plume(s) was(were) less than 25% of the cross-sectional area of the River.

In looking that the independent calculations, the plume from each port is expected to be stable. This means that the plumes will emanate from the port and expand outward in a bell-shaped geometry. This is important to keep in mind since CORMIX uses rectangular shapes for all model subsections after the initial jet zone.

Table 1. Model Results

SCENARIO	RIVER FLOW (cfs)	ACTIVE PORT(S)	TOTAL DISCHARGE (gpm)
Case 1, Min.	30	Port 1	102
Case 1, Max.	>=116	Port 1	396
Case 2, Min.	117	Ports 1 & 2	396
Case 2, Max.	>=233	Ports 1 & 2	793
Case 3, Min.	234	Ports 1, 2, & 3	793
Case 3, Max.	>=440	Ports 1, 2, & 3	1,499
Case 4, Min.	441	Ports 1, 2, 3, & 4	1,499
Case 4, Max.	>=906	Ports 1, 2, 3, & 4	3,085
Case 5, Min.	907	Ports 1, 2, 3, 4, & 5	3,085
Case 5, Max.	>=1,734	Ports 1, 2, 3, 4, & 5	5,905

SCENARIO	ACTIVE PORT(S)	ACUTE ZONE DISTANCE (ft)	ORIGINAL PREDICTED TOTAL MIXING ZONE DISTANCE (ft)	REVISED PREDICTED TOTAL MIXING ZONE DISTANCE (ft)
Case 1, Min.	Port 1	7.1	50	35
Case 1, Max.	Port 1	5.8	37	47
Case 2, Min.	Ports 1 & 2	4.4	36.6	36.6
Case 2, Max.	Ports 1 & 2	6.9	88	88
Case 3, Min.	Ports 1, 2, & 3	11.2	46	46
Case 3, Max.	Ports 1, 2, & 3	9.3	116	116
Case 4, Min.	Ports 1, 2, 3, & 4	13.9	176	176
Case 4, Max.	Ports 1, 2, 3, & 4	11.4	147	147
Case 5, Min.	Ports 1, 2, 3, 4, & 5	18.2		231.8
Case 5, Max.	Ports 1, 2, 3, 4, & 5	14.5		251

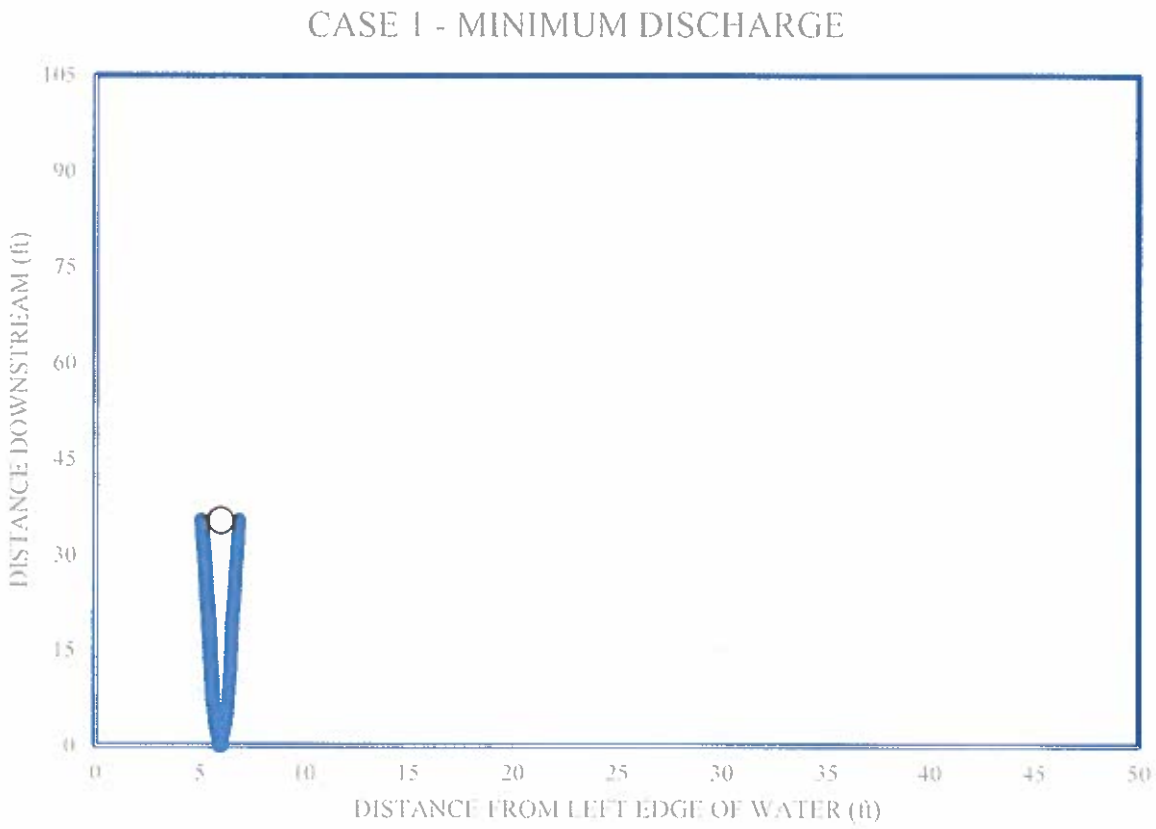
The results for each case will be discussed in more detail below, along with providing the graphics of the plan and profile views of the plume(s) for each Case.

Case 1 – 1st Port Only

Case 1 incorporates the minimum allowable flow based on the lowest projected flow for the Big Muddy River at the proposed diffuser location. Only the first port will be discharging during this condition. The discharge during this condition is 102 gallons per minute, which is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 1. The plan and profile for the maximum discharge condition under Case 1 are provided in Figure 2. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations.

Figure 1 Plan and Profile of the Model for Case 1 – Minimum Flow Condition



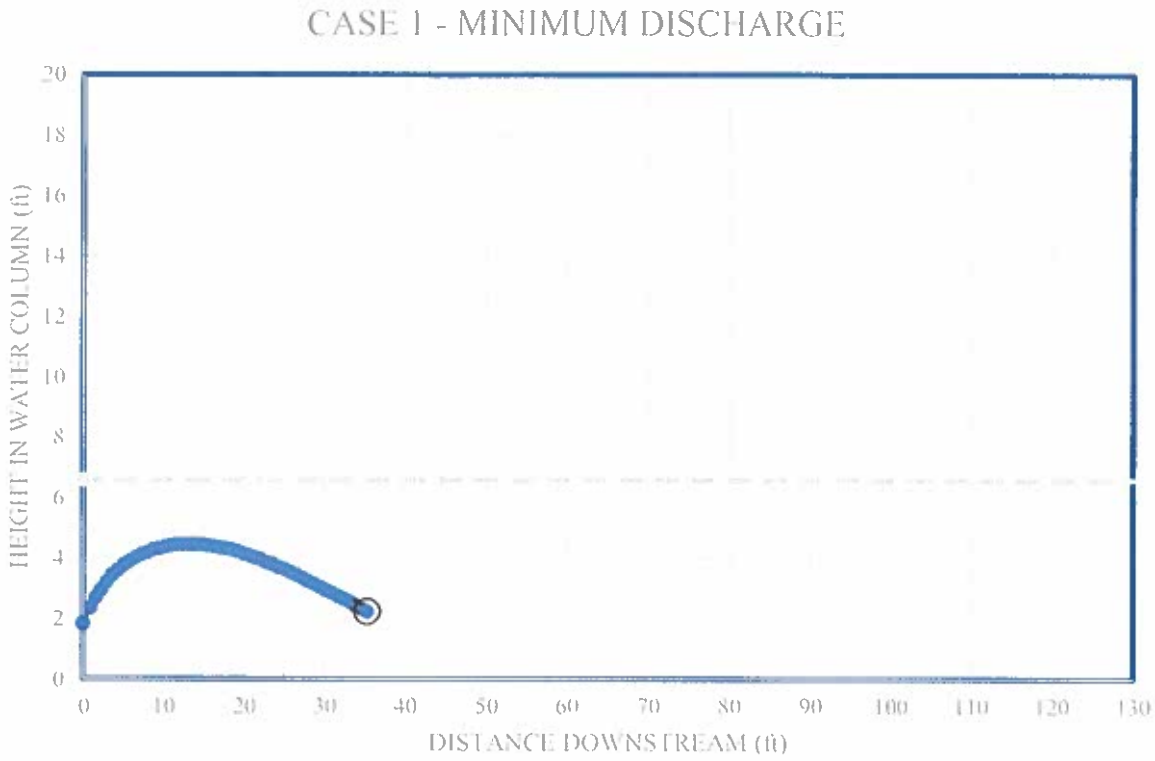
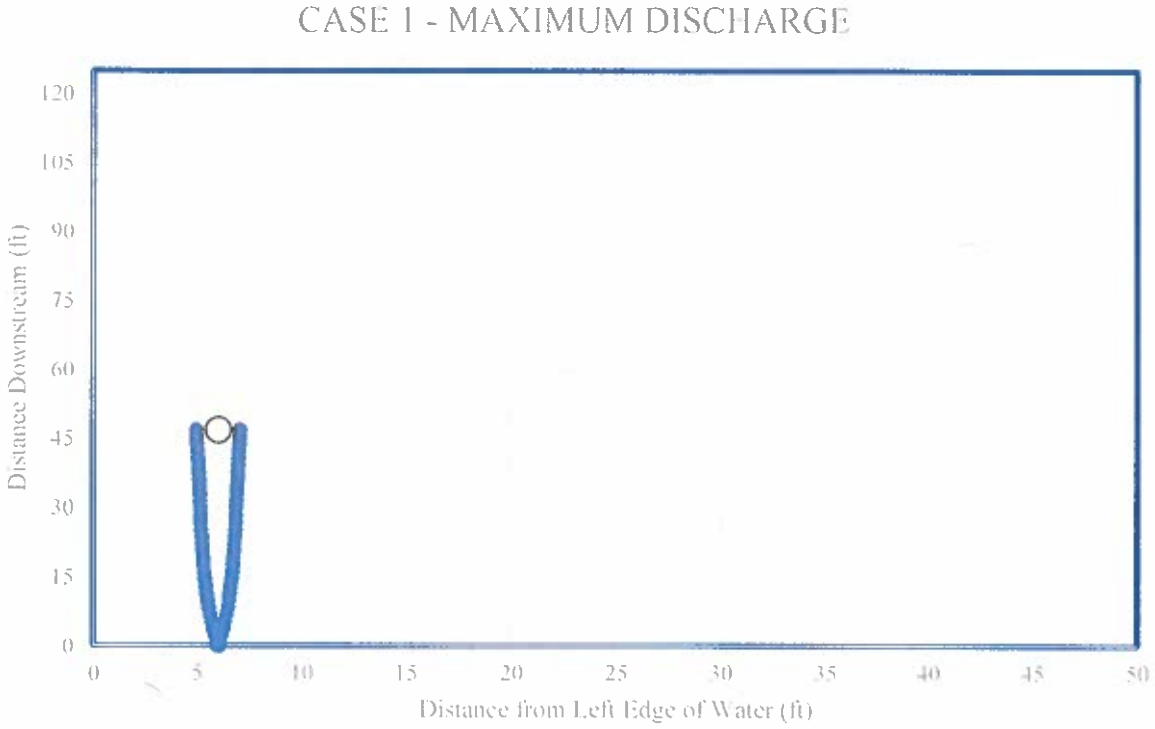
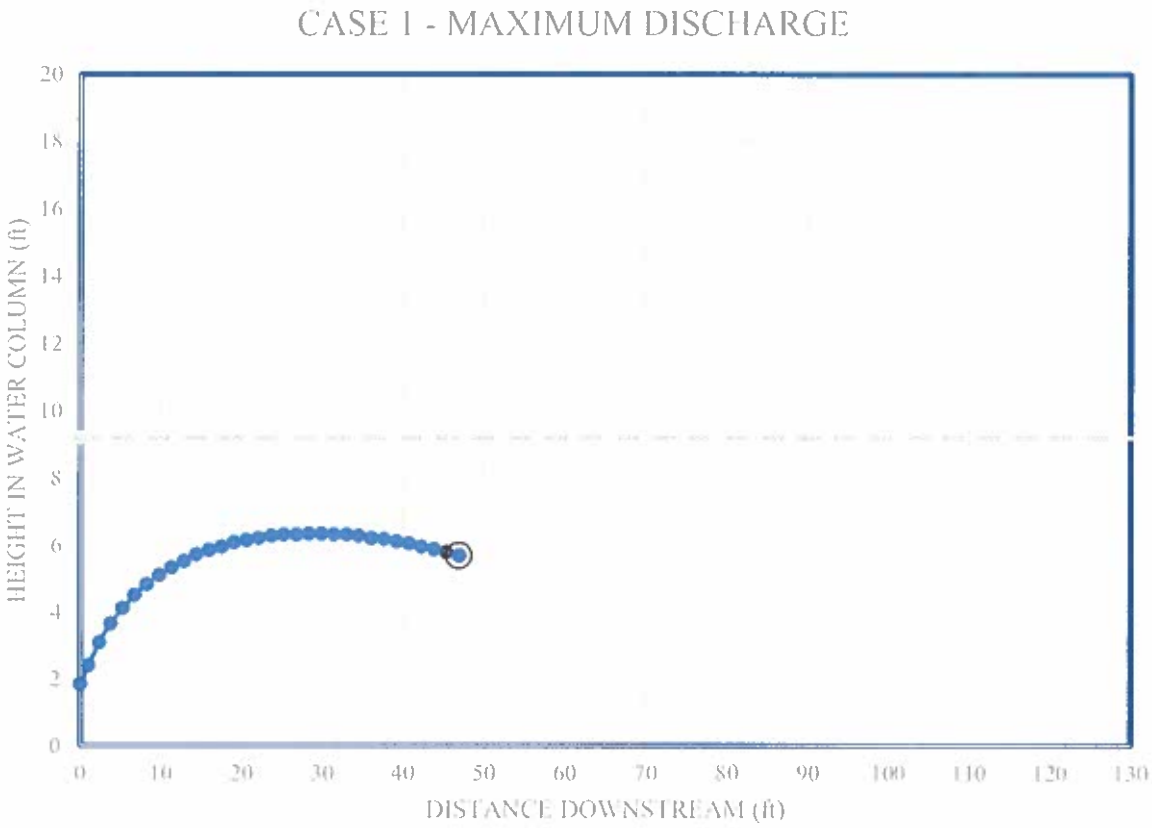


Figure 2. Plan and Profile of the Model for Case 1 – Maximum Flow Condition





These two scenarios represent the minimum and maximum flow conditions for Port 1 when only the first port is discharging. This occurs at lower River flows. The water quality criteria will be met at all flow conditions. For each of these cases, the plumes are less than 4% of the cross-sectional area.

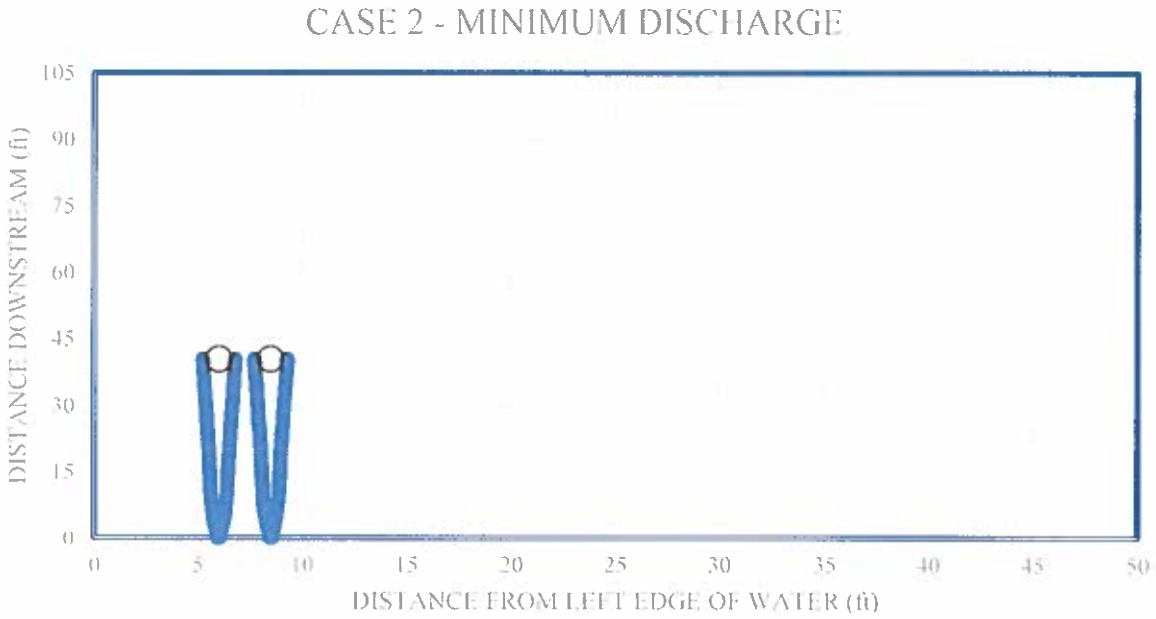
Case 2 – 1st and 2nd Ports Discharging

Case 2 begins at the maximum discharge for Case 1. Once the flow condition is met, the discharge is converted from the maximum discharge through Port 1 to equal discharges through Ports 1 and 2. In other words, the flows through Ports 1 and 2 at the Case 2 minimum flow condition are equivalent to the maximum discharge from Port 1 at Case 1. As with Case 1, the discharge during this condition is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 3. The plan and profile for the maximum discharge condition under Case 2 are provided in Figure 4. The profile picture appears as one line since the ports are equal. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations. For the minimum flow

condition, the plumes remain separate. For the maximum flow condition, the plumes merge near the point of meeting the water quality criteria.

Figure 3. Plan and Profile of the Model for Case 2 – Minimum Flow Condition



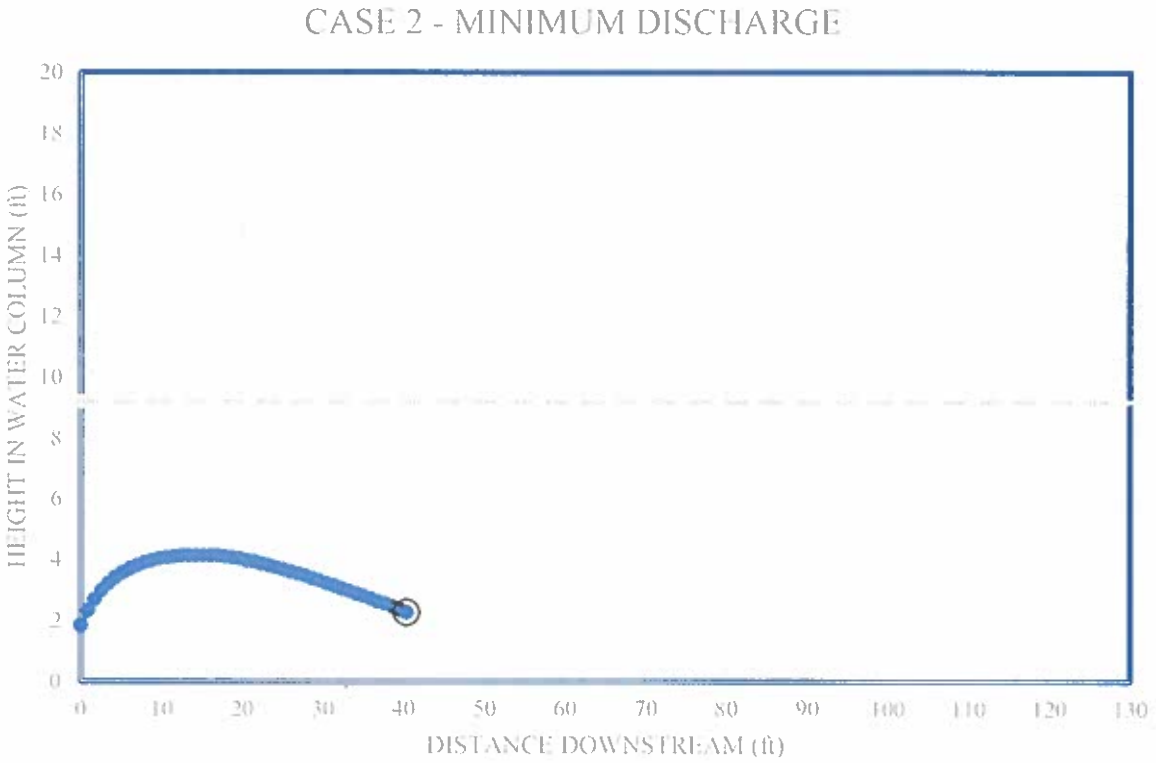
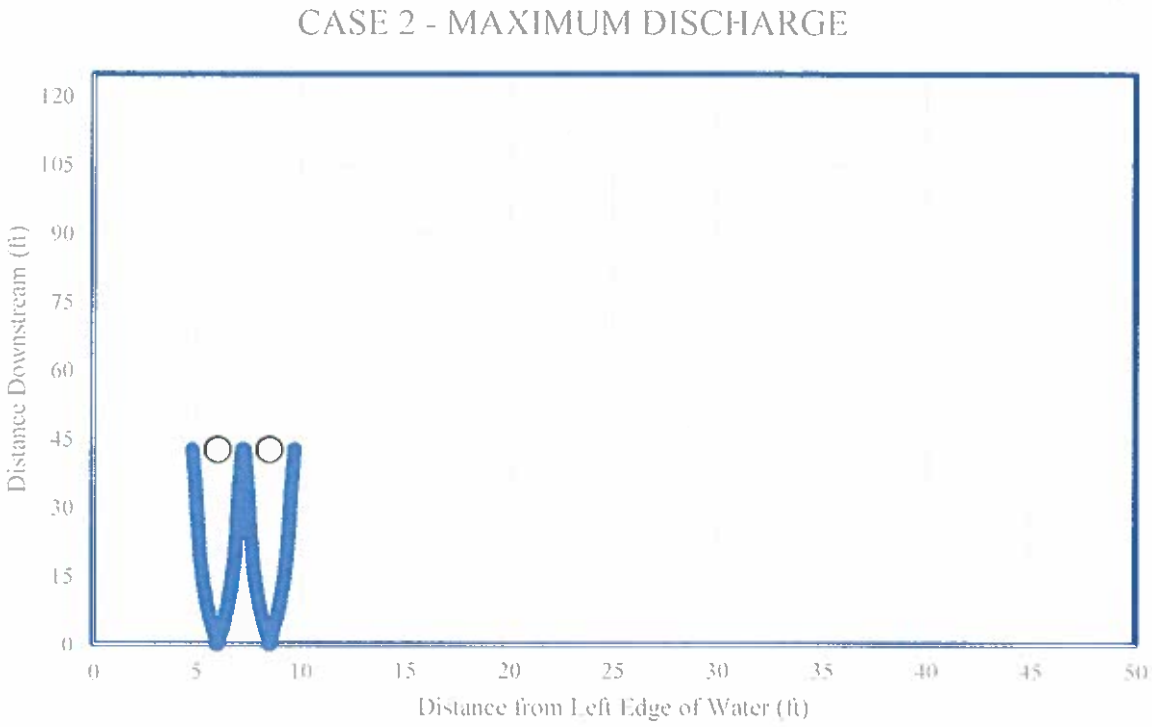
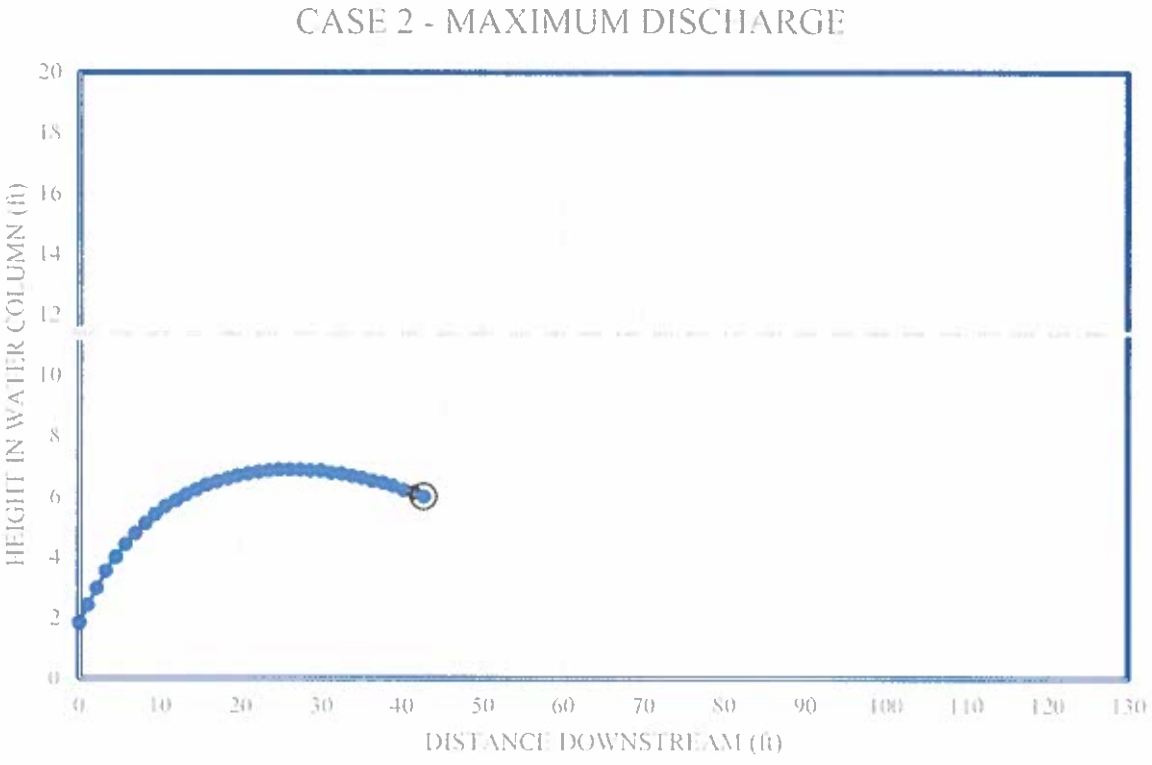


Figure 4. Plan and Profile of the Model for Case 2 – Maximum Flow Condition





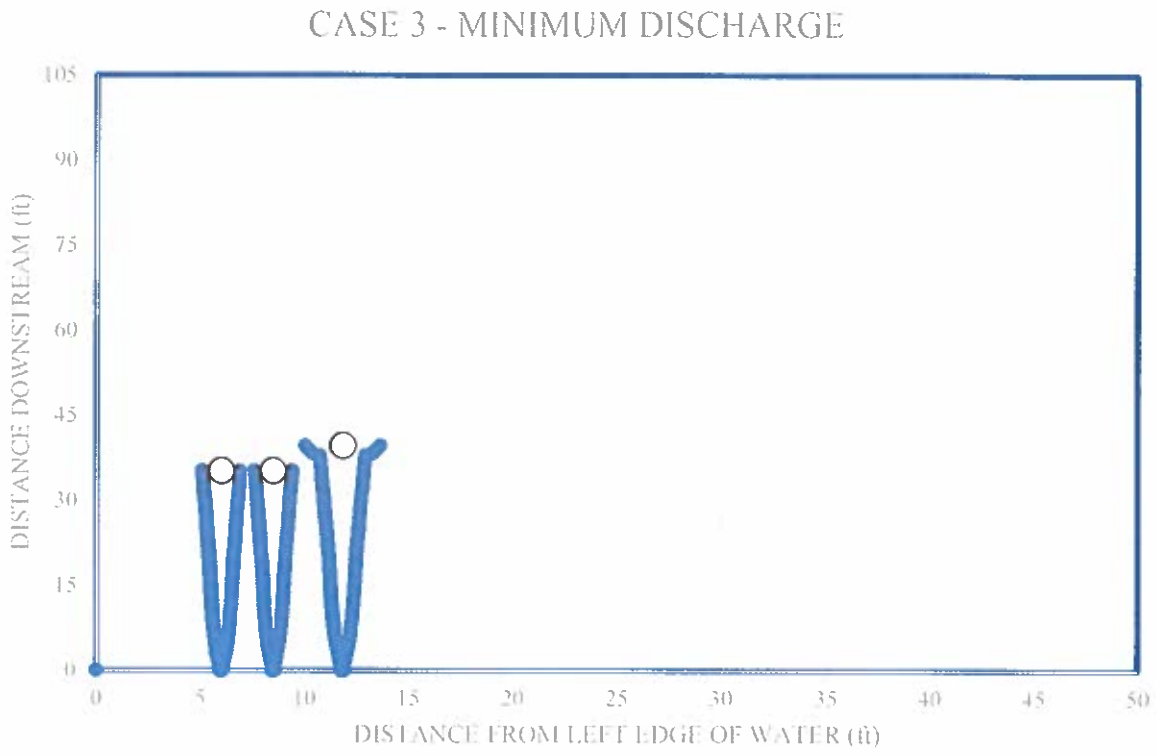
The water quality criteria will be met at all flow conditions for Case 2. For each of these scenarios, the plumes are less than 3% of the cross-sectional area. The calculation of the cross-sectional area accounts for both plumes at the point of meeting the water quality standard.

Case 3 – 1st, 2nd and 3rd Ports Discharging

Case 3 begins at the maximum discharge for Case 2. Once the flow condition is met, the discharge is converted from the maximum discharge through Ports 1 and 2 to discharges through Ports 1, 2 and 3. In other words, the flows through Ports 1, 2 and 3 at the Case 3 minimum flow condition are equivalent to the maximum discharge from Ports 1 and 2 at Case 2. As with Case 2, the discharge during this condition is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 5. The plan and profile for the maximum discharge condition under Case 3 are provided in Figure 6. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations.

Figure 5. Plan and Profile of the Model for Case 3 – Minimum Flow Condition



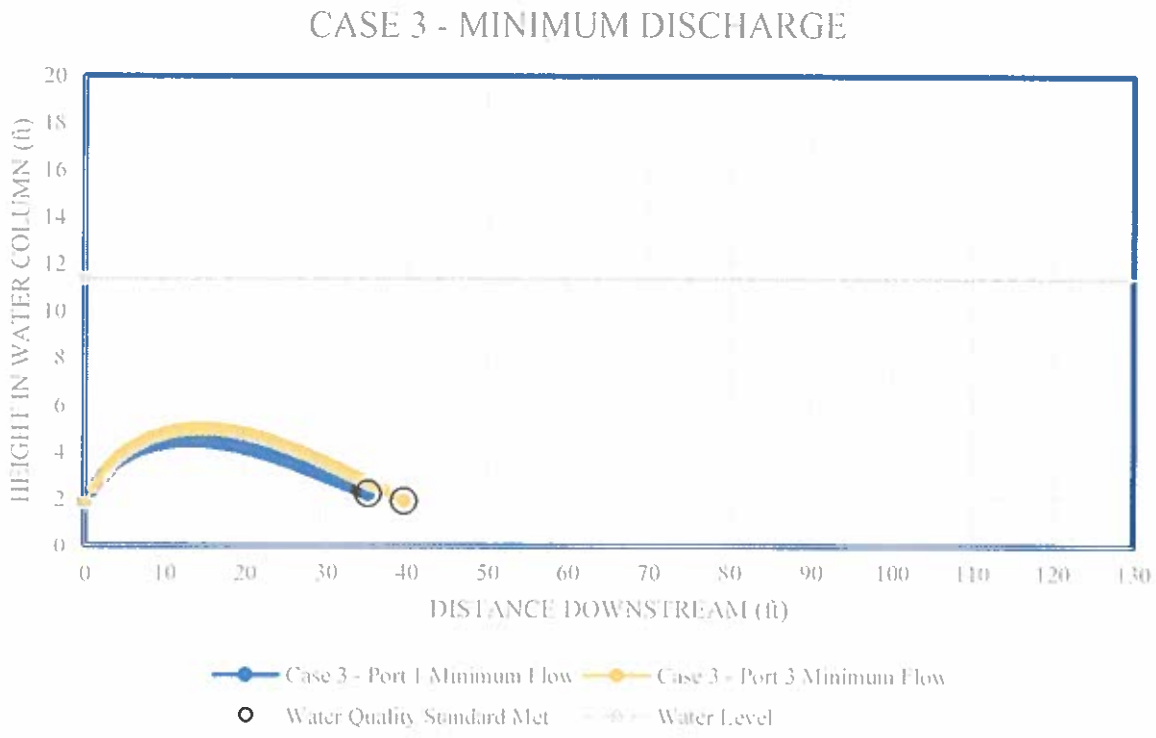
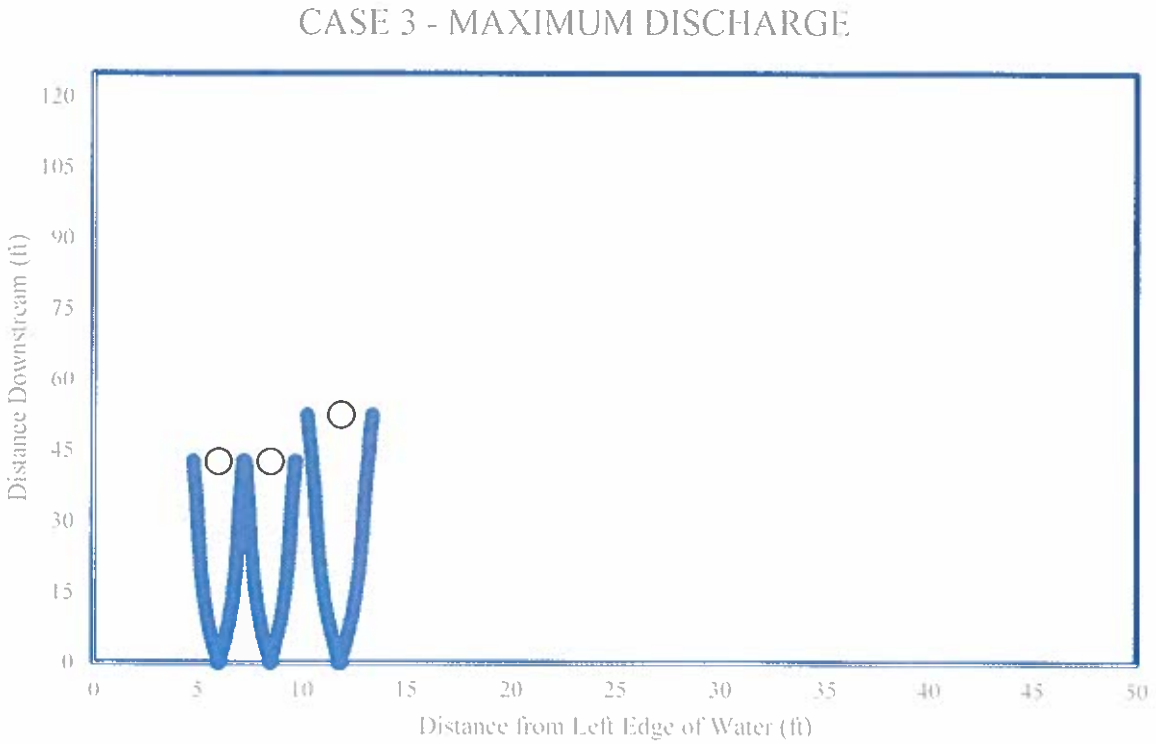
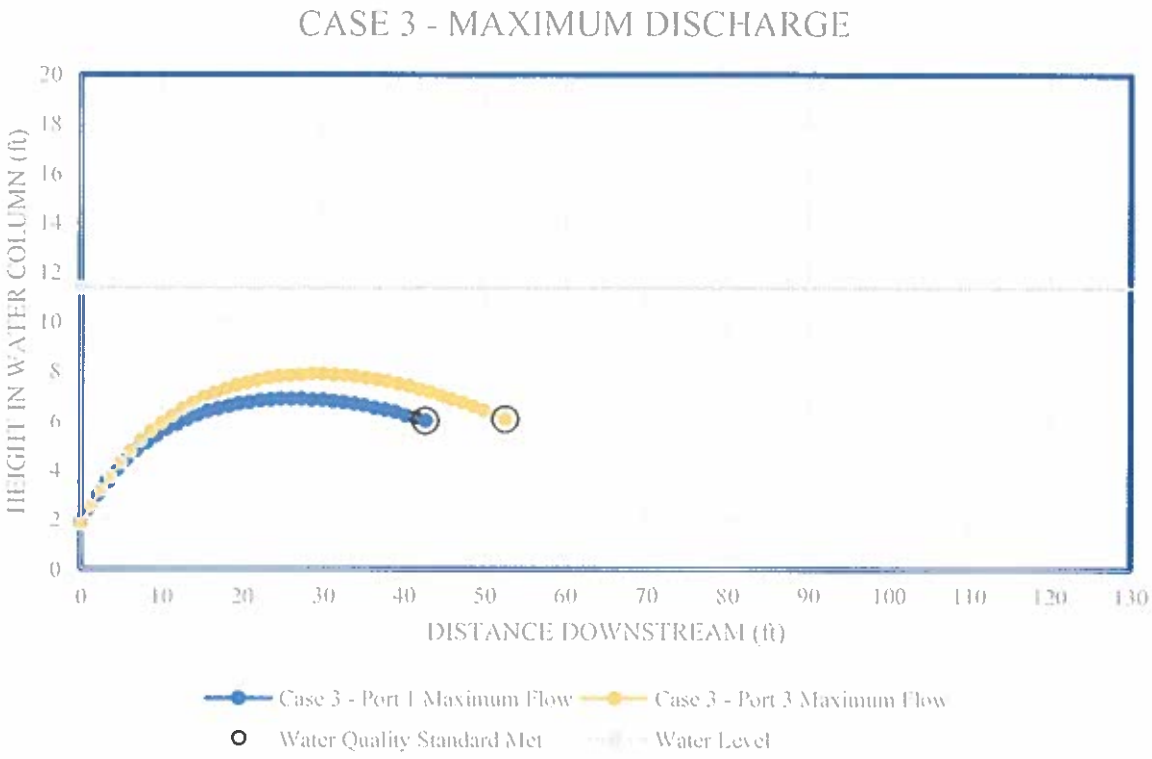


Figure 6. Plan and Profile of the Model for Case 3 – Maximum Flow Condition





The water quality criteria will be met at all flow conditions for Case 3. For each of these scenarios, the plumes are less than 6% of the cross-sectional area. Due to the staggered and unequal flow conditions for the ports after Port 2, the water quality criteria are met at different distances downstream. Ports 1 and 2 have been predicted to have the shortest distances. For those cases in which ports 3, 4, and/or 5 are discharging, the total mixing zone for each part includes the cross-sectional areas for each port.

Case 4 – 1st, 2nd, 3rd and 4th Ports Discharging

Case 4 begins at the maximum discharge for Case 3. Once the flow condition is met, the discharge is converted from the maximum discharge through Ports 1, 2 and 3 to discharges through Ports 1, 2, 3 and 4. In other words, the flows through Ports 1, 2, 3 and 4 at the Case 4 minimum flow condition are equivalent to the maximum discharge from Ports 1, 2, and 3 at Case 3. As with the previous cases, the discharge during this condition is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 7. The plan and profile for the maximum discharge condition under Case 4 are provided in Figure 8. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations.

Figure 7. Plan and Profile of the Model for Case 4 – Minimum Flow Condition

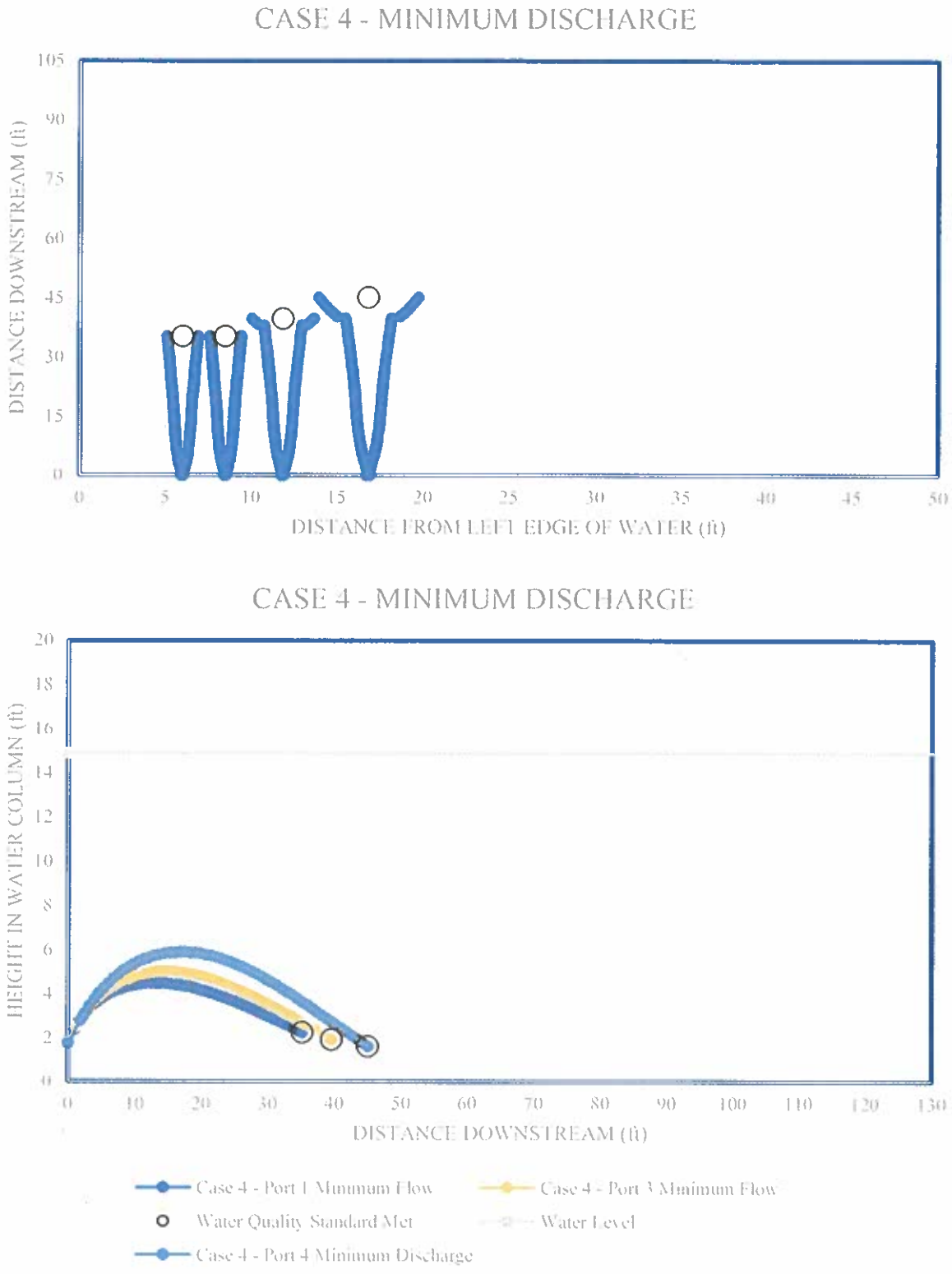
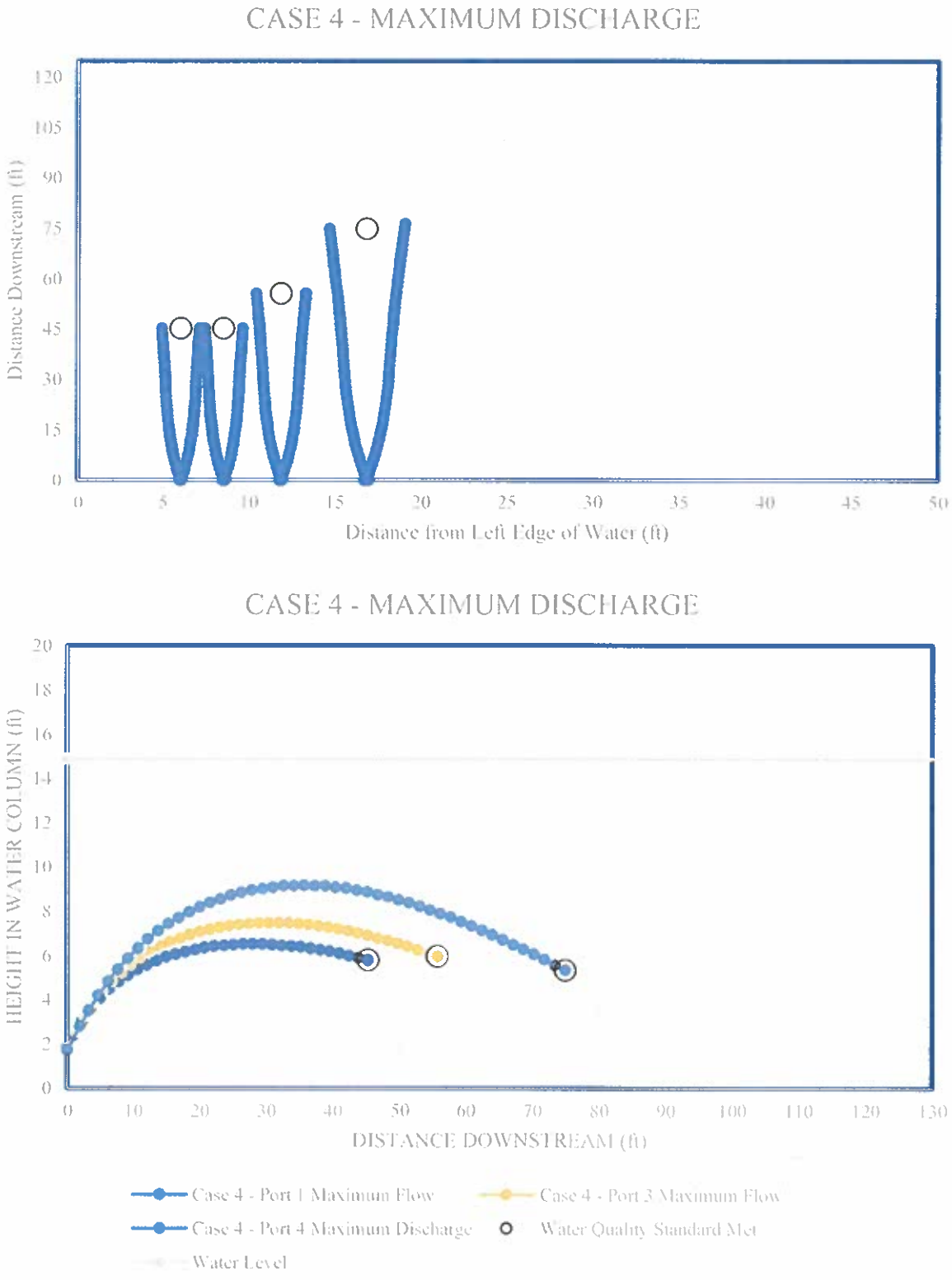


Figure 8. Plan and Profile of the Model for Case 4 – Maximum Flow Condition



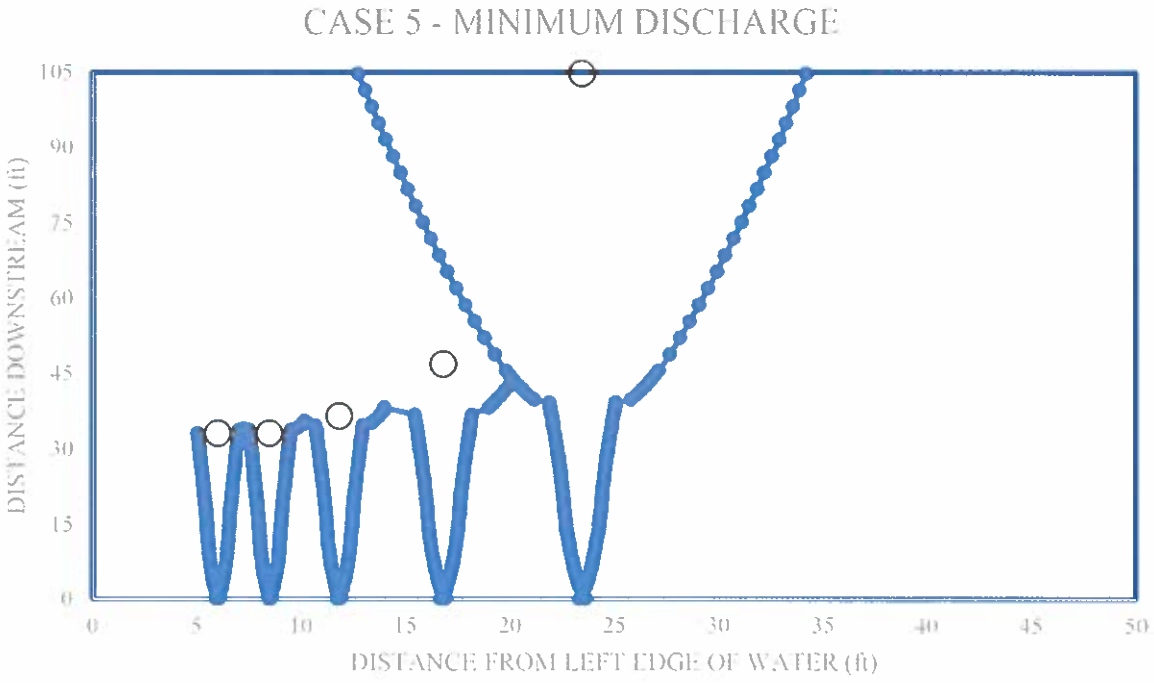
The water quality criteria will be met at all flow conditions for Case 4. For each of these scenarios, the plumes are less than 8% of the cross-sectional area. Due to the staggered and unequal flow conditions for the ports after Port 2, the water quality criteria are met at different distances downstream. Ports 1 and 2 have been predicted to have the shortest distances. For those cases in which ports 3, 4, and/or 5 are discharging, the total mixing zone for each part includes the cross-sectional areas for each port at the distance met by the respective port.

Case 5 – 1st, 2nd, 3rd, 4th and 5th Ports Discharging

Case 5 begins at the maximum discharge for Case 4. Once the flow condition is met, the discharge is converted from the maximum discharge through Ports 1, 2, 3 and 4 to discharges through Ports 1, 2, 3, 4 and 5. In other words, the flows through Ports 1, 2, 3, 4 and 5 at the Case 5 minimum flow condition are equivalent to the maximum discharge from Ports 1, 2, 3 and 4 at Case 4. As with the previous cases, the discharge during this condition is a small fraction of the flow in the Big Muddy River. The additional volumetric flow during this case should not affect water levels at the diffuser location or in downstream locales.

The plan and profile for the minimum discharge conditions are provided in Figure 9. The plan and profile for the maximum discharge condition under Case 5 are provided in Figure 10. The water quality criteria for chloride is met in a very short distance downstream for both of these iterations.

Figure 9. Plan and Profile of the Model for Case 5 – Minimum Flow Condition



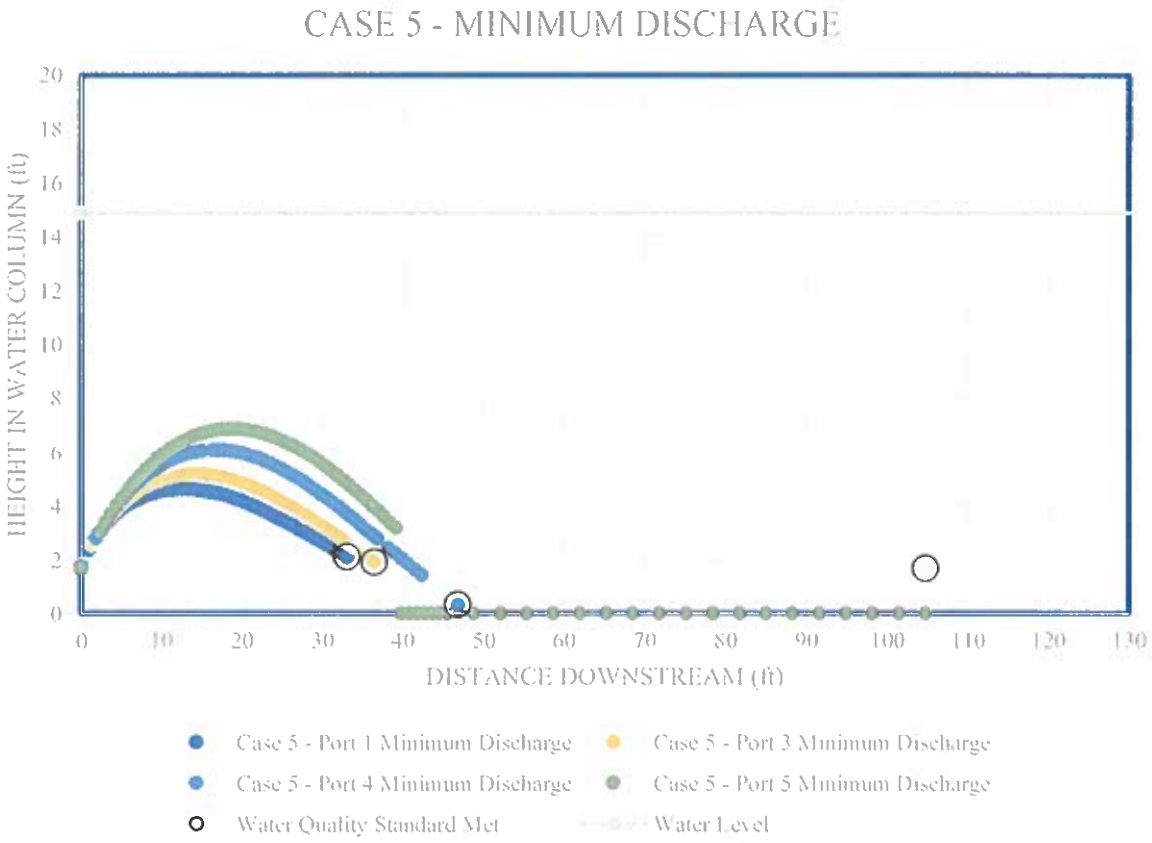
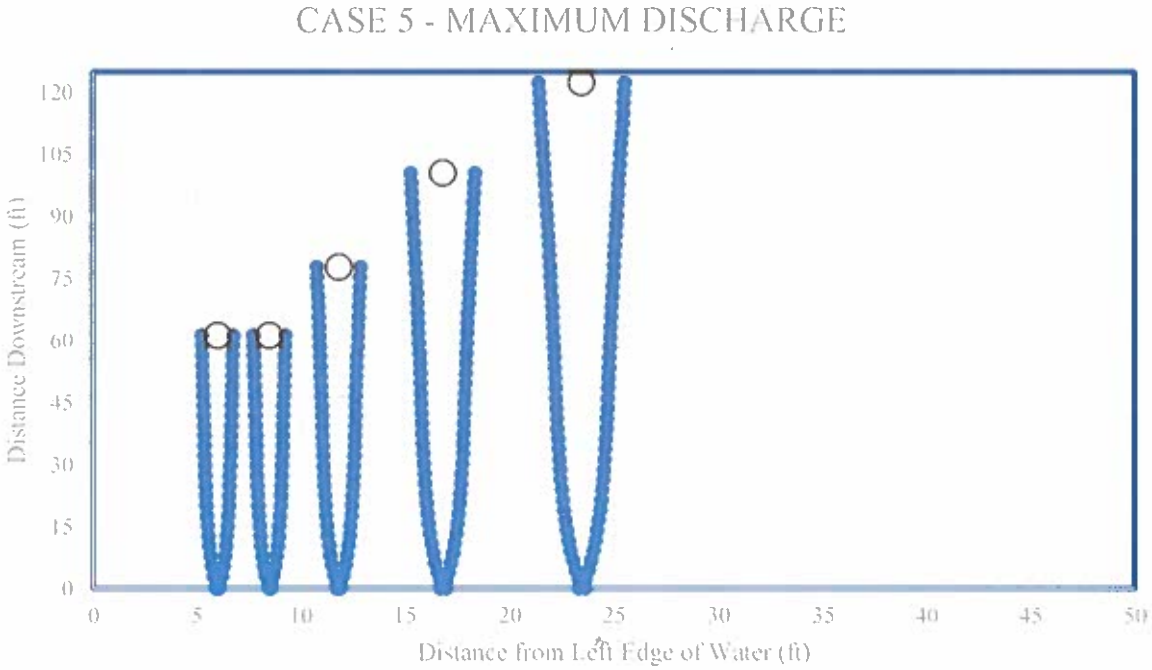
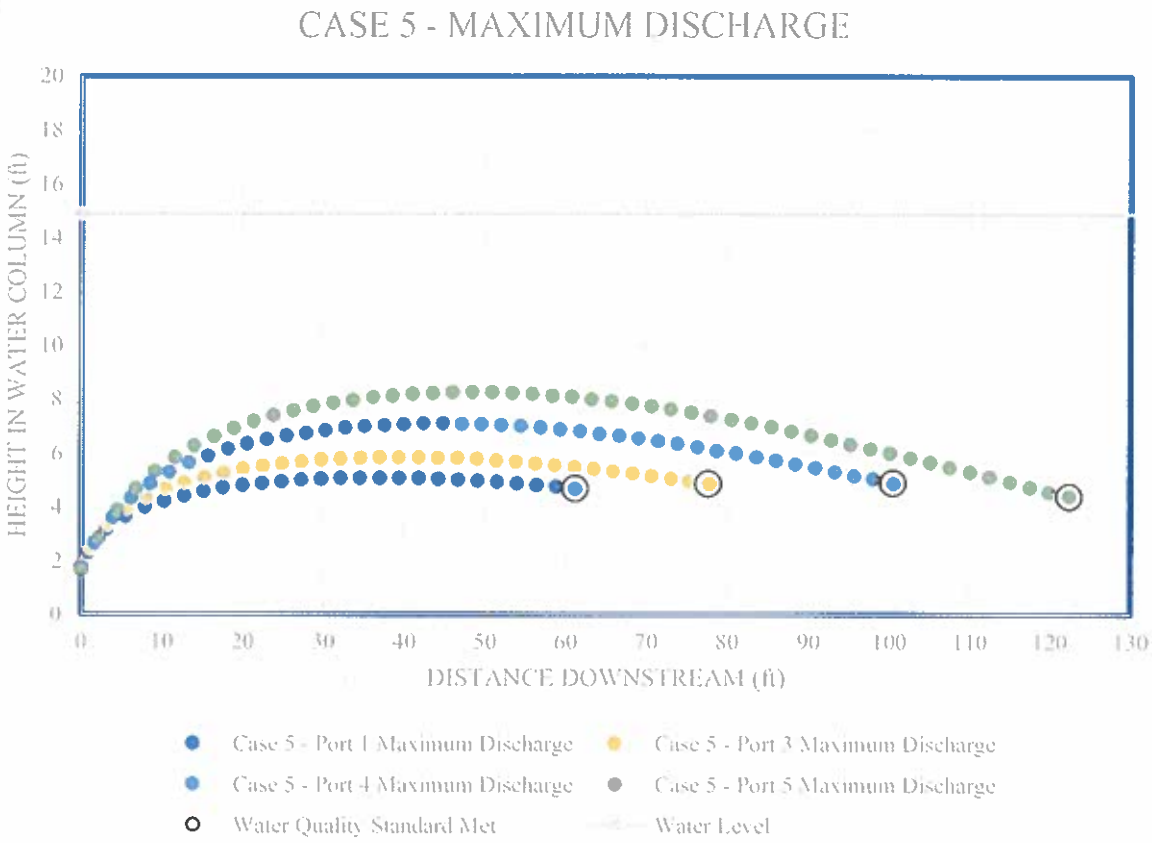


Figure 10. Plan and Profile of the Model for Case 5 – Maximum Flow Condition





The water quality criteria will be met at all flow conditions for Case 5. For each of these scenarios, the plumes are less than 8% of the cross-sectional area. Due to the staggered and unequal flow conditions for the ports after Port 2, the water quality criteria are met at different distances downstream. Ports 1 and 2 have been predicted to have the shortest distances. For those cases in which ports 3, 4, and/or 5 are discharging, the total mixing zone for each part includes the cross-sectional areas for each port at the distance met by the respective port.

It is noted that the apparent bottom interaction for Port 5 at its minimum discharge condition is an artifact of CORMIX's modules. The plume is predicted to extend higher at this point than when the centerline is projected at its maximum height.

UPDATES TO THE MODEL

As part of the project, Horner & Shifrin's design includes a transect of the proposed diffuser location. An excerpt of this transect is shown in Figure 11. The following data were derived for each of the model cases. The transect was treated as a trapezoid. For modeling purposes, CORMIX utilizes rectangular dimensions. The cross-sectional area of the trapezoid was translated to a rectangle for the model by keeping the height constant, then determining the width of the model rectangle. The dimensions for the River for the various cases are shown in Table 2.

Figure 11. Transect at Proposed Diffuser Location, Excerpt from Horner & Shifrin Design documents

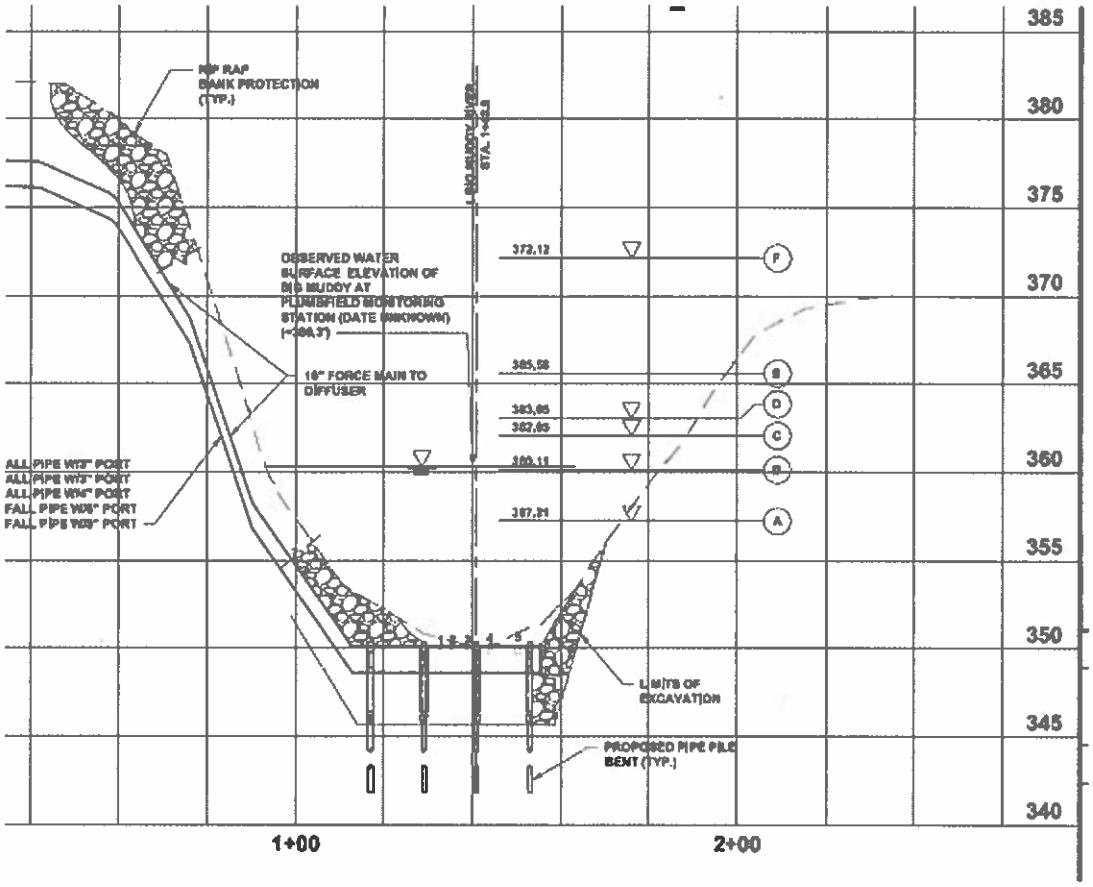


Table 2. Transect Dimensions

CASE	FLOW CONDITION	WATER COLUMN HEIGHT (ft)	AREA (ft^2)
Case 1	Minimum	6.6	376
	Maximum	9.2	605
Case 2	Minimum	9.2	605
	Maximum	11.4	807
Case 3	Minimum	11.4	807
	Maximum	12.5	903
Case 4	Minimum	12.5	903
	Maximum	14.9	1159
Case 5	Minimum	14.9	1159
	Maximum	14.9	1159

If you should have questions or comments concerning our assessment, please call us at (615) 373-8532 or by FAX at (615) 373-8512 or by e-mail at jmcorn@aquaeter.com.

```
CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges           CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:          MACH^BIG^MUDDY^RIVER
 Design case:              CASE^1^-^PORT^1^NORMAL^FLOW
 FILE NAME:                cormix\sim\MAC1-1N1.cx1
 Time of Fortran run:      01/13/20--21:45:52

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     17.37  AS    =     34.91  QA    =     10.02  ICHREG= 2
 HA    =      2.01  HD    =      2.01
 UA    =      .287  F     =       .076 USTAR = .2801E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =      8.00
 D0    =      .076 A0    =       .005 H0    =       .56
 THETA =    30.00  SIGMA =       .00
 U0    =     2.866 Q0    =       .013       = .1307E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .1307E-01  M0    = .3746E-01  J0    =-.1913E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =      .07  LM    =      1.95  Lm    =       .67  Lb    =       .08
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     27.14  R     =      9.98

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     2.01  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
```

```
 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
         8.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .100E+04     .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:              THETAE=     28.17  SIGMAE=        .00
  LE    =        .32  XE    =        .28  YE    =        .00  ZE    =        .72

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .100E+04     .04
       .28      .00      .72     1.0  .100E+04     .04
       .48      .00      .82     1.6  .640E+03     .07
       .68      .00      .90     2.3  .433E+03     .09
       .90      .00      .98     3.1  .321E+03     .12
      1.11      .00     1.05     3.9  .256E+03     .14
      1.33      .00     1.10     4.7  .212E+03     .16
      1.55      .00     1.15     5.5  .183E+03     .18
      1.77      .00     1.19     6.2  .161E+03     .19
      2.00      .00     1.23     6.9  .144E+03     .21
      2.22      .00     1.26     7.6  .132E+03     .22
      2.44      .00     1.28     8.2  .122E+03     .23
      2.67      .00     1.31     8.8  .114E+03     .24
      2.89      .00     1.32     9.3  .107E+03     .25
      3.12      .00     1.34     9.9  .101E+03     .26
      3.34      .00     1.35    10.3  .970E+02     .27
      3.57      .00     1.36    10.7  .931E+02     .28
      3.79      .00     1.36    11.1  .899E+02     .28
      4.02      .00     1.36    11.5  .872E+02     .29
```

```
  Maximum jet height has been reached.
      4.24      .00    1.36    11.8  .848E+02    .30
      4.47      .00    1.36    12.2  .823E+02    .30
      4.69      .00    1.35    12.6  .796E+02    .31
      4.92      .00    1.34    13.0  .769E+02    .31
      5.15      .00    1.33    13.5  .742E+02    .32
      5.37      .00    1.32    14.0  .715E+02    .33
      5.59      .00    1.31    14.5  .689E+02    .34
      5.82      .00    1.29    15.1  .662E+02    .34
      6.04      .00    1.27    15.7  .637E+02    .35
      6.27      .00    1.25    16.4  .611E+02    .36
      6.49      .00    1.23    17.0  .588E+02    .37
      6.72      .00    1.21    17.7  .564E+02    .38
      6.94      .00    1.18    18.5  .542E+02    .39
      7.16      .00    1.16    19.2  .521E+02    .40
      7.39      .00    1.13    20.0  .500E+02    .41
      7.61      .00    1.11    20.8  .480E+02    .42
      7.84      .00    1.08    21.7  .461E+02    .43
      8.06      .00    1.05    22.5  .444E+02    .43
      8.28      .00    1.02    23.4  .427E+02    .44
      8.51      .00     .99    24.3  .411E+02    .45
      8.73      .00     .96    25.3  .396E+02    .46
      8.95      .00     .93    26.2  .381E+02    .47
      9.17      .00     .90    27.2  .368E+02    .48
      9.39      .00     .87    28.2  .355E+02    .49
      9.62      .00     .84    29.2  .342E+02    .50
      9.84      .00     .81    30.2  .331E+02    .51
     10.07      .00     .78    31.3  .319E+02    .52
     10.29      .00     .74    32.4  .309E+02    .53
     10.52      .00     .71    33.5  .299E+02    .54
     10.74      .00     .68    34.6  .289E+02    .55
     10.96      .00     .65    35.7  .280E+02    .56
     11.18      .00     .62    36.8  .271E+02    .57
     11.40      .00     .58    38.0  .263E+02    .58
 Cumulative travel time =          22. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B
    11.40      .00     .58    38.0  .263E+02    .58

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.82	.00	.00	38.0	.263E+02	.00	.00	.00	.00
11.00	.00	.00	38.0	.263E+02	.76	.38	.76	.00
11.17	.00	.00	38.0	.263E+02	.90	.54	.90	.00
11.35	.00	.00	38.0	.263E+02	1.00	.66	1.00	.00
11.52	.00	.00	39.0	.256E+02	1.06	.77	1.06	.00
11.70	.00	.00	43.8	.228E+02	1.11	.86	1.11	.00
11.87	.00	.00	50.5	.198E+02	1.15	.94	1.15	.00
12.04	.00	.00	56.6	.177E+02	1.18	1.01	1.18	.00
12.22	.00	.00	60.8	.164E+02	1.20	1.08	1.20	.00
12.39	.00	.00	63.1	.159E+02	1.21	1.15	1.21	.00
12.57	.00	.00	64.5	.155E+02	1.21	1.21	1.21	.00

Cumulative travel time = 26. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
12.57	.00	.00	64.5	.155E+02	1.21	1.21	1.21	.00
13.33	.00	.00	66.1	.151E+02	1.15	1.31	1.15	.00
14.10	.00	.00	67.6	.148E+02	1.10	1.40	1.10	.00
14.86	.00	.00	69.0	.145E+02	1.05	1.49	1.05	.00
15.63	.00	.00	70.4	.142E+02	1.01	1.58	1.01	.00
16.39	.00	.00	71.8	.139E+02	.98	1.67	.98	.00
17.15	.00	.00	73.2	.137E+02	.95	1.75	.95	.00
17.92	.00	.00	74.6	.134E+02	.93	1.83	.93	.00
18.68	.00	.00	76.0	.132E+02	.91	1.91	.91	.00
19.45	.00	.00	77.5	.129E+02	.89	1.99	.89	.00
20.21	.00	.00	78.9	.127E+02	.87	2.06	.87	.00
20.98	.00	.00	80.4	.124E+02	.86	2.14	.86	.00
21.74	.00	.00	81.9	.122E+02	.84	2.21	.84	.00
22.50	.00	.00	83.5	.120E+02	.83	2.28	.83	.00
23.27	.00	.00	85.1	.117E+02	.82	2.35	.82	.00
24.03	.00	.00	86.8	.115E+02	.81	2.42	.81	.00
24.80	.00	.00	88.4	.113E+02	.81	2.49	.81	.00

25.56	.00	.00	90.2	.111E+02	.80	2.56	.80	.00
26.33	.00	.00	92.0	.109E+02	.80	2.63	.80	.00
27.09	.00	.00	93.8	.107E+02	.79	2.70	.79	.00
27.85	.00	.00	95.7	.104E+02	.79	2.76	.79	.00
28.62	.00	.00	97.6	.102E+02	.79	2.83	.79	.00
29.38	.00	.00	99.6	.100E+02	.78	2.89	.78	.00
30.15	.00	.00	101.7	.983E+01	.78	2.95	.78	.00
30.91	.00	.00	103.8	.963E+01	.78	3.02	.78	.00
31.68	.00	.00	106.0	.943E+01	.78	3.08	.78	.00
32.44	.00	.00	108.3	.924E+01	.78	3.14	.78	.00
33.20	.00	.00	110.6	.904E+01	.79	3.20	.79	.00
33.97	.00	.00	112.9	.885E+01	.79	3.26	.79	.00
34.73	.00	.00	115.4	.867E+01	.79	3.32	.79	.00
35.50	.00	.00	117.9	.848E+01	.79	3.38	.79	.00
36.26	.00	.00	120.5	.830E+01	.80	3.44	.80	.00
37.03	.00	.00	123.1	.812E+01	.80	3.50	.80	.00
37.79	.00	.00	125.8	.795E+01	.81	3.55	.81	.00
38.55	.00	.00	128.6	.778E+01	.81	3.61	.81	.00
39.32	.00	.00	131.5	.761E+01	.82	3.67	.82	.00
40.08	.00	.00	134.4	.744E+01	.82	3.73	.82	.00
40.85	.00	.00	137.4	.728E+01	.83	3.78	.83	.00
41.61	.00	.00	140.5	.712E+01	.83	3.84	.83	.00
42.38	.00	.00	143.6	.696E+01	.84	3.89	.84	.00
43.14	.00	.00	146.9	.681E+01	.85	3.95	.85	.00
43.90	.00	.00	150.2	.666E+01	.85	4.00	.85	.00
44.67	.00	.00	153.6	.651E+01	.86	4.06	.86	.00
45.43	.00	.00	157.0	.637E+01	.87	4.11	.87	.00
46.20	.00	.00	160.6	.623E+01	.88	4.16	.88	.00
46.96	.00	.00	164.2	.609E+01	.89	4.21	.89	.00
47.73	.00	.00	167.9	.596E+01	.90	4.27	.90	.00
48.49	.00	.00	171.7	.582E+01	.90	4.32	.90	.00
49.25	.00	.00	175.6	.570E+01	.91	4.37	.91	.00
50.02	.00	.00	179.5	.557E+01	.92	4.42	.92	.00
50.78	.00	.00	183.6	.545E+01	.93	4.47	.93	.00

Cumulative travel time = 159. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .113E-01 m^2/s
Horizontal diffusivity (initial value) = .282E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)

ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
50.78	.00	.00	183.6	.545E+01	.93	4.47	.93	.00
53.64	.00	.00	193.9	.516E+01	.97	4.57	.97	.00
56.50	.00	.00	204.9	.488E+01	1.00	4.67	1.00	.00
59.35	.00	.00	216.4	.462E+01	1.03	4.76	1.03	.00
62.21	.00	.00	228.5	.438E+01	1.07	4.85	1.07	.00
65.07	.00	.00	241.2	.415E+01	1.11	4.94	1.11	.00
67.92	.00	.00	254.6	.393E+01	1.15	5.03	1.15	.00
70.78	.00	.00	268.6	.372E+01	1.20	5.12	1.20	.00
73.64	.00	.00	283.2	.353E+01	1.24	5.20	1.24	.00
76.49	.00	.00	298.5	.335E+01	1.29	5.29	1.29	.00
79.35	.00	.00	314.3	.318E+01	1.33	5.37	1.33	.00
82.21	.00	.00	330.8	.302E+01	1.38	5.45	1.38	.00
85.07	.00	.00	347.8	.288E+01	1.43	5.53	1.43	.00
87.92	.00	.00	365.4	.274E+01	1.48	5.61	1.48	.00
90.78	.00	.00	383.5	.261E+01	1.54	5.69	1.54	.00
93.64	.00	.00	402.0	.249E+01	1.59	5.76	1.59	.00
96.49	.00	.00	421.1	.237E+01	1.64	5.84	1.64	.00
99.35	.00	.00	440.6	.227E+01	1.70	5.91	1.70	.00
102.21	.00	.00	460.4	.217E+01	1.75	5.99	1.75	.00
105.06	.00	.00	480.7	.208E+01	1.81	6.06	1.81	.00
107.92	.00	.00	501.3	.199E+01	1.86	6.13	1.86	.00
110.78	.00	.00	522.2	.192E+01	1.92	6.20	1.92	.00
113.64	.00	.00	543.3	.184E+01	1.97	6.27	1.97	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

116.49	.00	.00	560.1	.179E+01	2.01	6.34	2.01	.00
119.35	.00	.00	566.2	.177E+01	2.01	6.41	2.01	.00
122.21	.00	.00	572.2	.175E+01	2.01	6.48	2.01	.00
125.06	.00	.00	578.2	.173E+01	2.01	6.55	2.01	.00
127.92	.00	.00	584.1	.171E+01	2.01	6.62	2.01	.00
130.78	.00	.00	589.9	.170E+01	2.01	6.68	2.01	.00
133.63	.00	.00	595.7	.168E+01	2.01	6.75	2.01	.00
136.49	.00	.00	601.4	.166E+01	2.01	6.81	2.01	.00
139.35	.00	.00	607.1	.165E+01	2.01	6.88	2.01	.00
142.21	.00	.00	612.7	.163E+01	2.01	6.94	2.01	.00
145.06	.00	.00	618.3	.162E+01	2.01	7.00	2.01	.00
147.92	.00	.00	623.8	.160E+01	2.01	7.07	2.01	.00
150.78	.00	.00	629.3	.159E+01	2.01	7.13	2.01	.00
153.63	.00	.00	634.7	.158E+01	2.01	7.19	2.01	.00
156.49	.00	.00	640.1	.156E+01	2.01	7.25	2.01	.00
159.35	.00	.00	645.4	.155E+01	2.01	7.31	2.01	.00
162.20	.00	.00	650.7	.154E+01	2.01	7.37	2.01	.00
165.06	.00	.00	655.9	.152E+01	2.01	7.43	2.01	.00

167.92	.00	.00	661.1	.151E+01	2.01	7.49	2.01	.00
170.77	.00	.00	666.3	.150E+01	2.01	7.55	2.01	.00
173.63	.00	.00	671.4	.149E+01	2.01	7.61	2.01	.00
176.49	.00	.00	676.5	.148E+01	2.01	7.66	2.01	.00
179.35	.00	.00	681.5	.147E+01	2.01	7.72	2.01	.00
182.20	.00	.00	686.6	.146E+01	2.01	7.78	2.01	.00
185.06	.00	.00	691.5	.145E+01	2.01	7.83	2.01	.00
187.92	.00	.00	696.5	.144E+01	2.01	7.89	2.01	.00
190.77	.00	.00	701.4	.143E+01	2.01	7.94	2.01	.00
193.63	.00	.00	706.2	.142E+01	2.01	8.00	2.01	.00

Cumulative travel time = 656. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
193.63	8.00	.00	706.2	.142E+01	2.01	16.00	2.01	.00
209.76	8.00	.00	713.1	.140E+01	2.01	16.15	2.01	.00
225.89	8.00	.00	719.8	.139E+01	2.01	16.31	2.01	.00
242.01	8.00	.00	726.5	.138E+01	2.01	16.46	2.01	.00
258.14	8.00	.00	733.1	.136E+01	2.01	16.61	2.01	.00
274.27	8.00	.00	739.7	.135E+01	2.01	16.76	2.01	.00
290.39	8.00	.00	746.2	.134E+01	2.01	16.91	2.01	.00
306.52	8.00	.00	752.7	.133E+01	2.01	17.05	2.01	.00
322.65	8.00	.00	759.1	.132E+01	2.01	17.20	2.01	.00
338.78	8.00	.00	765.4	.131E+01	2.01	17.34	2.01	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 342.14 m.

354.90	8.00	.00	771.7	.130E+01	2.01	17.37	2.01	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

371.03	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
387.16	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
403.29	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
419.41	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
435.54	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
451.67	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
467.80	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
483.92	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
500.05	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
516.18	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
532.31	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
548.43	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
564.56	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
580.69	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
596.82	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
612.94	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
629.07	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
645.20	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00

661.32	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
677.45	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
693.58	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
709.71	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
725.83	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
741.96	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
758.09	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
774.22	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
790.34	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
806.47	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
822.60	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
838.73	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
854.85	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
870.98	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
887.11	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
903.24	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
919.36	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
935.49	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
951.62	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
967.74	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
983.87	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00
1000.00	8.00	.00	766.7	.130E+01	2.01	17.37	2.01	.00

Cumulative travel time = 3462. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges           CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^1^-^PORT^1^MAXIMUM^FLOW
 FILE NAME:               cormix\sim\MAC1-1X1.cx1
 Time of Fortran run:     01/13/20--21:41:13

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     20.06  AS    =     56.17  QA    =     22.24  ICHREG= 2
 HA    =      2.80  HD    =      2.80
 UA    =       .396 F     =       .068 USTAR = .3656E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     10.00
 D0    =       .076 A0    =       .005 H0    =       .56
 THETA =     30.00  SIGMA =       .00
 U0    =      5.487 Q0    =       .025       = .2502E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .2502E-01  M0    = .1373E+00  J0    =-.3662E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .07  LM    =      3.73  Lm    =       .94  Lb    =       .06
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     51.96  R     =     13.85

FLOW CLASSIFICATION
 11111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     2.80  1
 11111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        10.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .100E+04     .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:              THETAE=     28.68  SIGMAE=        .00
  LE    =        .34  XE    =        .29  YE    =        .00  ZE    =        .73

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .100E+04     .04
       .29      .00      .73     1.0  .100E+04     .04
       .71      .00      .94     2.3  .434E+03     .09
      1.15      .00     1.11     3.9  .255E+03     .15
      1.60      .00     1.25     5.7  .176E+03     .19
      2.05      .00     1.37     7.4  .135E+03     .24
      2.52      .00     1.47     9.1  .110E+03     .28
      2.98      .00     1.55    10.7  .932E+02     .31
      3.45      .00     1.62    12.3  .813E+02     .34
      3.92      .00     1.68    13.8  .727E+02     .36
      4.39      .00     1.74    15.1  .660E+02     .39
      4.86      .00     1.78    16.4  .609E+02     .41
      5.33      .00     1.81    17.6  .567E+02     .43
      5.80      .00     1.85    18.8  .533E+02     .44
      6.28      .00     1.87    19.8  .505E+02     .46
      6.74      .00     1.89    20.8  .482E+02     .47
      7.22      .00     1.91    21.7  .462E+02     .48
      7.69      .00     1.92    22.5  .445E+02     .50
      8.17      .00     1.92    23.2  .431E+02     .51
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      8.63      .00    1.93    23.9  .419E+02    .51
  Maximum jet height has been reached.
      9.11      .00    1.93    24.5  .408E+02    .52
      9.58      .00    1.92    25.2  .397E+02    .53
     10.06      .00    1.92    25.9  .386E+02    .54
     10.52      .00    1.91    26.7  .375E+02    .55
     11.00      .00    1.89    27.5  .363E+02    .56
     11.47      .00    1.88    28.4  .352E+02    .57
     11.95      .00    1.86    29.4  .340E+02    .58
     12.41      .00    1.84    30.4  .329E+02    .59
     12.89      .00    1.81    31.5  .318E+02    .60
     13.36      .00    1.79    32.6  .307E+02    .62
     13.83      .00    1.76    33.8  .296E+02    .63
     14.30      .00    1.73    35.0  .286E+02    .64
     14.78      .00    1.70    36.3  .276E+02    .66
     15.24      .00    1.67    37.6  .266E+02    .67
     15.72      .00    1.63    38.9  .257E+02    .68
     16.18      .00    1.60    40.3  .248E+02    .70
     16.66      .00    1.56    41.8  .239E+02    .71
     17.13      .00    1.52    43.2  .231E+02    .72
     17.60      .00    1.48    44.8  .223E+02    .74
     18.07      .00    1.44    46.3  .216E+02    .75
     18.54      .00    1.40    47.9  .209E+02    .77
     19.01      .00    1.36    49.5  .202E+02    .78
     19.49      .00    1.32    51.2  .195E+02    .80
     19.95      .00    1.28    52.9  .189E+02    .81
     20.43      .00    1.23    54.6  .183E+02    .82
     20.89      .00    1.19    56.3  .178E+02    .84
     21.37      .00    1.15    58.1  .172E+02    .85
     21.83      .00    1.10    59.9  .167E+02    .87
     22.31      .00    1.06    61.7  .162E+02    .88
     22.77      .00    1.01    63.6  .157E+02    .90
     23.25      .00     .97    65.5  .153E+02    .91
     23.72      .00     .93    67.3  .149E+02    .92
 Cumulative travel time =          37. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X         Y       Z         S        C        B
    23.72       .00     .93     67.3  .149E+02     .92

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
22.79	.00	.00	67.3	.149E+02	.00	.00	.00	.00
23.07	.00	.00	67.3	.149E+02	1.20	.60	1.20	.00
23.35	.00	.00	67.3	.149E+02	1.42	.85	1.42	.00
23.62	.00	.00	67.3	.149E+02	1.56	1.04	1.56	.00
23.90	.00	.00	69.2	.145E+02	1.67	1.20	1.67	.00
24.18	.00	.00	77.8	.129E+02	1.74	1.34	1.74	.00
24.46	.00	.00	89.6	.112E+02	1.80	1.47	1.80	.00
24.73	.00	.00	100.4	.996E+01	1.85	1.59	1.85	.00
25.01	.00	.00	107.8	.927E+01	1.88	1.70	1.88	.00
25.29	.00	.00	111.9	.894E+01	1.90	1.80	1.90	.00
25.56	.00	.00	114.5	.874E+01	1.90	1.90	1.90	.00

Cumulative travel time = 41. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
25.56	.00	.00	114.5	.874E+01	1.90	1.90	1.90	.00
26.01	.00	.00	115.4	.867E+01	1.88	1.94	1.88	.00
26.46	.00	.00	116.3	.860E+01	1.86	1.98	1.86	.00
26.90	.00	.00	117.2	.853E+01	1.83	2.02	1.83	.00
27.35	.00	.00	118.1	.847E+01	1.82	2.06	1.82	.00
27.80	.00	.00	119.0	.840E+01	1.80	2.09	1.80	.00
28.24	.00	.00	119.9	.834E+01	1.78	2.13	1.78	.00
28.69	.00	.00	120.8	.828E+01	1.76	2.17	1.76	.00
29.13	.00	.00	121.8	.821E+01	1.75	2.20	1.75	.00
29.58	.00	.00	122.7	.815E+01	1.73	2.24	1.73	.00
30.03	.00	.00	123.6	.809E+01	1.72	2.28	1.72	.00
30.47	.00	.00	124.6	.803E+01	1.70	2.31	1.70	.00
30.92	.00	.00	125.5	.797E+01	1.69	2.35	1.69	.00
31.36	.00	.00	126.5	.791E+01	1.68	2.38	1.68	.00
31.81	.00	.00	127.4	.785E+01	1.67	2.42	1.67	.00
32.26	.00	.00	128.4	.779E+01	1.65	2.45	1.65	.00
32.70	.00	.00	129.4	.773E+01	1.64	2.49	1.64	.00

33.15	.00	.00	130.4	.767E+01	1.63	2.52	1.63	.00
33.59	.00	.00	131.3	.761E+01	1.62	2.55	1.62	.00
34.04	.00	.00	132.4	.756E+01	1.62	2.59	1.62	.00
34.49	.00	.00	133.4	.750E+01	1.61	2.62	1.61	.00
34.93	.00	.00	134.4	.744E+01	1.60	2.65	1.60	.00
35.38	.00	.00	135.4	.738E+01	1.59	2.69	1.59	.00
35.82	.00	.00	136.5	.733E+01	1.58	2.72	1.58	.00
36.27	.00	.00	137.5	.727E+01	1.58	2.75	1.58	.00
36.72	.00	.00	138.6	.721E+01	1.57	2.79	1.57	.00
37.16	.00	.00	139.7	.716E+01	1.57	2.82	1.57	.00
37.61	.00	.00	140.8	.710E+01	1.56	2.85	1.56	.00
38.06	.00	.00	141.9	.705E+01	1.56	2.88	1.56	.00
38.50	.00	.00	143.0	.699E+01	1.55	2.91	1.55	.00
38.95	.00	.00	144.1	.694E+01	1.55	2.95	1.55	.00
39.39	.00	.00	145.3	.688E+01	1.54	2.98	1.54	.00
39.84	.00	.00	146.4	.683E+01	1.54	3.01	1.54	.00
40.29	.00	.00	147.6	.677E+01	1.53	3.04	1.53	.00
40.73	.00	.00	148.8	.672E+01	1.53	3.07	1.53	.00
41.18	.00	.00	150.0	.667E+01	1.53	3.10	1.53	.00
41.62	.00	.00	151.2	.661E+01	1.53	3.13	1.53	.00
42.07	.00	.00	152.4	.656E+01	1.52	3.16	1.52	.00
42.52	.00	.00	153.7	.651E+01	1.52	3.19	1.52	.00
42.96	.00	.00	154.9	.645E+01	1.52	3.22	1.52	.00
43.41	.00	.00	156.2	.640E+01	1.52	3.25	1.52	.00
43.85	.00	.00	157.5	.635E+01	1.52	3.28	1.52	.00
44.30	.00	.00	158.8	.630E+01	1.51	3.31	1.51	.00
44.75	.00	.00	160.1	.625E+01	1.51	3.34	1.51	.00
45.19	.00	.00	161.4	.619E+01	1.51	3.37	1.51	.00
45.64	.00	.00	162.8	.614E+01	1.51	3.40	1.51	.00
46.09	.00	.00	164.1	.609E+01	1.51	3.43	1.51	.00
46.53	.00	.00	165.5	.604E+01	1.51	3.46	1.51	.00
46.98	.00	.00	166.9	.599E+01	1.51	3.49	1.51	.00
47.42	.00	.00	168.3	.594E+01	1.51	3.52	1.51	.00
47.87	.00	.00	169.8	.589E+01	1.51	3.55	1.51	.00

Cumulative travel time = 98. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .205E-01 m^2/s
Horizontal diffusivity (initial value) = .512E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)

ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
47.87	.00	.00	169.8	.589E+01	1.51	3.55	1.51	.00
52.18	.00	.00	187.4	.534E+01	1.56	3.78	1.56	.00
56.49	.00	.00	205.8	.486E+01	1.62	4.01	1.62	.00
60.80	.00	.00	224.9	.445E+01	1.68	4.22	1.68	.00
65.10	.00	.00	244.8	.409E+01	1.75	4.42	1.75	.00
69.41	.00	.00	265.6	.377E+01	1.82	4.62	1.82	.00
73.72	.00	.00	287.3	.348E+01	1.89	4.80	1.89	.00
78.03	.00	.00	309.9	.323E+01	1.97	4.98	1.97	.00
82.34	.00	.00	333.3	.300E+01	2.04	5.15	2.04	.00
86.65	.00	.00	357.7	.280E+01	2.12	5.32	2.12	.00
90.96	.00	.00	382.8	.261E+01	2.21	5.48	2.21	.00
95.26	.00	.00	408.7	.245E+01	2.29	5.64	2.29	.00
99.57	.00	.00	435.3	.230E+01	2.37	5.79	2.37	.00
103.88	.00	.00	462.5	.216E+01	2.46	5.94	2.46	.00
108.19	.00	.00	490.4	.204E+01	2.55	6.09	2.55	.00
112.50	.00	.00	518.8	.193E+01	2.63	6.23	2.63	.00
116.81	.00	.00	547.8	.183E+01	2.72	6.37	2.72	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

121.12	.00	.00	576.4	.173E+01	2.80	6.50	2.80	.00
125.42	.00	.00	588.2	.170E+01	2.80	6.64	2.80	.00
129.73	.00	.00	599.8	.167E+01	2.80	6.77	2.80	.00
134.04	.00	.00	611.1	.164E+01	2.80	6.90	2.80	.00
138.35	.00	.00	622.3	.161E+01	2.80	7.02	2.80	.00
142.66	.00	.00	633.2	.158E+01	2.80	7.14	2.80	.00
146.97	.00	.00	644.0	.155E+01	2.80	7.27	2.80	.00
151.28	.00	.00	654.5	.153E+01	2.80	7.39	2.80	.00
155.58	.00	.00	664.9	.150E+01	2.80	7.50	2.80	.00
159.89	.00	.00	675.2	.148E+01	2.80	7.62	2.80	.00
164.20	.00	.00	685.3	.146E+01	2.80	7.73	2.80	.00
168.51	.00	.00	695.2	.144E+01	2.80	7.84	2.80	.00
172.82	.00	.00	705.1	.142E+01	2.80	7.95	2.80	.00
177.13	.00	.00	714.7	.140E+01	2.80	8.06	2.80	.00
181.43	.00	.00	724.3	.138E+01	2.80	8.17	2.80	.00
185.74	.00	.00	733.7	.136E+01	2.80	8.28	2.80	.00
190.05	.00	.00	743.0	.135E+01	2.80	8.38	2.80	.00
194.36	.00	.00	752.2	.133E+01	2.80	8.49	2.80	.00
198.67	.00	.00	761.3	.131E+01	2.80	8.59	2.80	.00
202.98	.00	.00	770.2	.130E+01	2.80	8.69	2.80	.00
207.29	.00	.00	779.1	.128E+01	2.80	8.79	2.80	.00
211.59	.00	.00	787.9	.127E+01	2.80	8.89	2.80	.00
215.90	.00	.00	796.5	.126E+01	2.80	8.99	2.80	.00
220.21	.00	.00	805.1	.124E+01	2.80	9.08	2.80	.00

224.52	.00	.00	813.6	.123E+01	2.80	9.18	2.80	.00
228.83	.00	.00	822.0	.122E+01	2.80	9.27	2.80	.00
233.14	.00	.00	830.3	.120E+01	2.80	9.37	2.80	.00
237.45	.00	.00	838.5	.119E+01	2.80	9.46	2.80	.00
241.75	.00	.00	846.7	.118E+01	2.80	9.55	2.80	.00
246.06	.00	.00	854.7	.117E+01	2.80	9.64	2.80	.00
250.37	.00	.00	862.7	.116E+01	2.80	9.73	2.80	.00
254.68	.00	.00	870.7	.115E+01	2.80	9.82	2.80	.00
258.99	.00	.00	878.5	.114E+01	2.80	9.91	2.80	.00
263.30	.00	.00	886.3	.113E+01	2.80	10.00	2.80	.00

Cumulative travel time = 641. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
263.30	10.00	.00	886.3	.113E+01	2.80	20.00	2.80	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 269.22 m.

278.03	10.00	.00	892.9	.112E+01	2.80	20.06	2.80	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

292.77	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
307.50	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
322.23	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
336.97	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
351.70	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
366.44	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
381.17	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
395.90	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
410.64	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
425.37	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
440.11	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
454.84	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
469.57	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
484.31	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
499.04	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
513.78	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
528.51	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
543.24	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
557.98	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
572.71	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
587.45	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
602.18	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
616.91	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
631.65	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
646.38	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
661.12	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
675.85	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00

690.59	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
705.32	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
720.05	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
734.79	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
749.52	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
764.26	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
778.99	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
793.72	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
808.46	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
823.19	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
837.93	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
852.66	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
867.39	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
882.13	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
896.86	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
911.60	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
926.33	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
941.06	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
955.80	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
970.53	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
985.27	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00
1000.00	10.00	.00	889.0	.112E+01	2.80	20.06	2.80	.00

Cumulative travel time = 2499. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^2^-^PORT^1^NORMAL^FLOW
 FILE NAME:               cormix\sim\MAC2-1N1.cx1
 Time of Fortran run:     01/13/20--21:36:05

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     20.06  AS    =     56.17  QA    =     22.24  ICHREG= 2
 HA    =      2.80  HD    =      2.80
 UA    =       .396 F     =       .068 USTAR = .3656E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     10.00
 D0    =       .076 A0    =       .005 H0    =       .56
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .013       = .1307E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .2000E+01  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .1307E-01  M0    = .3746E-01  J0    =-.1913E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .07  LM    =      1.95  Lm    =       .49  Lb    =       .03
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     27.14  R     =      7.23

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     2.80  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .2000E+01  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        10.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .200E+01     .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:              THETAE=     27.47  SIGMAE=        .00
  LE    =        .30  XE    =        .26  YE    =        .00  ZE    =        .71

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .200E+01     .04
       .26      .00      .71     1.0  .200E+01     .04
       .51      .00      .82     1.8  .112E+01     .07
       .77      .00      .91     2.8  .719E+00     .10
      1.04      .00      .98     3.8  .527E+00     .13
      1.30      .00     1.04     4.8  .420E+00     .15
      1.58      .00     1.09     5.7  .352E+00     .17
      1.85      .00     1.13     6.5  .306E+00     .18
      2.12      .00     1.16     7.3  .272E+00     .20
      2.40      .00     1.19     8.1  .248E+00     .21
      2.67      .00     1.21     8.8  .228E+00     .22
      2.95      .00     1.23     9.4  .213E+00     .23
      3.23      .00     1.24     9.9  .201E+00     .24
      3.50      .00     1.25    10.4  .191E+00     .24
      3.78      .00     1.26    10.9  .183E+00     .25
      4.05      .00     1.26    11.3  .177E+00     .26
      4.33      .00     1.26    11.7  .171E+00     .26
  Maximum jet height has been reached.
      4.60      .00     1.26    12.0  .166E+00     .27
```

4.88	.00	1.26	12.4	.161E+00	.27
5.16	.00	1.26	12.8	.156E+00	.28
5.43	.00	1.25	13.3	.150E+00	.28
5.71	.00	1.24	13.8	.145E+00	.29
5.99	.00	1.23	14.4	.139E+00	.29
6.26	.00	1.21	14.9	.134E+00	.30
6.54	.00	1.20	15.6	.128E+00	.31
6.81	.00	1.18	16.2	.123E+00	.32
7.09	.00	1.16	16.9	.118E+00	.32
7.36	.00	1.14	17.6	.113E+00	.33
7.64	.00	1.12	18.4	.109E+00	.34
7.91	.00	1.10	19.2	.104E+00	.35
8.19	.00	1.08	20.0	.100E+00	.36
8.46	.00	1.06	20.8	.960E-01	.36
8.74	.00	1.03	21.7	.922E-01	.37
9.01	.00	1.01	22.6	.886E-01	.38
9.29	.00	.98	23.5	.851E-01	.39
9.56	.00	.96	24.4	.818E-01	.40
9.84	.00	.93	25.4	.788E-01	.41
10.11	.00	.91	26.4	.758E-01	.41
10.39	.00	.88	27.4	.731E-01	.42
10.66	.00	.86	28.4	.705E-01	.43
10.94	.00	.83	29.4	.680E-01	.44
11.21	.00	.80	30.5	.656E-01	.45
11.49	.00	.78	31.5	.634E-01	.46
11.76	.00	.75	32.6	.613E-01	.47
12.04	.00	.72	33.7	.593E-01	.47
12.31	.00	.69	34.9	.574E-01	.48
12.58	.00	.67	36.0	.556E-01	.49
12.86	.00	.64	37.1	.539E-01	.50
13.13	.00	.61	38.3	.522E-01	.51
13.41	.00	.59	39.5	.507E-01	.52
13.68	.00	.56	40.6	.492E-01	.52
13.96	.00	.53	41.8	.478E-01	.53

Cumulative travel time = 23. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
13.96	.00	.53	41.8	.478E-01	.53

Profile definitions:

BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
13.42	.00	.00	41.8	.478E-01	.00	.00	.00	.00
13.58	.00	.00	41.8	.478E-01	.68	.34	.68	.00
13.74	.00	.00	41.8	.478E-01	.81	.48	.81	.00
13.90	.00	.00	41.8	.478E-01	.89	.59	.89	.00
14.06	.00	.00	43.0	.465E-01	.95	.69	.95	.00
14.22	.00	.00	48.3	.414E-01	.99	.77	.99	.00
14.38	.00	.00	55.7	.359E-01	1.03	.84	1.03	.00
14.54	.00	.00	62.4	.321E-01	1.05	.91	1.05	.00
14.70	.00	.00	67.0	.299E-01	1.07	.97	1.07	.00
14.86	.00	.00	69.5	.288E-01	1.08	1.03	1.08	.00
15.02	.00	.00	71.1	.281E-01	1.08	1.08	1.08	.00

Cumulative travel time = 26. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
15.02	.00	.00	71.1	.281E-01	1.08	1.08	1.08	.00
15.22	.00	.00	71.5	.280E-01	1.07	1.10	1.07	.00
15.42	.00	.00	72.0	.278E-01	1.06	1.12	1.06	.00
15.61	.00	.00	72.4	.276E-01	1.06	1.13	1.06	.00
15.81	.00	.00	72.9	.274E-01	1.05	1.15	1.05	.00
16.01	.00	.00	73.3	.273E-01	1.04	1.16	1.04	.00
16.21	.00	.00	73.8	.271E-01	1.03	1.18	1.03	.00
16.40	.00	.00	74.2	.270E-01	1.02	1.20	1.02	.00
16.60	.00	.00	74.7	.268E-01	1.02	1.21	1.02	.00
16.80	.00	.00	75.1	.266E-01	1.01	1.23	1.01	.00
17.00	.00	.00	75.6	.265E-01	1.00	1.24	1.00	.00
17.20	.00	.00	76.0	.263E-01	1.00	1.26	1.00	.00
17.39	.00	.00	76.5	.262E-01	.99	1.27	.99	.00
17.59	.00	.00	76.9	.260E-01	.98	1.29	.98	.00
17.79	.00	.00	77.4	.258E-01	.98	1.31	.98	.00
17.99	.00	.00	77.9	.257E-01	.97	1.32	.97	.00
18.18	.00	.00	78.3	.255E-01	.97	1.34	.97	.00

18.38	.00	.00	78.8	.254E-01	.96	1.35	.96	.00
18.58	.00	.00	79.3	.252E-01	.96	1.37	.96	.00
18.78	.00	.00	79.8	.251E-01	.95	1.38	.95	.00
18.98	.00	.00	80.2	.249E-01	.95	1.39	.95	.00
19.17	.00	.00	80.7	.248E-01	.95	1.41	.95	.00
19.37	.00	.00	81.2	.246E-01	.94	1.42	.94	.00
19.57	.00	.00	81.7	.245E-01	.94	1.44	.94	.00
19.77	.00	.00	82.2	.243E-01	.93	1.45	.93	.00
19.96	.00	.00	82.7	.242E-01	.93	1.47	.93	.00
20.16	.00	.00	83.2	.240E-01	.93	1.48	.93	.00
20.36	.00	.00	83.7	.239E-01	.92	1.50	.92	.00
20.56	.00	.00	84.3	.237E-01	.92	1.51	.92	.00
20.76	.00	.00	84.8	.236E-01	.92	1.52	.92	.00
20.95	.00	.00	85.3	.234E-01	.92	1.54	.92	.00
21.15	.00	.00	85.8	.233E-01	.91	1.55	.91	.00
21.35	.00	.00	86.4	.232E-01	.91	1.57	.91	.00
21.55	.00	.00	86.9	.230E-01	.91	1.58	.91	.00
21.74	.00	.00	87.4	.229E-01	.91	1.59	.91	.00
21.94	.00	.00	88.0	.227E-01	.90	1.61	.90	.00
22.14	.00	.00	88.6	.226E-01	.90	1.62	.90	.00
22.34	.00	.00	89.1	.224E-01	.90	1.63	.90	.00
22.53	.00	.00	89.7	.223E-01	.90	1.65	.90	.00
22.73	.00	.00	90.2	.222E-01	.90	1.66	.90	.00
22.93	.00	.00	90.8	.220E-01	.89	1.67	.89	.00
23.13	.00	.00	91.4	.219E-01	.89	1.69	.89	.00
23.33	.00	.00	92.0	.217E-01	.89	1.70	.89	.00
23.52	.00	.00	92.6	.216E-01	.89	1.71	.89	.00
23.72	.00	.00	93.2	.215E-01	.89	1.73	.89	.00
23.92	.00	.00	93.8	.213E-01	.89	1.74	.89	.00
24.12	.00	.00	94.4	.212E-01	.89	1.75	.89	.00
24.31	.00	.00	95.0	.211E-01	.89	1.77	.89	.00
24.51	.00	.00	95.6	.209E-01	.89	1.78	.89	.00
24.71	.00	.00	96.2	.208E-01	.89	1.79	.89	.00
24.91	.00	.00	96.9	.206E-01	.88	1.81	.88	.00

Cumulative travel time = 51. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .205E-01 m^2/s
Horizontal diffusivity (initial value) = .512E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)

ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
24.91	.00	.00	96.9	.206E-01	.88	1.81	.88	.00
29.67	.00	.00	126.8	.158E-01	.92	2.28	.92	.00
34.44	.00	.00	155.7	.128E-01	.96	2.67	.96	.00
39.20	.00	.00	185.6	.108E-01	1.02	3.01	1.02	.00
43.97	.00	.00	217.6	.919E-02	1.08	3.32	1.08	.00
48.73	.00	.00	252.5	.792E-02	1.16	3.60	1.16	.00
53.50	.00	.00	291.0	.687E-02	1.25	3.86	1.25	.00
58.26	.00	.00	333.2	.600E-02	1.34	4.10	1.34	.00
63.03	.00	.00	379.2	.527E-02	1.45	4.33	1.45	.00
67.79	.00	.00	428.8	.466E-02	1.56	4.55	1.56	.00
72.56	.00	.00	481.9	.415E-02	1.67	4.75	1.67	.00
77.32	.00	.00	537.9	.372E-02	1.79	4.95	1.79	.00
82.09	.00	.00	596.6	.335E-02	1.91	5.15	1.91	.00
86.85	.00	.00	657.6	.304E-02	2.04	5.33	2.04	.00
91.62	.00	.00	720.4	.278E-02	2.16	5.51	2.16	.00
96.38	.00	.00	784.7	.255E-02	2.28	5.68	2.28	.00
101.15	.00	.00	850.4	.235E-02	2.40	5.85	2.40	.00
105.91	.00	.00	917.2	.218E-02	2.52	6.01	2.52	.00
110.68	.00	.00	984.9	.203E-02	2.63	6.17	2.63	.00
115.44	.00	.00	1053.4	.190E-02	2.75	6.33	2.75	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

120.21	.00	.00	1099.1	.182E-02	2.80	6.48	2.80	.00
124.97	.00	.00	1124.2	.178E-02	2.80	6.63	2.80	.00
129.74	.00	.00	1148.7	.174E-02	2.80	6.77	2.80	.00
134.50	.00	.00	1172.7	.171E-02	2.80	6.91	2.80	.00
139.27	.00	.00	1196.2	.167E-02	2.80	7.05	2.80	.00
144.03	.00	.00	1219.3	.164E-02	2.80	7.19	2.80	.00
148.80	.00	.00	1241.9	.161E-02	2.80	7.32	2.80	.00
153.56	.00	.00	1264.1	.158E-02	2.80	7.45	2.80	.00
158.33	.00	.00	1286.0	.156E-02	2.80	7.58	2.80	.00
163.09	.00	.00	1307.4	.153E-02	2.80	7.71	2.80	.00
167.86	.00	.00	1328.6	.151E-02	2.80	7.83	2.80	.00
172.62	.00	.00	1349.4	.148E-02	2.80	7.95	2.80	.00
177.39	.00	.00	1369.9	.146E-02	2.80	8.07	2.80	.00
182.15	.00	.00	1390.1	.144E-02	2.80	8.19	2.80	.00
186.92	.00	.00	1409.9	.142E-02	2.80	8.31	2.80	.00
191.68	.00	.00	1429.6	.140E-02	2.80	8.42	2.80	.00
196.45	.00	.00	1448.9	.138E-02	2.80	8.54	2.80	.00
201.21	.00	.00	1468.0	.136E-02	2.80	8.65	2.80	.00
205.98	.00	.00	1486.9	.135E-02	2.80	8.76	2.80	.00
210.74	.00	.00	1505.5	.133E-02	2.80	8.87	2.80	.00
215.51	.00	.00	1523.9	.131E-02	2.80	8.98	2.80	.00

220.27	.00	.00	1542.0	.130E-02	2.80	9.09	2.80	.00
225.04	.00	.00	1560.0	.128E-02	2.80	9.19	2.80	.00
229.80	.00	.00	1577.8	.127E-02	2.80	9.30	2.80	.00
234.57	.00	.00	1595.3	.125E-02	2.80	9.40	2.80	.00
239.33	.00	.00	1612.7	.124E-02	2.80	9.50	2.80	.00
244.10	.00	.00	1629.9	.123E-02	2.80	9.61	2.80	.00
248.86	.00	.00	1646.9	.121E-02	2.80	9.71	2.80	.00
253.63	.00	.00	1663.7	.120E-02	2.80	9.80	2.80	.00
258.39	.00	.00	1680.3	.119E-02	2.80	9.90	2.80	.00
263.16	.00	.00	1696.8	.118E-02	2.80	10.00	2.80	.00

Cumulative travel time = 652. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
263.16	10.00	.00	1696.8	.118E-02	2.80	20.00	2.80	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 269.07 m.

277.89	10.00	.00	1709.5	.117E-02	2.80	20.06	2.80	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

292.63	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
307.37	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
322.10	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
336.84	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
351.58	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
366.31	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
381.05	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
395.79	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
410.52	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
425.26	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
440.00	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
454.73	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
469.47	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
484.21	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
498.95	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
513.68	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
528.42	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
543.16	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
557.89	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
572.63	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
587.37	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
602.10	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
616.84	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
631.58	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
646.31	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
661.05	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
675.79	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00

690.52	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
705.26	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
720.00	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
734.74	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
749.47	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
764.21	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
778.95	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
793.68	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
808.42	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
823.16	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
837.89	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
852.63	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
867.37	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
882.10	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
896.84	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
911.58	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
926.31	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
941.05	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
955.79	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
970.53	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
985.26	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00
1000.00	10.00	.00	1701.9	.118E-02	2.80	20.06	2.80	.00

Cumulative travel time = 2512. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^2^-^PORT^1^MAXIMUM^FLOW
 FILE NAME:               cormix\sim\MAC2-1X1.cx1
 Time of Fortran run:     01/13/20--20:50:38

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     20.06  AS    =     69.61  QA    =     19.98  ICHREG= 2
 HA    =      3.47  HD    =      3.47
 UA    =       .287 F     =       .064 USTAR = .2557E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     10.00
 D0    =       .076 A0    =       .005 H0    =       .56
 THETA =     30.00  SIGMA =       .00
 U0    =      5.487 Q0    =       .025       = .2502E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1013E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .2502E-01  M0    = .1373E+00  J0    =-.3662E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .07  LM    =      3.73  Lm    =      1.29  Lb    =       .15
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     51.96  R     =     19.11

FLOW CLASSIFICATION
 1111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     3.47  1
 1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1013E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        10.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .101E+04     .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:              THETAE=     29.04  SIGMAE=       .00
  LE    =       .35  XE    =       .30  YE    =       .00  ZE    =       .74

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .101E+04     .04
       .30      .00      .74     1.0  .101E+04     .04
       .65      .00      .91     2.0  .510E+03     .08
      1.00      .00     1.08     3.2  .315E+03     .13
      1.37      .00     1.22     4.6  .222E+03     .17
      1.74      .00     1.35     5.9  .171E+03     .22
      2.11      .00     1.46     7.3  .138E+03     .25
      2.49      .00     1.56     8.8  .116E+03     .29
      2.87      .00     1.65    10.1  .100E+03     .32
      3.25      .00     1.73    11.4  .885E+02     .35
      3.65      .00     1.79    12.8  .794E+02     .38
      4.03      .00     1.85    14.0  .724E+02     .41
      4.41      .00     1.90    15.2  .669E+02     .43
      4.81      .00     1.95    16.3  .622E+02     .45
      5.20      .00     1.98    17.3  .584E+02     .47
      5.60      .00     2.01    18.4  .552E+02     .49
      5.98      .00     2.04    19.3  .526E+02     .51
      6.37      .00     2.06    20.1  .503E+02     .52
      6.77      .00     2.08    21.0  .484E+02     .53
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      7.16      .00    2.09    21.7  .467E+02    .55
      7.54      .00    2.10    22.4  .453E+02    .56
      7.94      .00    2.10    23.0  .441E+02    .57
  Maximum jet height has been reached.
      8.33      .00    2.10    23.6  .430E+02    .58
      8.72      .00    2.09    24.2  .418E+02    .59
      9.12      .00    2.09    24.9  .406E+02    .60
      9.51      .00    2.07    25.7  .395E+02    .61
      9.89      .00    2.06    26.5  .383E+02    .62
     10.29      .00    2.04    27.4  .371E+02    .63
     10.68      .00    2.02    28.3  .359E+02    .64
     11.08      .00    1.99    29.2  .347E+02    .66
     11.46      .00    1.97    30.2  .335E+02    .67
     11.85      .00    1.94    31.3  .324E+02    .69
     12.25      .00    1.90    32.4  .312E+02    .70
     12.64      .00    1.87    33.6  .302E+02    .71
     13.02      .00    1.83    34.8  .291E+02    .73
     13.42      .00    1.79    36.1  .281E+02    .75
     13.80      .00    1.75    37.4  .271E+02    .76
     14.19      .00    1.71    38.7  .262E+02    .78
     14.59      .00    1.67    40.1  .253E+02    .79
     14.97      .00    1.62    41.5  .244E+02    .81
     15.37      .00    1.57    43.0  .236E+02    .83
     15.75      .00    1.53    44.5  .228E+02    .84
     16.14      .00    1.48    46.0  .220E+02    .86
     16.54      .00    1.43    47.6  .213E+02    .88
     16.92      .00    1.38    49.2  .206E+02    .89
     17.30      .00    1.33    50.9  .199E+02    .91
     17.70      .00    1.28    52.6  .193E+02    .93
     18.08      .00    1.23    54.3  .187E+02    .94
     18.47      .00    1.17    56.0  .181E+02    .96
     18.86      .00    1.12    57.8  .175E+02    .98
     19.25      .00    1.07    59.6  .170E+02    .99
     19.63      .00    1.01    61.4  .165E+02   1.01
 Cumulative travel time =          35. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
--------------------------------------------------------------------------------
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BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B
     19.63      .00    1.01    61.4  .165E+02   1.01

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
18.62	.00	.00	61.4	.165E+02	.00	.00	.00	.00
18.92	.00	.00	61.4	.165E+02	1.34	.67	1.34	.00
19.23	.00	.00	61.4	.165E+02	1.59	.95	1.59	.00
19.53	.00	.00	61.4	.165E+02	1.75	1.17	1.75	.00
19.83	.00	.00	63.1	.161E+02	1.87	1.35	1.87	.00
20.14	.00	.00	70.9	.143E+02	1.96	1.51	1.96	.00
20.44	.00	.00	81.7	.124E+02	2.02	1.65	2.02	.00
20.74	.00	.00	91.6	.111E+02	2.07	1.78	2.07	.00
21.05	.00	.00	98.4	.103E+02	2.11	1.91	2.11	.00
21.35	.00	.00	102.0	.993E+01	2.13	2.02	2.13	.00
21.66	.00	.00	104.4	.971E+01	2.13	2.13	2.13	.00

Cumulative travel time = 42. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
21.66	.00	.00	104.4	.971E+01	2.13	2.13	2.13	.00
23.59	.00	.00	107.9	.939E+01	1.97	2.39	1.97	.00
25.53	.00	.00	111.1	.912E+01	1.84	2.63	1.84	.00
27.47	.00	.00	114.1	.888E+01	1.74	2.86	1.74	.00
29.40	.00	.00	117.1	.865E+01	1.66	3.08	1.66	.00
31.34	.00	.00	120.1	.844E+01	1.59	3.29	1.59	.00
33.28	.00	.00	123.0	.824E+01	1.53	3.50	1.53	.00
35.22	.00	.00	125.9	.805E+01	1.48	3.70	1.48	.00
37.15	.00	.00	128.9	.786E+01	1.44	3.89	1.44	.00
39.09	.00	.00	132.0	.768E+01	1.41	4.08	1.41	.00
41.03	.00	.00	135.1	.750E+01	1.38	4.27	1.38	.00
42.96	.00	.00	138.3	.733E+01	1.35	4.45	1.35	.00
44.90	.00	.00	141.6	.716E+01	1.33	4.63	1.33	.00
46.84	.00	.00	145.0	.699E+01	1.32	4.81	1.32	.00
48.78	.00	.00	148.5	.682E+01	1.30	4.98	1.30	.00
50.71	.00	.00	152.2	.666E+01	1.29	5.15	1.29	.00
52.65	.00	.00	156.0	.650E+01	1.28	5.31	1.28	.00

54.59	.00	.00	159.9	.634E+01	1.27	5.48	1.27	.00
56.53	.00	.00	163.9	.618E+01	1.27	5.64	1.27	.00
58.46	.00	.00	168.1	.603E+01	1.26	5.80	1.26	.00
60.40	.00	.00	172.5	.587E+01	1.26	5.95	1.26	.00
62.34	.00	.00	177.0	.572E+01	1.26	6.11	1.26	.00
64.27	.00	.00	181.7	.558E+01	1.27	6.26	1.27	.00
66.21	.00	.00	186.6	.543E+01	1.27	6.41	1.27	.00
68.15	.00	.00	191.6	.529E+01	1.27	6.56	1.27	.00
70.09	.00	.00	196.8	.515E+01	1.28	6.71	1.28	.00
72.02	.00	.00	202.1	.501E+01	1.29	6.85	1.29	.00
73.96	.00	.00	207.7	.488E+01	1.29	7.00	1.29	.00
75.90	.00	.00	213.4	.475E+01	1.30	7.14	1.30	.00
77.84	.00	.00	219.3	.462E+01	1.31	7.28	1.31	.00
79.77	.00	.00	225.5	.449E+01	1.32	7.42	1.32	.00
81.71	.00	.00	231.8	.437E+01	1.34	7.56	1.34	.00
83.65	.00	.00	238.3	.425E+01	1.35	7.70	1.35	.00
85.58	.00	.00	245.0	.414E+01	1.36	7.84	1.36	.00
87.52	.00	.00	251.9	.402E+01	1.38	7.97	1.38	.00
89.46	.00	.00	259.0	.391E+01	1.39	8.11	1.39	.00
91.40	.00	.00	266.3	.381E+01	1.41	8.24	1.41	.00
93.33	.00	.00	273.8	.370E+01	1.43	8.37	1.43	.00
95.27	.00	.00	281.5	.360E+01	1.44	8.50	1.44	.00
97.21	.00	.00	289.4	.350E+01	1.46	8.63	1.46	.00
99.15	.00	.00	297.6	.341E+01	1.48	8.76	1.48	.00
101.08	.00	.00	306.0	.331E+01	1.50	8.89	1.50	.00
103.02	.00	.00	314.5	.322E+01	1.52	9.02	1.52	.00
104.96	.00	.00	323.4	.313E+01	1.54	9.14	1.54	.00
106.89	.00	.00	332.4	.305E+01	1.56	9.27	1.56	.00
108.83	.00	.00	341.6	.297E+01	1.59	9.39	1.59	.00
110.77	.00	.00	351.1	.289E+01	1.61	9.51	1.61	.00
112.71	.00	.00	360.8	.281E+01	1.63	9.64	1.63	.00
114.64	.00	.00	370.8	.273E+01	1.66	9.76	1.66	.00
116.58	.00	.00	380.9	.266E+01	1.68	9.88	1.68	.00
118.52	.00	.00	391.3	.259E+01	1.71	10.00	1.71	.00

Cumulative travel time = 379. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
118.52	10.00	.00	391.3	.259E+01	1.71	20.00	1.71	.00
118.54	10.00	.00	391.4	.259E+01	1.71	20.00	1.71	.00
118.56	10.00	.00	391.5	.259E+01	1.71	20.00	1.71	.00
118.58	10.00	.00	391.6	.259E+01	1.71	20.00	1.71	.00
118.60	10.00	.00	391.7	.259E+01	1.71	20.00	1.71	.00
118.61	10.00	.00	391.8	.259E+01	1.71	20.01	1.71	.00
118.63	10.00	.00	391.9	.259E+01	1.71	20.01	1.71	.00
118.65	10.00	.00	392.0	.258E+01	1.71	20.01	1.71	.00

118.67	10.00	.00	392.1	.258E+01	1.71	20.01	1.71	.00
118.69	10.00	.00	392.2	.258E+01	1.71	20.01	1.71	.00
118.71	10.00	.00	392.3	.258E+01	1.71	20.01	1.71	.00
118.73	10.00	.00	392.4	.258E+01	1.71	20.01	1.71	.00
118.75	10.00	.00	392.5	.258E+01	1.71	20.01	1.71	.00
118.77	10.00	.00	392.6	.258E+01	1.71	20.02	1.71	.00
118.79	10.00	.00	392.7	.258E+01	1.71	20.02	1.71	.00
118.81	10.00	.00	392.8	.258E+01	1.71	20.02	1.71	.00
118.83	10.00	.00	392.9	.258E+01	1.71	20.02	1.71	.00
118.85	10.00	.00	393.0	.258E+01	1.71	20.02	1.71	.00
118.87	10.00	.00	393.1	.258E+01	1.71	20.02	1.71	.00
118.89	10.00	.00	393.2	.258E+01	1.71	20.02	1.71	.00
118.91	10.00	.00	393.3	.258E+01	1.71	20.02	1.71	.00
118.93	10.00	.00	393.4	.258E+01	1.71	20.03	1.71	.00
118.95	10.00	.00	393.5	.258E+01	1.71	20.03	1.71	.00
118.97	10.00	.00	393.6	.257E+01	1.71	20.03	1.71	.00
118.98	10.00	.00	393.7	.257E+01	1.71	20.03	1.71	.00
119.00	10.00	.00	393.8	.257E+01	1.71	20.03	1.71	.00
119.02	10.00	.00	393.9	.257E+01	1.71	20.03	1.71	.00
119.04	10.00	.00	394.0	.257E+01	1.71	20.03	1.71	.00
119.06	10.00	.00	394.1	.257E+01	1.71	20.03	1.71	.00
119.08	10.00	.00	394.2	.257E+01	1.72	20.03	1.72	.00
119.10	10.00	.00	394.3	.257E+01	1.72	20.04	1.72	.00
119.12	10.00	.00	394.4	.257E+01	1.72	20.04	1.72	.00
119.14	10.00	.00	394.5	.257E+01	1.72	20.04	1.72	.00
119.16	10.00	.00	394.6	.257E+01	1.72	20.04	1.72	.00
119.18	10.00	.00	394.7	.257E+01	1.72	20.04	1.72	.00
119.20	10.00	.00	394.8	.257E+01	1.72	20.04	1.72	.00
119.22	10.00	.00	394.9	.257E+01	1.72	20.04	1.72	.00
119.24	10.00	.00	395.0	.257E+01	1.72	20.04	1.72	.00
119.26	10.00	.00	395.1	.256E+01	1.72	20.05	1.72	.00
119.28	10.00	.00	395.2	.256E+01	1.72	20.05	1.72	.00
119.30	10.00	.00	395.3	.256E+01	1.72	20.05	1.72	.00
119.32	10.00	.00	395.4	.256E+01	1.72	20.05	1.72	.00
119.34	10.00	.00	395.5	.256E+01	1.72	20.05	1.72	.00
119.35	10.00	.00	395.6	.256E+01	1.72	20.05	1.72	.00
119.37	10.00	.00	395.7	.256E+01	1.72	20.05	1.72	.00
119.39	10.00	.00	395.8	.256E+01	1.72	20.05	1.72	.00
119.41	10.00	.00	395.9	.256E+01	1.72	20.06	1.72	.00
119.43	10.00	.00	396.0	.256E+01	1.72	20.06	1.72	.00
119.45	10.00	.00	396.1	.256E+01	1.72	20.06	1.72	.00
119.47	10.00	.00	396.2	.256E+01	1.72	20.06	1.72	.00
119.49	10.00	.00	396.3	.256E+01	1.72	20.06	1.72	.00

Cumulative travel time = 383. sec
Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .178E-01 m^2/s
Horizontal diffusivity (initial value) = .444E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
119.49	10.00	.00	396.3	.256E+01	1.72	20.06	1.72	.00
137.10	10.00	.00	440.4	.230E+01	1.91	20.06	1.91	.00
154.71	10.00	.00	488.8	.207E+01	2.12	20.06	2.12	.00
172.32	10.00	.00	541.0	.187E+01	2.35	20.06	2.35	.00
189.93	10.00	.00	596.4	.170E+01	2.59	20.06	2.59	.00
207.54	10.00	.00	654.1	.155E+01	2.84	20.06	2.84	.00
225.15	10.00	.00	713.5	.142E+01	3.10	20.06	3.10	.00
242.76	10.00	.00	773.8	.131E+01	3.36	20.06	3.36	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

260.37	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

277.98	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
295.59	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
313.20	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
330.81	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
348.42	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
366.03	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
383.64	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
401.25	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
418.86	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
436.47	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
454.08	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
471.69	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
489.30	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
506.91	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
524.53	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
542.14	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
559.75	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
577.36	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
594.97	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00

612.58	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
630.19	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
647.80	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
665.41	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
683.02	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
700.63	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
718.24	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
735.85	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
753.46	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
771.07	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
788.68	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
806.29	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
823.90	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
841.51	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
859.12	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
876.73	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
894.34	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
911.95	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
929.56	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
947.17	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
964.78	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
982.39	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00
1000.00	10.00	.00	798.5	.127E+01	3.47	20.06	3.47	.00

Cumulative travel time = 3447. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
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                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         Mach^Big^Muddy^River
 Design case:             CASE^3^-^PORT^1^NORMAL^FLOW
 FILE NAME:               cormix\sim\MAC3-1N1.cx1
 Time of Fortran run:     01/13/20--19:49:39

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     21.58  AS    =     74.88  QA    =     21.49  ICHREG= 2
 HA    =      3.47  HD    =      3.47
 UA    =       .287 F     =       .064 USTAR = .2557E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     10.70
 D0    =       .076 A0    =       .005 H0    =       .56
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .013       = .1307E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .1307E-01  M0    = .3746E-01  J0    =-.1913E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .07  LM    =      1.95  Lm    =       .67  Lb    =       .08
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     27.14  R     =      9.98

FLOW CLASSIFICATION
 11111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     3.47  1
 11111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        10.70 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .100E+04     .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:              THETAE=     28.17  SIGMAE=        .00
  LE    =        .32  XE    =        .28  YE    =        .00  ZE    =        .72

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .100E+04     .04
       .28      .00      .72     1.0  .100E+04     .04
       .48      .00      .82     1.6  .640E+03     .07
       .68      .00      .90     2.3  .433E+03     .09
       .90      .00      .98     3.1  .321E+03     .12
      1.11      .00     1.05     3.9  .256E+03     .14
      1.33      .00     1.10     4.7  .212E+03     .16
      1.55      .00     1.15     5.5  .183E+03     .18
      1.77      .00     1.19     6.2  .161E+03     .19
      2.00      .00     1.23     6.9  .144E+03     .21
      2.22      .00     1.26     7.6  .132E+03     .22
      2.44      .00     1.28     8.2  .122E+03     .23
      2.67      .00     1.31     8.8  .114E+03     .24
      2.89      .00     1.32     9.3  .107E+03     .25
      3.12      .00     1.34     9.9  .101E+03     .26
      3.34      .00     1.35    10.3  .970E+02     .27
      3.57      .00     1.36    10.7  .931E+02     .28
      3.79      .00     1.36    11.1  .899E+02     .28
      4.02      .00     1.36    11.5  .872E+02     .29
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 Maximum jet height has been reached.
     4.24      .00    1.36    11.8  .848E+02    .30
     4.47      .00    1.36    12.2  .823E+02    .30
     4.69      .00    1.35    12.6  .796E+02    .31
     4.92      .00    1.34    13.0  .769E+02    .31
     5.15      .00    1.33    13.5  .742E+02    .32
     5.37      .00    1.32    14.0  .715E+02    .33
     5.59      .00    1.31    14.5  .689E+02    .34
     5.82      .00    1.29    15.1  .662E+02    .34
     6.04      .00    1.27    15.7  .637E+02    .35
     6.27      .00    1.25    16.4  .611E+02    .36
     6.49      .00    1.23    17.0  .588E+02    .37
     6.72      .00    1.21    17.7  .564E+02    .38
     6.94      .00    1.18    18.5  .542E+02    .39
     7.16      .00    1.16    19.2  .521E+02    .40
     7.39      .00    1.13    20.0  .500E+02    .41
     7.61      .00    1.11    20.8  .480E+02    .42
     7.84      .00    1.08    21.7  .461E+02    .43
     8.06      .00    1.05    22.5  .444E+02    .43
     8.28      .00    1.02    23.4  .427E+02    .44
     8.51      .00     .99    24.3  .411E+02    .45
     8.73      .00     .96    25.3  .396E+02    .46
     8.95      .00     .93    26.2  .381E+02    .47
     9.17      .00     .90    27.2  .368E+02    .48
     9.39      .00     .87    28.2  .355E+02    .49
     9.62      .00     .84    29.2  .342E+02    .50
     9.84      .00     .81    30.2  .331E+02    .51
    10.07      .00     .78    31.3  .319E+02    .52
    10.29      .00     .74    32.4  .309E+02    .53
    10.52      .00     .71    33.5  .299E+02    .54
    10.74      .00     .68    34.6  .289E+02    .55
    10.96      .00     .65    35.7  .280E+02    .56
    11.18      .00     .62    36.8  .271E+02    .57
    11.40      .00     .58    38.0  .263E+02    .58
 Cumulative travel time =          22. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
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BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B
    11.40      .00     .58    38.0  .263E+02    .58

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.82	.00	.00	38.0	.263E+02	.00	.00	.00	.00
11.00	.00	.00	38.0	.263E+02	.76	.38	.76	.00
11.17	.00	.00	38.0	.263E+02	.90	.54	.90	.00
11.35	.00	.00	38.0	.263E+02	1.00	.66	1.00	.00
11.52	.00	.00	39.0	.256E+02	1.06	.77	1.06	.00
11.70	.00	.00	43.8	.228E+02	1.11	.86	1.11	.00
11.87	.00	.00	50.5	.198E+02	1.15	.94	1.15	.00
12.04	.00	.00	56.6	.177E+02	1.18	1.01	1.18	.00
12.22	.00	.00	60.8	.164E+02	1.20	1.08	1.20	.00
12.39	.00	.00	63.1	.159E+02	1.21	1.15	1.21	.00
12.57	.00	.00	64.5	.155E+02	1.21	1.21	1.21	.00

Cumulative travel time = 26. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
12.57	.00	.00	64.5	.155E+02	1.21	1.21	1.21	.00
13.56	.00	.00	66.4	.151E+02	1.13	1.34	1.13	.00
14.56	.00	.00	68.2	.147E+02	1.07	1.46	1.07	.00
15.55	.00	.00	69.9	.143E+02	1.01	1.57	1.01	.00
16.55	.00	.00	71.6	.140E+02	.97	1.68	.97	.00
17.54	.00	.00	73.3	.137E+02	.93	1.79	.93	.00
18.53	.00	.00	74.9	.134E+02	.90	1.89	.90	.00
19.53	.00	.00	76.6	.131E+02	.87	1.99	.87	.00
20.52	.00	.00	78.2	.128E+02	.85	2.09	.85	.00
21.52	.00	.00	79.9	.125E+02	.83	2.19	.83	.00
22.51	.00	.00	81.7	.122E+02	.81	2.28	.81	.00
23.51	.00	.00	83.4	.120E+02	.80	2.38	.80	.00
24.50	.00	.00	85.2	.117E+02	.79	2.47	.79	.00
25.49	.00	.00	87.1	.115E+02	.78	2.56	.78	.00
26.49	.00	.00	89.1	.112E+02	.77	2.64	.77	.00
27.48	.00	.00	91.0	.110E+02	.76	2.73	.76	.00
28.48	.00	.00	93.1	.107E+02	.75	2.82	.75	.00

29.47	.00	.00	95.2	.105E+02	.75	2.90	.75	.00
30.46	.00	.00	97.4	.103E+02	.74	2.98	.74	.00
31.46	.00	.00	99.7	.100E+02	.74	3.06	.74	.00
32.45	.00	.00	102.0	.980E+01	.74	3.14	.74	.00
33.45	.00	.00	104.5	.957E+01	.74	3.22	.74	.00
34.44	.00	.00	107.0	.935E+01	.74	3.30	.74	.00
35.44	.00	.00	109.5	.913E+01	.74	3.38	.74	.00
36.43	.00	.00	112.2	.891E+01	.74	3.45	.74	.00
37.42	.00	.00	115.0	.870E+01	.74	3.53	.74	.00
38.42	.00	.00	117.8	.849E+01	.74	3.60	.74	.00
39.41	.00	.00	120.8	.828E+01	.75	3.68	.75	.00
40.41	.00	.00	123.8	.808E+01	.75	3.75	.75	.00
41.40	.00	.00	126.9	.788E+01	.76	3.82	.76	.00
42.40	.00	.00	130.1	.769E+01	.76	3.89	.76	.00
43.39	.00	.00	133.4	.749E+01	.77	3.97	.77	.00
44.38	.00	.00	136.8	.731E+01	.77	4.04	.77	.00
45.38	.00	.00	140.4	.712E+01	.78	4.11	.78	.00
46.37	.00	.00	144.0	.695E+01	.78	4.18	.78	.00
47.37	.00	.00	147.7	.677E+01	.79	4.24	.79	.00
48.36	.00	.00	151.5	.660E+01	.80	4.31	.80	.00
49.35	.00	.00	155.4	.643E+01	.81	4.38	.81	.00
50.35	.00	.00	159.4	.627E+01	.82	4.45	.82	.00
51.34	.00	.00	163.6	.611E+01	.83	4.51	.83	.00
52.34	.00	.00	167.8	.596E+01	.83	4.58	.83	.00
53.33	.00	.00	172.2	.581E+01	.84	4.65	.84	.00
54.33	.00	.00	176.6	.566E+01	.85	4.71	.85	.00
55.32	.00	.00	181.2	.552E+01	.86	4.78	.86	.00
56.31	.00	.00	185.9	.538E+01	.87	4.84	.87	.00
57.31	.00	.00	190.6	.525E+01	.89	4.90	.89	.00
58.30	.00	.00	195.5	.511E+01	.90	4.97	.90	.00
59.30	.00	.00	200.6	.499E+01	.91	5.03	.91	.00
60.29	.00	.00	205.7	.486E+01	.92	5.09	.92	.00
61.29	.00	.00	211.0	.474E+01	.93	5.16	.93	.00
62.28	.00	.00	216.3	.462E+01	.94	5.22	.94	.00

Cumulative travel time = 199. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .178E-01 m^2/s
Horizontal diffusivity (initial value) = .444E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)

ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
62.28	.00	.00	216.3	.462E+01	.94	5.22	.94	.00
65.87	.00	.00	227.1	.440E+01	.96	5.38	.96	.00
69.47	.00	.00	238.3	.420E+01	.98	5.54	.98	.00
73.06	.00	.00	249.8	.400E+01	1.00	5.70	1.00	.00
76.66	.00	.00	261.7	.382E+01	1.02	5.85	1.02	.00
80.25	.00	.00	274.1	.365E+01	1.04	6.00	1.04	.00
83.84	.00	.00	286.9	.348E+01	1.06	6.14	1.06	.00
87.44	.00	.00	300.4	.333E+01	1.09	6.28	1.09	.00
91.03	.00	.00	314.4	.318E+01	1.12	6.42	1.12	.00
94.63	.00	.00	329.1	.304E+01	1.14	6.55	1.14	.00
98.22	.00	.00	344.5	.290E+01	1.17	6.68	1.17	.00
101.81	.00	.00	360.6	.277E+01	1.20	6.81	1.20	.00
105.41	.00	.00	377.5	.265E+01	1.24	6.94	1.24	.00
109.00	.00	.00	395.2	.253E+01	1.27	7.06	1.27	.00
112.60	.00	.00	413.8	.242E+01	1.31	7.19	1.31	.00
116.19	.00	.00	433.4	.231E+01	1.35	7.31	1.35	.00
119.78	.00	.00	453.9	.220E+01	1.39	7.43	1.39	.00
123.38	.00	.00	475.4	.210E+01	1.44	7.54	1.44	.00
126.97	.00	.00	498.0	.201E+01	1.48	7.66	1.48	.00
130.57	.00	.00	521.6	.192E+01	1.53	7.77	1.53	.00
134.16	.00	.00	546.4	.183E+01	1.58	7.88	1.58	.00
137.75	.00	.00	572.2	.175E+01	1.63	7.99	1.63	.00
141.35	.00	.00	599.2	.167E+01	1.68	8.10	1.68	.00
144.94	.00	.00	627.3	.159E+01	1.74	8.21	1.74	.00
148.54	.00	.00	656.5	.152E+01	1.80	8.31	1.80	.00
152.13	.00	.00	686.9	.146E+01	1.86	8.42	1.86	.00
155.72	.00	.00	718.3	.139E+01	1.92	8.52	1.92	.00
159.32	.00	.00	750.8	.133E+01	1.98	8.62	1.98	.00
162.91	.00	.00	784.4	.127E+01	2.05	8.72	2.05	.00
166.51	.00	.00	819.0	.122E+01	2.11	8.82	2.11	.00
170.10	.00	.00	854.5	.117E+01	2.18	8.92	2.18	.00
173.69	.00	.00	891.0	.112E+01	2.25	9.02	2.25	.00
177.29	.00	.00	928.3	.108E+01	2.32	9.11	2.32	.00
180.88	.00	.00	966.5	.103E+01	2.39	9.21	2.39	.00
184.48	.00	.00	1005.5	.995E+00	2.46	9.30	2.46	.00
188.07	.00	.00	1045.2	.957E+00	2.53	9.40	2.53	.00
191.66	.00	.00	1085.6	.921E+00	2.60	9.49	2.60	.00
195.26	.00	.00	1126.6	.888E+00	2.68	9.58	2.68	.00
198.85	.00	.00	1168.2	.856E+00	2.75	9.67	2.75	.00
202.45	.00	.00	1210.3	.826E+00	2.82	9.76	2.82	.00
206.04	.00	.00	1253.0	.798E+00	2.90	9.85	2.90	.00
209.63	.00	.00	1296.2	.772E+00	2.97	9.94	2.97	.00
213.23	.00	.00	1339.7	.746E+00	3.04	10.03	3.04	.00
216.82	.00	.00	1383.7	.723E+00	3.12	10.11	3.12	.00

220.42	.00	.00	1428.0	.700E+00	3.19	10.20	3.19	.00
224.01	.00	.00	1472.7	.679E+00	3.26	10.28	3.26	.00
227.60	.00	.00	1517.7	.659E+00	3.33	10.37	3.33	.00
231.20	.00	.00	1562.9	.640E+00	3.40	10.45	3.40	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

234.79	.00	.00	1605.7	.623E+00	3.47	10.54	3.47	.00
238.39	.00	.00	1618.3	.618E+00	3.47	10.62	3.47	.00
241.98	.00	.00	1630.7	.613E+00	3.47	10.70	3.47	.00

Cumulative travel time = 825. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
241.98	10.70	.00	1630.7	.613E+00	3.47	21.40	3.47	.00
257.14	10.70	.00	1643.8	.608E+00	3.47	21.57	3.47	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.
The x-coordinate of bank attachment is 257.91 m.

272.30	10.70	.00	1656.7	.604E+00	3.47	21.58	3.47	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

287.46	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
302.62	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
317.78	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
332.94	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
348.10	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
363.26	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
378.42	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
393.58	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
408.74	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
423.90	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
439.07	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
454.23	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
469.39	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
484.55	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
499.71	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
514.87	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
530.03	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
545.19	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
560.35	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
575.51	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
590.67	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
605.83	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
620.99	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
636.15	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
651.31	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
666.47	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00

681.63	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
696.79	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
711.95	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
727.11	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
742.27	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
757.43	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
772.59	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
787.75	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
802.91	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
818.08	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
833.24	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
848.40	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
863.56	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
878.72	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
893.88	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
909.04	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
924.20	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
939.36	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
954.52	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
969.68	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
984.84	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00
1000.00	10.70	.00	1644.4	.608E+00	3.47	21.58	3.47	.00

Cumulative travel time = 3464. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^3^-^PORT^1^MAXIMUM^FLOW
 FILE NAME:               cormix\sim\MAC3-1X1.cx1
 Time of Fortran run:     01/13/20--20:00:41

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     30.89  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .287 F     =       .058 USTAR = .2445E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.80
 D0    =       .076 A0    =       .005 H0    =       .56
 THETA =     30.00  SIGMA =       .00
 U0    =      5.487 Q0    =       .025       = .2502E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .2502E-01  M0    = .1373E+00  J0    =-.3662E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .07  LM    =      3.73  Lm    =      1.29  Lb    =       .15
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     51.96  R     =     19.11

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y       Z        S       C       B
       .00      .00     .56     1.0  .100E+04    .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     29.04  SIGMAE=        .00
  LE    =        .35  XE    =        .30  YE    =        .00  ZE    =        .74

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
       .00      .00     .56     1.0  .100E+04    .04
       .30      .00     .74     1.0  .100E+04    .04
       .65      .00     .91     2.0  .503E+03    .08
      1.00      .00    1.08     3.2  .311E+03    .13
      1.37      .00    1.22     4.6  .219E+03    .17
      1.74      .00    1.35     5.9  .168E+03    .22
      2.11      .00    1.46     7.3  .136E+03    .25
      2.49      .00    1.56     8.8  .114E+03    .29
      2.87      .00    1.65    10.1  .988E+02    .32
      3.25      .00    1.73    11.4  .873E+02    .35
      3.65      .00    1.79    12.8  .783E+02    .38
      4.03      .00    1.85    14.0  .715E+02    .41
      4.41      .00    1.90    15.2  .660E+02    .43
      4.81      .00    1.95    16.3  .614E+02    .45
      5.20      .00    1.98    17.3  .577E+02    .47
      5.60      .00    2.01    18.4  .545E+02    .49
      5.98      .00    2.04    19.3  .519E+02    .51
      6.37      .00    2.06    20.1  .497E+02    .52
      6.77      .00    2.08    21.0  .477E+02    .53
```

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      7.16      .00    2.09    21.7  .461E+02    .55
      7.54      .00    2.10    22.4  .447E+02    .56
      7.94      .00    2.10    23.0  .435E+02    .57
  Maximum jet height has been reached.
      8.33      .00    2.10    23.6  .424E+02    .58
      8.72      .00    2.09    24.2  .413E+02    .59
      9.12      .00    2.09    24.9  .401E+02    .60
      9.51      .00    2.07    25.7  .389E+02    .61
      9.89      .00    2.06    26.5  .378E+02    .62
     10.29      .00    2.04    27.4  .366E+02    .63
     10.68      .00    2.02    28.3  .354E+02    .64
     11.08      .00    1.99    29.2  .342E+02    .66
     11.46      .00    1.97    30.2  .331E+02    .67
     11.85      .00    1.94    31.3  .320E+02    .69
     12.25      .00    1.90    32.4  .308E+02    .70
     12.64      .00    1.87    33.6  .298E+02    .71
     13.02      .00    1.83    34.8  .287E+02    .73
     13.42      .00    1.79    36.1  .277E+02    .75
     13.80      .00    1.75    37.4  .268E+02    .76
     14.19      .00    1.71    38.7  .258E+02    .78
     14.59      .00    1.67    40.1  .249E+02    .79
     14.97      .00    1.62    41.5  .241E+02    .81
     15.37      .00    1.57    43.0  .232E+02    .83
     15.75      .00    1.53    44.5  .225E+02    .84
     16.14      .00    1.48    46.0  .217E+02    .86
     16.54      .00    1.43    47.6  .210E+02    .88
     16.92      .00    1.38    49.2  .203E+02    .89
     17.30      .00    1.33    50.9  .197E+02    .91
     17.70      .00    1.28    52.6  .190E+02    .93
     18.08      .00    1.23    54.3  .184E+02    .94
     18.47      .00    1.17    56.0  .179E+02    .96
     18.86      .00    1.12    57.8  .173E+02    .98
     19.25      .00    1.07    59.6  .168E+02    .99
     19.63      .00    1.01    61.4  .163E+02   1.01
 Cumulative travel time =          35. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
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--------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X         Y        Z         S        C        B
     19.63      .00    1.01    61.4  .163E+02   1.01

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
18.62	.00	.00	61.4	.163E+02	.00	.00	.00	.00
18.92	.00	.00	61.4	.163E+02	1.34	.67	1.34	.00
19.23	.00	.00	61.4	.163E+02	1.59	.95	1.59	.00
19.53	.00	.00	61.4	.163E+02	1.75	1.17	1.75	.00
19.83	.00	.00	63.1	.158E+02	1.87	1.35	1.87	.00
20.14	.00	.00	70.9	.141E+02	1.96	1.51	1.96	.00
20.44	.00	.00	81.7	.122E+02	2.02	1.65	2.02	.00
20.74	.00	.00	91.6	.109E+02	2.07	1.78	2.07	.00
21.05	.00	.00	98.4	.102E+02	2.11	1.91	2.11	.00
21.35	.00	.00	102.0	.980E+01	2.13	2.02	2.13	.00
21.66	.00	.00	104.4	.958E+01	2.13	2.13	2.13	.00

Cumulative travel time = 42. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
21.66	.00	.00	104.4	.958E+01	2.13	2.13	2.13	.00
23.90	.00	.00	108.3	.923E+01	1.95	2.43	1.95	.00
26.14	.00	.00	111.9	.894E+01	1.81	2.70	1.81	.00
28.38	.00	.00	115.3	.867E+01	1.70	2.96	1.70	.00
30.62	.00	.00	118.6	.843E+01	1.61	3.21	1.61	.00
32.87	.00	.00	121.8	.821E+01	1.54	3.45	1.54	.00
35.11	.00	.00	125.0	.800E+01	1.48	3.69	1.48	.00
37.35	.00	.00	128.3	.780E+01	1.43	3.91	1.43	.00
39.59	.00	.00	131.6	.760E+01	1.39	4.13	1.39	.00
41.84	.00	.00	135.0	.741E+01	1.35	4.35	1.35	.00
44.08	.00	.00	138.4	.722E+01	1.32	4.56	1.32	.00
46.32	.00	.00	142.0	.704E+01	1.30	4.76	1.30	.00
48.56	.00	.00	145.7	.686E+01	1.28	4.96	1.28	.00
50.80	.00	.00	149.6	.669E+01	1.26	5.16	1.26	.00
53.05	.00	.00	153.6	.651E+01	1.25	5.35	1.25	.00
55.29	.00	.00	157.7	.634E+01	1.24	5.54	1.24	.00
57.53	.00	.00	162.1	.617E+01	1.23	5.72	1.23	.00

59.77	.00	.00	166.5	.600E+01	1.23	5.90	1.23	.00
62.02	.00	.00	171.2	.584E+01	1.23	6.08	1.23	.00
64.26	.00	.00	176.1	.568E+01	1.23	6.26	1.23	.00
66.50	.00	.00	181.1	.552E+01	1.23	6.44	1.23	.00
68.74	.00	.00	186.3	.537E+01	1.23	6.61	1.23	.00
70.99	.00	.00	191.8	.521E+01	1.23	6.78	1.23	.00
73.23	.00	.00	197.4	.507E+01	1.24	6.95	1.24	.00
75.47	.00	.00	203.3	.492E+01	1.25	7.11	1.25	.00
77.71	.00	.00	209.4	.478E+01	1.25	7.28	1.25	.00
79.95	.00	.00	215.6	.464E+01	1.26	7.44	1.26	.00
82.20	.00	.00	222.2	.450E+01	1.27	7.60	1.27	.00
84.44	.00	.00	228.9	.437E+01	1.29	7.76	1.29	.00
86.68	.00	.00	235.9	.424E+01	1.30	7.92	1.30	.00
88.92	.00	.00	243.1	.411E+01	1.31	8.07	1.31	.00
91.17	.00	.00	250.5	.399E+01	1.33	8.22	1.33	.00
93.41	.00	.00	258.2	.387E+01	1.34	8.38	1.34	.00
95.65	.00	.00	266.2	.376E+01	1.36	8.53	1.36	.00
97.89	.00	.00	274.3	.365E+01	1.38	8.68	1.38	.00
100.13	.00	.00	282.8	.354E+01	1.40	8.83	1.40	.00
102.38	.00	.00	291.5	.343E+01	1.42	8.98	1.42	.00
104.62	.00	.00	300.4	.333E+01	1.44	9.12	1.44	.00
106.86	.00	.00	309.6	.323E+01	1.46	9.27	1.46	.00
109.10	.00	.00	319.1	.313E+01	1.48	9.41	1.48	.00
111.35	.00	.00	328.8	.304E+01	1.50	9.55	1.50	.00
113.59	.00	.00	338.8	.295E+01	1.52	9.70	1.52	.00
115.83	.00	.00	349.0	.286E+01	1.55	9.84	1.55	.00
118.07	.00	.00	359.6	.278E+01	1.57	9.98	1.57	.00
120.32	.00	.00	370.4	.270E+01	1.60	10.11	1.60	.00
122.56	.00	.00	381.5	.262E+01	1.62	10.25	1.62	.00
124.80	.00	.00	392.8	.255E+01	1.65	10.39	1.65	.00
127.04	.00	.00	404.5	.247E+01	1.68	10.53	1.68	.00
129.28	.00	.00	416.4	.240E+01	1.70	10.66	1.70	.00
131.53	.00	.00	428.6	.233E+01	1.73	10.79	1.73	.00
133.77	.00	.00	441.1	.227E+01	1.76	10.93	1.76	.00

Cumulative travel time = 433. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .222E-01 m^2/s
Horizontal diffusivity (initial value) = .555E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)

ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
133.77	.00	.00	441.1	.227E+01	1.76	10.93	1.76	.00
134.42	.00	.00	443.0	.226E+01	1.76	10.95	1.76	.00
135.07	.00	.00	445.0	.225E+01	1.77	10.96	1.77	.00
135.73	.00	.00	446.9	.224E+01	1.77	10.98	1.77	.00
136.38	.00	.00	448.9	.223E+01	1.78	11.00	1.78	.00
137.03	.00	.00	450.9	.222E+01	1.78	11.02	1.78	.00
137.68	.00	.00	452.9	.221E+01	1.79	11.04	1.79	.00
138.34	.00	.00	454.8	.220E+01	1.79	11.05	1.79	.00
138.99	.00	.00	456.8	.219E+01	1.80	11.07	1.80	.00
139.64	.00	.00	458.9	.218E+01	1.80	11.09	1.80	.00
140.29	.00	.00	460.9	.217E+01	1.81	11.11	1.81	.00
140.94	.00	.00	462.9	.216E+01	1.81	11.13	1.81	.00
141.60	.00	.00	465.0	.215E+01	1.82	11.14	1.82	.00
142.25	.00	.00	467.0	.214E+01	1.82	11.16	1.82	.00
142.90	.00	.00	469.1	.213E+01	1.83	11.18	1.83	.00
143.55	.00	.00	471.1	.212E+01	1.83	11.20	1.83	.00
144.21	.00	.00	473.2	.211E+01	1.84	11.21	1.84	.00
144.86	.00	.00	475.3	.210E+01	1.84	11.23	1.84	.00
145.51	.00	.00	477.4	.209E+01	1.85	11.25	1.85	.00
146.16	.00	.00	479.5	.209E+01	1.86	11.27	1.86	.00
146.82	.00	.00	481.7	.208E+01	1.86	11.29	1.86	.00
147.47	.00	.00	483.8	.207E+01	1.87	11.30	1.87	.00
148.12	.00	.00	486.0	.206E+01	1.87	11.32	1.87	.00
148.77	.00	.00	488.1	.205E+01	1.88	11.34	1.88	.00
149.42	.00	.00	490.3	.204E+01	1.88	11.36	1.88	.00
150.08	.00	.00	492.5	.203E+01	1.89	11.37	1.89	.00
150.73	.00	.00	494.6	.202E+01	1.89	11.39	1.89	.00
151.38	.00	.00	496.8	.201E+01	1.90	11.41	1.90	.00
152.03	.00	.00	499.1	.200E+01	1.90	11.42	1.90	.00
152.69	.00	.00	501.3	.199E+01	1.91	11.44	1.91	.00
153.34	.00	.00	503.5	.199E+01	1.92	11.46	1.92	.00
153.99	.00	.00	505.7	.198E+01	1.92	11.48	1.92	.00
154.64	.00	.00	508.0	.197E+01	1.93	11.49	1.93	.00
155.29	.00	.00	510.3	.196E+01	1.93	11.51	1.93	.00
155.95	.00	.00	512.5	.195E+01	1.94	11.53	1.94	.00
156.60	.00	.00	514.8	.194E+01	1.94	11.55	1.94	.00
157.25	.00	.00	517.1	.193E+01	1.95	11.56	1.95	.00
157.90	.00	.00	519.4	.193E+01	1.96	11.58	1.96	.00
158.56	.00	.00	521.8	.192E+01	1.96	11.60	1.96	.00
159.21	.00	.00	524.1	.191E+01	1.97	11.61	1.97	.00
159.86	.00	.00	526.4	.190E+01	1.97	11.63	1.97	.00
160.51	.00	.00	528.8	.189E+01	1.98	11.65	1.98	.00
161.17	.00	.00	531.2	.188E+01	1.98	11.66	1.98	.00
161.82	.00	.00	533.5	.187E+01	1.99	11.68	1.99	.00

162.47	.00	.00	535.9	.187E+01	2.00	11.70	2.00	.00
163.12	.00	.00	538.3	.186E+01	2.00	11.72	2.00	.00
163.77	.00	.00	540.7	.185E+01	2.01	11.73	2.01	.00
164.43	.00	.00	543.2	.184E+01	2.02	11.75	2.02	.00
165.08	.00	.00	545.6	.183E+01	2.02	11.77	2.02	.00
165.73	.00	.00	548.1	.182E+01	2.03	11.78	2.03	.00
166.38	.00	.00	550.5	.182E+01	2.03	11.80	2.03	.00

Cumulative travel time = 546. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
166.38	11.80	.00	550.5	.182E+01	2.03	23.60	2.03	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 174.95 m.

183.06	11.80	.00	601.1	.166E+01	2.20	23.71	2.20	.00
199.73	11.80	.00	647.8	.154E+01	2.38	23.71	2.38	.00
216.40	11.80	.00	700.8	.143E+01	2.58	23.71	2.58	.00
233.07	11.80	.00	757.2	.132E+01	2.78	23.71	2.78	.00
249.75	11.80	.00	816.5	.122E+01	3.00	23.71	3.00	.00
266.42	11.80	.00	878.4	.114E+01	3.23	23.71	3.23	.00
283.09	11.80	.00	942.4	.106E+01	3.47	23.71	3.47	.00
299.76	11.80	.00	1007.9	.992E+00	3.71	23.71	3.71	.00
316.43	11.80	.00	1074.5	.931E+00	3.95	23.71	3.95	.00
333.11	11.80	.00	1141.8	.876E+00	4.20	23.71	4.20	.00
349.78	11.80	.00	1209.4	.827E+00	4.45	23.71	4.45	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

366.45	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

383.12	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
399.80	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
416.47	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
433.14	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
449.81	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
466.49	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
483.16	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
499.83	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
516.50	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
533.18	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
549.85	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
566.52	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
583.19	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
599.86	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
616.54	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
633.21	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00

649.88	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
666.55	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
683.23	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
699.90	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
716.57	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
733.24	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
749.92	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
766.59	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
783.26	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
799.93	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
816.60	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
833.28	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
849.95	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
866.62	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
883.29	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
899.97	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
916.64	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
933.31	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
949.98	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
966.66	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
983.33	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00
1000.00	11.80	.00	1234.7	.810E+00	4.54	23.71	4.54	.00

Cumulative travel time = 3448. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges           CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         Mach^Big^Muddy^River
 Design case:             Case^3^-^Port^3^Normal^Flow
 FILE NAME:               cormix\sim\MAC3-3N1.cx1
 Time of Fortran run:     01/13/20--19:37:08

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     21.58  AS    =     74.88  QA    =     21.49  ICHREG= 2
 HA    =      3.47  HD    =      3.47
 UA    =      .287  F     =       .064 USTAR = .2557E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =    10.70
 D0    =      .102 A0    =       .008 H0    =       .55
 THETA =    30.00  SIGMA =       .00
 U0    =     2.866 Q0    =       .023       = .2324E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .2324E-01  M0    = .6659E-01  J0    =-.3400E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =      .09  LM    =     2.25  Lm    =       .90  Lb    =       .14
                                    Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =    23.50  R     =     9.98

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     3.47  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        10.70 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
       .00      .00      .55     1.0  .100E+04    .05

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:              THETAE=     28.17  SIGMAE=        .00
  LE    =        .43  XE    =        .37  YE    =        .00  ZE    =        .76

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
       .00      .00      .55     1.0  .100E+04    .05
       .37      .00      .76     1.0  .100E+04    .05
       .57      .00      .86     1.4  .720E+03    .08
       .78      .00      .95     1.9  .516E+03    .10
       .99      .00     1.03     2.5  .398E+03    .13
      1.21      .00     1.11     3.1  .320E+03    .15
      1.42      .00     1.17     3.7  .270E+03    .18
      1.64      .00     1.23     4.3  .233E+03    .20
      1.87      .00     1.28     4.9  .205E+03    .22
      2.09      .00     1.32     5.4  .184E+03    .23
      2.31      .00     1.36     6.0  .168E+03    .25
      2.53      .00     1.40     6.5  .155E+03    .26
      2.77      .00     1.42     7.0  .144E+03    .28
      2.99      .00     1.45     7.4  .135E+03    .29
      3.21      .00     1.47     7.8  .128E+03    .30
      3.45      .00     1.49     8.2  .121E+03    .31
      3.67      .00     1.50     8.6  .116E+03    .32
      3.90      .00     1.51     8.9  .112E+03    .33
      4.13      .00     1.52     9.3  .108E+03    .34
```

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      4.35      .00    1.52     9.5  .105E+03    .34
  Maximum jet height has been reached.
      4.58      .00    1.52     9.8  .102E+03    .35
      4.80      .00    1.52    10.1  .994E+02    .36
      5.04      .00    1.51    10.4  .964E+02    .36
      5.26      .00    1.50    10.7  .935E+02    .37
      5.49      .00    1.49    11.0  .905E+02    .38
      5.72      .00    1.48    11.4  .874E+02    .39
      5.94      .00    1.46    11.8  .844E+02    .39
      6.17      .00    1.45    12.3  .815E+02    .40
      6.39      .00    1.43    12.7  .786E+02    .41
      6.62      .00    1.41    13.2  .756E+02    .42
      6.85      .00    1.38    13.7  .728E+02    .43
      7.07      .00    1.36    14.3  .701E+02    .44
      7.30      .00    1.33    14.8  .674E+02    .45
      7.53      .00    1.30    15.4  .649E+02    .46
      7.75      .00    1.27    16.0  .625E+02    .47
      7.98      .00    1.24    16.6  .601E+02    .49
      8.20      .00    1.21    17.3  .578E+02    .50
      8.43      .00    1.18    17.9  .557E+02    .51
      8.65      .00    1.15    18.6  .537E+02    .52
      8.88      .00    1.11    19.4  .517E+02    .53
      9.10      .00    1.08    20.1  .498E+02    .54
      9.32      .00    1.04    20.8  .481E+02    .55
      9.56      .00    1.01    21.6  .463E+02    .56
      9.78      .00     .97    22.4  .447E+02    .58
     10.00      .00     .93    23.1  .432E+02    .59
     10.23      .00     .90    24.0  .417E+02    .60
     10.45      .00     .86    24.8  .403E+02    .61
     10.67      .00     .82    25.6  .390E+02    .62
     10.89      .00     .79    26.5  .378E+02    .63
     11.13      .00     .75    27.4  .365E+02    .65
     11.35      .00     .71    28.2  .354E+02    .66
     11.57      .00     .67    29.1  .343E+02    .67
 Cumulative travel time =          20. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
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BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X         Y        Z         S        C        B
     11.57      .00     .67    29.1  .343E+02    .67

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.90	.00	.00	29.1	.343E+02	.00	.00	.00	.00
11.10	.00	.00	29.1	.343E+02	.89	.45	.89	.00
11.30	.00	.00	29.1	.343E+02	1.06	.63	1.06	.00
11.50	.00	.00	29.1	.343E+02	1.16	.78	1.16	.00
11.70	.00	.00	29.9	.334E+02	1.24	.90	1.24	.00
11.90	.00	.00	33.6	.297E+02	1.30	1.00	1.30	.00
12.10	.00	.00	38.8	.258E+02	1.34	1.10	1.34	.00
12.30	.00	.00	43.4	.230E+02	1.38	1.18	1.38	.00
12.51	.00	.00	46.6	.214E+02	1.40	1.27	1.40	.00
12.71	.00	.00	48.4	.207E+02	1.41	1.34	1.41	.00
12.91	.00	.00	49.5	.202E+02	1.42	1.42	1.42	.00

Cumulative travel time = 25. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
12.91	.00	.00	49.5	.202E+02	1.42	1.42	1.42	.00
14.85	.00	.00	52.2	.192E+02	1.24	1.71	1.24	.00
16.79	.00	.00	54.5	.183E+02	1.11	1.98	1.11	.00
18.74	.00	.00	56.7	.176E+02	1.03	2.23	1.03	.00
20.68	.00	.00	58.7	.170E+02	.96	2.47	.96	.00
22.63	.00	.00	60.8	.164E+02	.91	2.70	.91	.00
24.57	.00	.00	62.9	.159E+02	.87	2.92	.87	.00
26.51	.00	.00	65.0	.154E+02	.84	3.13	.84	.00
28.46	.00	.00	67.2	.149E+02	.81	3.34	.81	.00
30.40	.00	.00	69.4	.144E+02	.79	3.54	.79	.00
32.34	.00	.00	71.8	.139E+02	.78	3.73	.78	.00
34.29	.00	.00	74.3	.135E+02	.77	3.92	.77	.00
36.23	.00	.00	76.9	.130E+02	.76	4.10	.76	.00
38.18	.00	.00	79.7	.126E+02	.75	4.28	.75	.00
40.12	.00	.00	82.5	.121E+02	.75	4.46	.75	.00
42.06	.00	.00	85.6	.117E+02	.75	4.63	.75	.00
44.01	.00	.00	88.8	.113E+02	.75	4.80	.75	.00

45.95	.00	.00	92.1	.109E+02	.75	4.96	.75	.00
47.90	.00	.00	95.7	.105E+02	.76	5.13	.76	.00
49.84	.00	.00	99.4	.101E+02	.76	5.29	.76	.00
51.78	.00	.00	103.3	.968E+01	.77	5.45	.77	.00
53.73	.00	.00	107.3	.932E+01	.78	5.60	.78	.00
55.67	.00	.00	111.6	.896E+01	.78	5.76	.78	.00
57.61	.00	.00	116.0	.862E+01	.79	5.91	.79	.00
59.56	.00	.00	120.7	.829E+01	.81	6.06	.81	.00
61.50	.00	.00	125.5	.797E+01	.82	6.21	.82	.00
63.45	.00	.00	130.5	.766E+01	.83	6.35	.83	.00
65.39	.00	.00	135.8	.737E+01	.85	6.50	.85	.00
67.33	.00	.00	141.2	.708E+01	.86	6.64	.86	.00
69.28	.00	.00	146.9	.681E+01	.88	6.78	.88	.00
71.22	.00	.00	152.8	.655E+01	.89	6.92	.89	.00
73.17	.00	.00	158.9	.630E+01	.91	7.06	.91	.00
75.11	.00	.00	165.2	.605E+01	.93	7.20	.93	.00
77.05	.00	.00	171.7	.582E+01	.95	7.34	.95	.00
79.00	.00	.00	178.5	.560E+01	.97	7.47	.97	.00
80.94	.00	.00	185.4	.539E+01	.99	7.61	.99	.00
82.88	.00	.00	192.7	.519E+01	1.01	7.74	1.01	.00
84.83	.00	.00	200.1	.500E+01	1.03	7.87	1.03	.00
86.77	.00	.00	207.8	.481E+01	1.05	8.00	1.05	.00
88.72	.00	.00	215.7	.464E+01	1.07	8.13	1.07	.00
90.66	.00	.00	223.9	.447E+01	1.10	8.26	1.10	.00
92.60	.00	.00	232.3	.431E+01	1.12	8.39	1.12	.00
94.55	.00	.00	240.9	.415E+01	1.15	8.51	1.15	.00
96.49	.00	.00	249.8	.400E+01	1.17	8.64	1.17	.00
98.43	.00	.00	259.0	.386E+01	1.20	8.76	1.20	.00
100.38	.00	.00	268.3	.373E+01	1.22	8.89	1.22	.00
102.32	.00	.00	278.0	.360E+01	1.25	9.01	1.25	.00
104.27	.00	.00	287.9	.347E+01	1.28	9.13	1.28	.00
106.21	.00	.00	298.0	.336E+01	1.30	9.25	1.30	.00
108.15	.00	.00	308.4	.324E+01	1.33	9.37	1.33	.00
110.10	.00	.00	319.1	.313E+01	1.36	9.49	1.36	.00

Cumulative travel time = 363. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .178E-01 m^2/s
Horizontal diffusivity (initial value) = .444E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)

ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
110.10	.00	.00	319.1	.313E+01	1.36	9.49	1.36	.00
111.10	.00	.00	321.9	.311E+01	1.37	9.52	1.37	.00
112.11	.00	.00	324.7	.308E+01	1.38	9.54	1.38	.00
113.11	.00	.00	327.5	.305E+01	1.39	9.57	1.39	.00
114.12	.00	.00	330.3	.303E+01	1.39	9.59	1.39	.00
115.13	.00	.00	333.2	.300E+01	1.40	9.62	1.40	.00
116.13	.00	.00	336.1	.298E+01	1.41	9.64	1.41	.00
117.14	.00	.00	339.1	.295E+01	1.42	9.67	1.42	.00
118.14	.00	.00	342.0	.292E+01	1.43	9.69	1.43	.00
119.15	.00	.00	345.0	.290E+01	1.44	9.72	1.44	.00
120.15	.00	.00	348.1	.287E+01	1.45	9.75	1.45	.00
121.16	.00	.00	351.1	.285E+01	1.45	9.77	1.45	.00
122.16	.00	.00	354.2	.282E+01	1.46	9.80	1.46	.00
123.17	.00	.00	357.3	.280E+01	1.47	9.82	1.47	.00
124.17	.00	.00	360.5	.277E+01	1.48	9.84	1.48	.00
125.18	.00	.00	363.7	.275E+01	1.49	9.87	1.49	.00
126.18	.00	.00	366.9	.273E+01	1.50	9.89	1.50	.00
127.19	.00	.00	370.2	.270E+01	1.51	9.92	1.51	.00
128.20	.00	.00	373.4	.268E+01	1.52	9.94	1.52	.00
129.20	.00	.00	376.8	.265E+01	1.53	9.97	1.53	.00
130.21	.00	.00	380.1	.263E+01	1.54	9.99	1.54	.00
131.21	.00	.00	383.5	.261E+01	1.55	10.02	1.55	.00
132.22	.00	.00	386.9	.258E+01	1.56	10.04	1.56	.00
133.22	.00	.00	390.4	.256E+01	1.57	10.07	1.57	.00
134.23	.00	.00	393.9	.254E+01	1.58	10.09	1.58	.00
135.23	.00	.00	397.4	.252E+01	1.59	10.11	1.59	.00
136.24	.00	.00	401.0	.249E+01	1.60	10.14	1.60	.00
137.24	.00	.00	404.6	.247E+01	1.61	10.16	1.61	.00
138.25	.00	.00	408.2	.245E+01	1.62	10.19	1.62	.00
139.26	.00	.00	411.8	.243E+01	1.63	10.21	1.63	.00
140.26	.00	.00	415.5	.241E+01	1.64	10.23	1.64	.00
141.27	.00	.00	419.3	.239E+01	1.65	10.26	1.65	.00
142.27	.00	.00	423.1	.236E+01	1.67	10.28	1.67	.00
143.28	.00	.00	426.9	.234E+01	1.68	10.31	1.68	.00
144.28	.00	.00	430.7	.232E+01	1.69	10.33	1.69	.00
145.29	.00	.00	434.6	.230E+01	1.70	10.35	1.70	.00
146.29	.00	.00	438.5	.228E+01	1.71	10.38	1.71	.00
147.30	.00	.00	442.5	.226E+01	1.72	10.40	1.72	.00
148.30	.00	.00	446.5	.224E+01	1.73	10.42	1.73	.00
149.31	.00	.00	450.5	.222E+01	1.75	10.45	1.75	.00
150.32	.00	.00	454.6	.220E+01	1.76	10.47	1.76	.00
151.32	.00	.00	458.7	.218E+01	1.77	10.49	1.77	.00
152.33	.00	.00	462.8	.216E+01	1.78	10.52	1.78	.00
153.33	.00	.00	467.0	.214E+01	1.79	10.54	1.79	.00

154.34	.00	.00	471.2	.212E+01	1.81	10.56	1.81	.00
155.34	.00	.00	475.5	.210E+01	1.82	10.59	1.82	.00
156.35	.00	.00	479.8	.208E+01	1.83	10.61	1.83	.00
157.35	.00	.00	484.1	.207E+01	1.84	10.63	1.84	.00
158.36	.00	.00	488.5	.205E+01	1.86	10.65	1.86	.00
159.36	.00	.00	492.9	.203E+01	1.87	10.68	1.87	.00
160.37	.00	.00	497.3	.201E+01	1.88	10.70	1.88	.00

Cumulative travel time = 538. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
160.37	10.70	.00	497.3	.201E+01	1.88	21.40	1.88	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 176.31 m.

177.16	10.70	.00	561.8	.178E+01	2.11	21.58	2.11	.00
193.96	10.70	.00	626.3	.160E+01	2.35	21.58	2.35	.00
210.75	10.70	.00	694.5	.144E+01	2.61	21.58	2.61	.00
227.54	10.70	.00	765.0	.131E+01	2.87	21.58	2.87	.00
244.33	10.70	.00	836.7	.120E+01	3.14	21.58	3.14	.00
261.13	10.70	.00	908.8	.110E+01	3.41	21.58	3.41	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

277.92	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

294.71	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
311.50	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
328.30	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
345.09	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
361.88	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
378.67	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
395.47	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
412.26	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
429.05	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
445.84	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
462.64	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
479.43	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
496.22	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
513.01	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
529.81	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
546.60	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
563.39	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
580.19	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
596.98	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
613.77	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
630.56	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00

647.36	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
664.15	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
680.94	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
697.73	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
714.53	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
731.32	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
748.11	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
764.90	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
781.70	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
798.49	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
815.28	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
832.07	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
848.87	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
865.66	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
882.45	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
899.24	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
916.04	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
932.83	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
949.62	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
966.42	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
983.21	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00
1000.00	10.70	.00	925.0	.108E+01	3.47	21.58	3.47	.00

Cumulative travel time = 3460. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^3^-^PORT^3^MAXIMUM^FLOW
 FILE NAME:               cormix\sim\MAC3-3X1.cx1
 Time of Fortran run:     01/13/20--19:56:57

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     30.89  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =      .287  F     =       .058 USTAR = .2445E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.00
 D0    =      .102 A0    =       .008 H0    =       .55
 THETA =    30.00  SIGMA =       .00
 U0    =     5.487 Q0    =       .044       = .4448E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .4448E-01  M0    = .2441E+00  J0    =-.6510E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =      .09  LM    =      4.30  Lm    =      1.72  Lb    =       .28
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     44.99  R     =     19.11

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
       .00      .00      .55     1.0  .100E+04     .05

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:              THETAE=     29.04  SIGMAE=        .00
  LE    =        .47  XE    =        .40  YE    =        .00  ZE    =        .78

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
       .00      .00      .55     1.0  .100E+04     .05
       .40      .00      .78     1.0  .100E+04     .05
       .75      .00      .97     1.7  .582E+03     .10
      1.13      .00     1.14     2.7  .375E+03     .15
      1.51      .00     1.31     3.7  .272E+03     .19
      1.88      .00     1.45     4.7  .213E+03     .24
      2.27      .00     1.58     5.8  .173E+03     .28
      2.66      .00     1.70     6.9  .146E+03     .32
      3.05      .00     1.80     7.9  .126E+03     .36
      3.45      .00     1.89     9.0  .111E+03     .40
      3.85      .00     1.98    10.0  .997E+02     .43
      4.24      .00     2.05    11.0  .909E+02     .46
      4.65      .00     2.12    12.0  .835E+02     .49
      5.06      .00     2.17    12.9  .775E+02     .51
      5.45      .00     2.22    13.8  .726E+02     .54
      5.86      .00     2.27    14.6  .684E+02     .56
      6.27      .00     2.30    15.4  .649E+02     .58
      6.67      .00     2.33    16.1  .619E+02     .60
      7.08      .00     2.36    16.9  .593E+02     .62
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      7.49      .00    2.38    17.5  .571E+02    .63
      7.89      .00    2.39    18.1  .552E+02    .65
      8.30      .00    2.40    18.7  .535E+02    .66
      8.72      .00    2.41    19.2  .521E+02    .67
  Maximum jet height has been reached.
      9.11      .00    2.41    19.7  .508E+02    .68
      9.53      .00    2.40    20.2  .495E+02    .70
      9.94      .00    2.39    20.8  .482E+02    .71
     10.33      .00    2.38    21.3  .468E+02    .72
     10.75      .00    2.36    22.0  .455E+02    .73
     11.16      .00    2.34    22.7  .441E+02    .75
     11.55      .00    2.32    23.4  .427E+02    .76
     11.97      .00    2.29    24.2  .414E+02    .78
     12.38      .00    2.26    25.0  .400E+02    .80
     12.77      .00    2.22    25.8  .387E+02    .81
     13.18      .00    2.19    26.7  .374E+02    .83
     13.60      .00    2.14    27.7  .361E+02    .85
     13.99      .00    2.10    28.6  .349E+02    .86
     14.40      .00    2.06    29.7  .337E+02    .88
     14.81      .00    2.01    30.7  .326E+02    .90
     15.20      .00    1.96    31.8  .315E+02    .92
     15.61      .00    1.91    32.9  .304E+02    .94
     16.02      .00    1.85    34.1  .293E+02    .96
     16.41      .00    1.80    35.2  .284E+02    .98
     16.82      .00    1.74    36.5  .274E+02   1.00
     17.23      .00    1.68    37.7  .265E+02   1.02
     17.62      .00    1.62    39.0  .257E+02   1.04
     18.03      .00    1.56    40.3  .248E+02   1.06
     18.44      .00    1.50    41.7  .240E+02   1.08
     18.83      .00    1.44    43.0  .232E+02   1.10
     19.24      .00    1.38    44.4  .225E+02   1.12
     19.65      .00    1.31    45.9  .218E+02   1.14
     20.04      .00    1.25    47.3  .211E+02   1.16
     20.45      .00    1.18    48.8  .205E+02   1.18
 Cumulative travel time =          33. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X         Y        Z         S        C        B
     20.45      .00    1.18    48.8  .205E+02   1.18

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
19.27	.00	.00	48.8	.205E+02	.00	.00	.00	.00
19.62	.00	.00	48.8	.205E+02	1.59	.80	1.59	.00
19.97	.00	.00	48.8	.205E+02	1.89	1.13	1.89	.00
20.33	.00	.00	48.8	.205E+02	2.08	1.39	2.08	.00
20.68	.00	.00	50.1	.200E+02	2.22	1.60	2.22	.00
21.04	.00	.00	56.3	.178E+02	2.32	1.79	2.32	.00
21.39	.00	.00	64.9	.154E+02	2.40	1.96	2.40	.00
21.75	.00	.00	72.7	.137E+02	2.46	2.12	2.46	.00
22.10	.00	.00	78.1	.128E+02	2.50	2.27	2.50	.00
22.46	.00	.00	81.0	.123E+02	2.53	2.40	2.53	.00
22.81	.00	.00	82.9	.121E+02	2.53	2.53	2.53	.00

Cumulative travel time = 41. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
22.81	.00	.00	82.9	.121E+02	2.53	2.53	2.53	.00
24.47	.00	.00	85.2	.117E+02	2.36	2.80	2.36	.00
26.12	.00	.00	87.2	.115E+02	2.21	3.05	2.21	.00
27.77	.00	.00	89.1	.112E+02	2.10	3.30	2.10	.00
29.43	.00	.00	90.9	.110E+02	2.00	3.53	2.00	.00
31.08	.00	.00	92.7	.108E+02	1.91	3.76	1.91	.00
32.74	.00	.00	94.3	.106E+02	1.84	3.98	1.84	.00
34.39	.00	.00	95.9	.104E+02	1.77	4.19	1.77	.00
36.05	.00	.00	97.5	.103E+02	1.72	4.40	1.72	.00
37.70	.00	.00	99.1	.101E+02	1.67	4.61	1.67	.00
39.36	.00	.00	100.6	.994E+01	1.62	4.81	1.62	.00
41.01	.00	.00	102.2	.979E+01	1.58	5.00	1.58	.00
42.66	.00	.00	103.7	.964E+01	1.55	5.19	1.55	.00
44.32	.00	.00	105.3	.950E+01	1.52	5.38	1.52	.00
45.97	.00	.00	106.8	.936E+01	1.49	5.57	1.49	.00
47.63	.00	.00	108.4	.923E+01	1.46	5.75	1.46	.00
49.28	.00	.00	110.0	.909E+01	1.44	5.93	1.44	.00

50.94	.00	.00	111.6	.896E+01	1.42	6.10	1.42	.00
52.59	.00	.00	113.2	.883E+01	1.40	6.28	1.40	.00
54.25	.00	.00	114.9	.870E+01	1.38	6.45	1.38	.00
55.90	.00	.00	116.6	.858E+01	1.37	6.62	1.37	.00
57.55	.00	.00	118.3	.845E+01	1.35	6.79	1.35	.00
59.21	.00	.00	120.1	.833E+01	1.34	6.95	1.34	.00
60.86	.00	.00	121.9	.821E+01	1.33	7.11	1.33	.00
62.52	.00	.00	123.7	.808E+01	1.32	7.28	1.32	.00
64.17	.00	.00	125.6	.796E+01	1.31	7.43	1.31	.00
65.83	.00	.00	127.5	.784E+01	1.30	7.59	1.30	.00
67.48	.00	.00	129.4	.773E+01	1.29	7.75	1.29	.00
69.14	.00	.00	131.4	.761E+01	1.29	7.90	1.29	.00
70.79	.00	.00	133.5	.749E+01	1.28	8.06	1.28	.00
72.44	.00	.00	135.6	.738E+01	1.28	8.21	1.28	.00
74.10	.00	.00	137.7	.726E+01	1.28	8.36	1.28	.00
75.75	.00	.00	139.9	.715E+01	1.27	8.51	1.27	.00
77.41	.00	.00	142.1	.704E+01	1.27	8.66	1.27	.00
79.06	.00	.00	144.4	.693E+01	1.27	8.80	1.27	.00
80.72	.00	.00	146.7	.682E+01	1.27	8.95	1.27	.00
82.37	.00	.00	149.1	.671E+01	1.27	9.09	1.27	.00
84.03	.00	.00	151.6	.660E+01	1.27	9.23	1.27	.00
85.68	.00	.00	154.0	.649E+01	1.27	9.38	1.27	.00
87.34	.00	.00	156.6	.639E+01	1.28	9.52	1.28	.00
88.99	.00	.00	159.2	.628E+01	1.28	9.66	1.28	.00
90.64	.00	.00	161.9	.618E+01	1.28	9.79	1.28	.00
92.30	.00	.00	164.6	.608E+01	1.28	9.93	1.28	.00
93.95	.00	.00	167.3	.598E+01	1.29	10.07	1.29	.00
95.61	.00	.00	170.2	.588E+01	1.29	10.20	1.29	.00
97.26	.00	.00	173.1	.578E+01	1.30	10.34	1.30	.00
98.92	.00	.00	176.0	.568E+01	1.30	10.47	1.30	.00
100.57	.00	.00	179.0	.559E+01	1.31	10.61	1.31	.00
102.23	.00	.00	182.1	.549E+01	1.31	10.74	1.31	.00
103.88	.00	.00	185.3	.540E+01	1.32	10.87	1.32	.00
105.53	.00	.00	188.4	.531E+01	1.33	11.00	1.33	.00

Cumulative travel time = 329. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
105.53	11.00	.00	188.4	.531E+01	1.33	22.00	1.33	.00
105.98	11.00	.00	189.2	.528E+01	1.33	22.03	1.33	.00
106.42	11.00	.00	190.0	.526E+01	1.33	22.07	1.33	.00
106.87	11.00	.00	190.8	.524E+01	1.34	22.10	1.34	.00
107.31	11.00	.00	191.6	.522E+01	1.34	22.14	1.34	.00
107.76	11.00	.00	192.4	.520E+01	1.34	22.17	1.34	.00
108.20	11.00	.00	193.2	.517E+01	1.35	22.21	1.35	.00
108.65	11.00	.00	194.1	.515E+01	1.35	22.24	1.35	.00

109.09	11.00	.00	194.9	.513E+01	1.36	22.28	1.36	.00
109.53	11.00	.00	195.7	.511E+01	1.36	22.31	1.36	.00
109.98	11.00	.00	196.5	.509E+01	1.36	22.35	1.36	.00
110.42	11.00	.00	197.3	.507E+01	1.37	22.38	1.37	.00
110.87	11.00	.00	198.1	.505E+01	1.37	22.42	1.37	.00
111.31	11.00	.00	199.0	.503E+01	1.37	22.45	1.37	.00
111.76	11.00	.00	199.8	.501E+01	1.38	22.49	1.38	.00
112.20	11.00	.00	200.6	.498E+01	1.38	22.52	1.38	.00
112.64	11.00	.00	201.4	.496E+01	1.38	22.56	1.38	.00
113.09	11.00	.00	202.3	.494E+01	1.39	22.59	1.39	.00
113.53	11.00	.00	203.1	.492E+01	1.39	22.62	1.39	.00
113.98	11.00	.00	203.9	.490E+01	1.39	22.66	1.39	.00
114.42	11.00	.00	204.8	.488E+01	1.40	22.69	1.40	.00
114.87	11.00	.00	205.6	.486E+01	1.40	22.73	1.40	.00
115.31	11.00	.00	206.5	.484E+01	1.41	22.76	1.41	.00
115.76	11.00	.00	207.3	.482E+01	1.41	22.80	1.41	.00
116.20	11.00	.00	208.2	.480E+01	1.41	22.83	1.41	.00
116.64	11.00	.00	209.0	.478E+01	1.42	22.86	1.42	.00
117.09	11.00	.00	209.9	.476E+01	1.42	22.90	1.42	.00
117.53	11.00	.00	210.7	.475E+01	1.42	22.93	1.42	.00
117.98	11.00	.00	211.6	.473E+01	1.43	22.97	1.43	.00
118.42	11.00	.00	212.5	.471E+01	1.43	23.00	1.43	.00
118.87	11.00	.00	213.3	.469E+01	1.44	23.04	1.44	.00
119.31	11.00	.00	214.2	.467E+01	1.44	23.07	1.44	.00
119.76	11.00	.00	215.1	.465E+01	1.44	23.10	1.44	.00
120.20	11.00	.00	215.9	.463E+01	1.45	23.14	1.45	.00
120.64	11.00	.00	216.8	.461E+01	1.45	23.17	1.45	.00
121.09	11.00	.00	217.7	.459E+01	1.45	23.21	1.45	.00
121.53	11.00	.00	218.6	.458E+01	1.46	23.24	1.46	.00
121.98	11.00	.00	219.4	.456E+01	1.46	23.27	1.46	.00
122.42	11.00	.00	220.3	.454E+01	1.46	23.31	1.46	.00
122.87	11.00	.00	221.2	.452E+01	1.47	23.34	1.47	.00
123.31	11.00	.00	222.1	.450E+01	1.47	23.38	1.47	.00
123.76	11.00	.00	223.0	.448E+01	1.48	23.41	1.48	.00
124.20	11.00	.00	223.9	.447E+01	1.48	23.44	1.48	.00
124.64	11.00	.00	224.8	.445E+01	1.48	23.48	1.48	.00
125.09	11.00	.00	225.7	.443E+01	1.49	23.51	1.49	.00
125.53	11.00	.00	226.6	.441E+01	1.49	23.54	1.49	.00
125.98	11.00	.00	227.5	.440E+01	1.50	23.58	1.50	.00
126.42	11.00	.00	228.4	.438E+01	1.50	23.61	1.50	.00
126.87	11.00	.00	229.3	.436E+01	1.50	23.65	1.50	.00
127.31	11.00	.00	230.2	.434E+01	1.51	23.68	1.51	.00
127.75	11.00	.00	231.1	.433E+01	1.51	23.71	1.51	.00

Cumulative travel time = 406. sec
Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .222E-01 m^2/s
Horizontal diffusivity (initial value) = .555E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
127.75	11.00	.00	231.1	.433E+01	1.51	23.71	1.51	.00
145.20	11.00	.00	239.8	.417E+01	1.57	23.71	1.57	.00
162.64	11.00	.00	248.9	.402E+01	1.63	23.71	1.63	.00
180.09	11.00	.00	258.7	.387E+01	1.69	23.71	1.69	.00
197.53	11.00	.00	269.0	.372E+01	1.76	23.71	1.76	.00
214.98	11.00	.00	280.1	.357E+01	1.83	23.71	1.83	.00
232.42	11.00	.00	291.8	.343E+01	1.91	23.71	1.91	.00
249.87	11.00	.00	304.3	.329E+01	1.99	23.71	1.99	.00
267.31	11.00	.00	317.5	.315E+01	2.08	23.71	2.08	.00
284.76	11.00	.00	331.6	.302E+01	2.17	23.71	2.17	.00
302.20	11.00	.00	346.6	.289E+01	2.26	23.71	2.26	.00
319.65	11.00	.00	362.4	.276E+01	2.37	23.71	2.37	.00
337.09	11.00	.00	379.2	.264E+01	2.48	23.71	2.48	.00
354.54	11.00	.00	397.0	.252E+01	2.59	23.71	2.59	.00
371.98	11.00	.00	415.7	.241E+01	2.72	23.71	2.72	.00
389.43	11.00	.00	435.4	.230E+01	2.85	23.71	2.85	.00
406.87	11.00	.00	456.1	.219E+01	2.98	23.71	2.98	.00
424.32	11.00	.00	477.8	.209E+01	3.12	23.71	3.12	.00
441.76	11.00	.00	500.4	.200E+01	3.27	23.71	3.27	.00
459.21	11.00	.00	524.0	.191E+01	3.42	23.71	3.42	.00
476.65	11.00	.00	548.4	.182E+01	3.58	23.71	3.58	.00
494.10	11.00	.00	573.6	.174E+01	3.75	23.71	3.75	.00
511.54	11.00	.00	599.7	.167E+01	3.92	23.71	3.92	.00
528.99	11.00	.00	626.4	.160E+01	4.09	23.71	4.09	.00
546.43	11.00	.00	653.7	.153E+01	4.27	23.71	4.27	.00
563.88	11.00	.00	681.6	.147E+01	4.45	23.71	4.45	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

581.32	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

598.77	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00

616.21	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
633.66	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
651.10	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
668.55	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
685.99	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
703.44	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
720.88	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
738.33	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
755.77	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
773.22	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
790.66	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
808.11	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
825.55	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
843.00	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
860.44	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
877.89	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
895.33	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
912.78	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
930.22	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
947.66	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
965.11	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
982.55	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00
1000.00	11.00	.00	694.7	.144E+01	4.54	23.71	4.54	.00

Cumulative travel time = 3441. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^4^-^PORT^1^NORMAL^FLOW
 FILE NAME:               cormix\sim\MAC4-1N1.cx1
 Time of Fortran run:     01/13/20--20:12:32

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     30.89  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .287 F     =       .058 USTAR = .2445E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.00
 D0    =       .076 A0    =       .005 H0    =       .56
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .013       = .1307E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .1307E-01  M0    = .3746E-01  J0    =-.1913E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .07  LM    =      1.95  Lm    =       .67  Lb    =       .08
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     27.14  R     =      9.98

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y       Z        S       C       B
       .00      .00     .56     1.0  .100E+04    .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.17  SIGMAE=       .00
  LE    =       .32  XE    =       .28  YE    =       .00  ZE    =       .72

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
       .00      .00     .56     1.0  .100E+04    .04
       .28      .00     .72     1.0  .100E+04    .04
       .48      .00     .82     1.6  .640E+03    .07
       .68      .00     .90     2.3  .433E+03    .09
       .90      .00     .98     3.1  .321E+03    .12
      1.11      .00    1.05     3.9  .256E+03    .14
      1.33      .00    1.10     4.7  .212E+03    .16
      1.55      .00    1.15     5.5  .183E+03    .18
      1.77      .00    1.19     6.2  .161E+03    .19
      2.00      .00    1.23     6.9  .144E+03    .21
      2.22      .00    1.26     7.6  .132E+03    .22
      2.44      .00    1.28     8.2  .122E+03    .23
      2.67      .00    1.31     8.8  .114E+03    .24
      2.89      .00    1.32     9.3  .107E+03    .25
      3.12      .00    1.34     9.9  .101E+03    .26
      3.34      .00    1.35    10.3  .970E+02    .27
      3.57      .00    1.36    10.7  .931E+02    .28
      3.79      .00    1.36    11.1  .899E+02    .28
      4.02      .00    1.36    11.5  .872E+02    .29
```

Maximum jet height has been reached.

4.24	.00	1.36	11.8	.848E+02	.30
4.47	.00	1.36	12.2	.823E+02	.30
4.69	.00	1.35	12.6	.796E+02	.31
4.92	.00	1.34	13.0	.769E+02	.31
5.15	.00	1.33	13.5	.742E+02	.32
5.37	.00	1.32	14.0	.715E+02	.33
5.59	.00	1.31	14.5	.689E+02	.34
5.82	.00	1.29	15.1	.662E+02	.34
6.04	.00	1.27	15.7	.637E+02	.35
6.27	.00	1.25	16.4	.611E+02	.36
6.49	.00	1.23	17.0	.588E+02	.37
6.72	.00	1.21	17.7	.564E+02	.38
6.94	.00	1.18	18.5	.542E+02	.39
7.16	.00	1.16	19.2	.521E+02	.40
7.39	.00	1.13	20.0	.500E+02	.41
7.61	.00	1.11	20.8	.480E+02	.42
7.84	.00	1.08	21.7	.461E+02	.43
8.06	.00	1.05	22.5	.444E+02	.43
8.28	.00	1.02	23.4	.427E+02	.44
8.51	.00	.99	24.3	.411E+02	.45
8.73	.00	.96	25.3	.396E+02	.46
8.95	.00	.93	26.2	.381E+02	.47
9.17	.00	.90	27.2	.368E+02	.48
9.39	.00	.87	28.2	.355E+02	.49
9.62	.00	.84	29.2	.342E+02	.50
9.84	.00	.81	30.2	.331E+02	.51
10.07	.00	.78	31.3	.319E+02	.52
10.29	.00	.74	32.4	.309E+02	.53
10.52	.00	.71	33.5	.299E+02	.54
10.74	.00	.68	34.6	.289E+02	.55
10.96	.00	.65	35.7	.280E+02	.56
11.18	.00	.62	36.8	.271E+02	.57
11.40	.00	.58	38.0	.263E+02	.58

Cumulative travel time = 22. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
11.40	.00	.58	38.0	.263E+02	.58

Profile definitions:

BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.82	.00	.00	38.0	.263E+02	.00	.00	.00	.00
11.00	.00	.00	38.0	.263E+02	.76	.38	.76	.00
11.17	.00	.00	38.0	.263E+02	.90	.54	.90	.00
11.35	.00	.00	38.0	.263E+02	1.00	.66	1.00	.00
11.52	.00	.00	39.0	.256E+02	1.06	.77	1.06	.00
11.70	.00	.00	43.8	.228E+02	1.11	.86	1.11	.00
11.87	.00	.00	50.5	.198E+02	1.15	.94	1.15	.00
12.04	.00	.00	56.6	.177E+02	1.18	1.01	1.18	.00
12.22	.00	.00	60.8	.164E+02	1.20	1.08	1.20	.00
12.39	.00	.00	63.1	.159E+02	1.21	1.15	1.21	.00
12.57	.00	.00	64.5	.155E+02	1.21	1.21	1.21	.00

Cumulative travel time = 26. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
12.57	.00	.00	64.5	.155E+02	1.21	1.21	1.21	.00
13.75	.00	.00	66.7	.150E+02	1.12	1.36	1.12	.00
14.93	.00	.00	68.8	.145E+02	1.04	1.50	1.04	.00
16.11	.00	.00	70.7	.141E+02	.99	1.63	.99	.00
17.29	.00	.00	72.6	.138E+02	.94	1.76	.94	.00
18.47	.00	.00	74.5	.134E+02	.90	1.89	.90	.00
19.65	.00	.00	76.3	.131E+02	.87	2.01	.87	.00
20.83	.00	.00	78.2	.128E+02	.84	2.12	.84	.00
22.01	.00	.00	80.1	.125E+02	.82	2.24	.82	.00
23.18	.00	.00	82.0	.122E+02	.80	2.35	.80	.00
24.36	.00	.00	84.0	.119E+02	.78	2.46	.78	.00
25.54	.00	.00	86.0	.116E+02	.76	2.56	.76	.00
26.72	.00	.00	88.2	.113E+02	.75	2.67	.75	.00
27.90	.00	.00	90.3	.111E+02	.74	2.77	.74	.00
29.08	.00	.00	92.6	.108E+02	.74	2.87	.74	.00
30.26	.00	.00	94.9	.105E+02	.73	2.96	.73	.00
31.44	.00	.00	97.4	.103E+02	.72	3.06	.72	.00

32.62	.00	.00	99.9	.100E+02	.72	3.16	.72	.00
33.80	.00	.00	102.5	.976E+01	.72	3.25	.72	.00
34.98	.00	.00	105.2	.951E+01	.72	3.34	.72	.00
36.16	.00	.00	108.0	.926E+01	.72	3.43	.72	.00
37.34	.00	.00	110.9	.902E+01	.72	3.52	.72	.00
38.52	.00	.00	113.9	.878E+01	.72	3.61	.72	.00
39.70	.00	.00	117.1	.854E+01	.72	3.70	.72	.00
40.88	.00	.00	120.3	.831E+01	.72	3.79	.72	.00
42.06	.00	.00	123.7	.809E+01	.73	3.87	.73	.00
43.24	.00	.00	127.1	.787E+01	.73	3.96	.73	.00
44.42	.00	.00	130.7	.765E+01	.74	4.04	.74	.00
45.60	.00	.00	134.4	.744E+01	.74	4.12	.74	.00
46.78	.00	.00	138.3	.723E+01	.75	4.20	.75	.00
47.96	.00	.00	142.2	.703E+01	.76	4.29	.76	.00
49.13	.00	.00	146.3	.683E+01	.76	4.37	.76	.00
50.31	.00	.00	150.5	.664E+01	.77	4.45	.77	.00
51.49	.00	.00	154.9	.646E+01	.78	4.52	.78	.00
52.67	.00	.00	159.4	.628E+01	.79	4.60	.79	.00
53.85	.00	.00	164.0	.610E+01	.80	4.68	.80	.00
55.03	.00	.00	168.7	.593E+01	.81	4.76	.81	.00
56.21	.00	.00	173.6	.576E+01	.82	4.83	.82	.00
57.39	.00	.00	178.6	.560E+01	.83	4.91	.83	.00
58.57	.00	.00	183.8	.544E+01	.84	4.98	.84	.00
59.75	.00	.00	189.1	.529E+01	.85	5.06	.85	.00
60.93	.00	.00	194.5	.514E+01	.86	5.13	.86	.00
62.11	.00	.00	200.1	.500E+01	.87	5.21	.87	.00
63.29	.00	.00	205.8	.486E+01	.89	5.28	.89	.00
64.47	.00	.00	211.7	.472E+01	.90	5.35	.90	.00
65.65	.00	.00	217.7	.459E+01	.91	5.43	.91	.00
66.83	.00	.00	223.8	.447E+01	.93	5.50	.93	.00
68.01	.00	.00	230.2	.434E+01	.94	5.57	.94	.00
69.19	.00	.00	236.6	.423E+01	.96	5.64	.96	.00
70.37	.00	.00	243.2	.411E+01	.97	5.71	.97	.00
71.55	.00	.00	250.0	.400E+01	.99	5.78	.99	.00

Cumulative travel time = 231. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .222E-01 m^2/s
Horizontal diffusivity (initial value) = .555E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)

ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
71.55	.00	.00	250.0	.400E+01	.99	5.78	.99	.00
74.43	.00	.00	258.8	.386E+01	.99	5.93	.99	.00
77.31	.00	.00	267.7	.374E+01	1.00	6.07	1.00	.00
80.20	.00	.00	276.6	.361E+01	1.01	6.22	1.01	.00
83.08	.00	.00	285.7	.350E+01	1.02	6.36	1.02	.00
85.96	.00	.00	294.9	.339E+01	1.03	6.49	1.03	.00
88.85	.00	.00	304.3	.329E+01	1.05	6.63	1.05	.00
91.73	.00	.00	313.8	.319E+01	1.06	6.76	1.06	.00
94.61	.00	.00	323.5	.309E+01	1.07	6.89	1.07	.00
97.49	.00	.00	333.4	.300E+01	1.08	7.01	1.08	.00
100.38	.00	.00	343.5	.291E+01	1.10	7.14	1.10	.00
103.26	.00	.00	353.9	.283E+01	1.11	7.26	1.11	.00
106.14	.00	.00	364.5	.274E+01	1.12	7.38	1.12	.00
109.03	.00	.00	375.3	.266E+01	1.14	7.49	1.14	.00
111.91	.00	.00	386.5	.259E+01	1.16	7.61	1.16	.00
114.79	.00	.00	398.0	.251E+01	1.17	7.72	1.17	.00
117.68	.00	.00	409.7	.244E+01	1.19	7.84	1.19	.00
120.56	.00	.00	421.9	.237E+01	1.21	7.95	1.21	.00
123.44	.00	.00	434.4	.230E+01	1.23	8.06	1.23	.00
126.33	.00	.00	447.2	.224E+01	1.25	8.17	1.25	.00
129.21	.00	.00	460.5	.217E+01	1.27	8.27	1.27	.00
132.09	.00	.00	474.2	.211E+01	1.29	8.38	1.29	.00
134.98	.00	.00	488.3	.205E+01	1.31	8.48	1.31	.00
137.86	.00	.00	502.9	.199E+01	1.33	8.58	1.33	.00
140.74	.00	.00	518.0	.193E+01	1.36	8.69	1.36	.00
143.63	.00	.00	533.6	.187E+01	1.38	8.79	1.38	.00
146.51	.00	.00	549.7	.182E+01	1.41	8.89	1.41	.00
149.39	.00	.00	566.3	.177E+01	1.44	8.98	1.44	.00
152.28	.00	.00	583.6	.171E+01	1.46	9.08	1.46	.00
155.16	.00	.00	601.4	.166E+01	1.49	9.18	1.49	.00
158.04	.00	.00	619.8	.161E+01	1.52	9.27	1.52	.00
160.93	.00	.00	638.9	.157E+01	1.55	9.37	1.55	.00
163.81	.00	.00	658.6	.152E+01	1.59	9.46	1.59	.00
166.69	.00	.00	679.0	.147E+01	1.62	9.55	1.62	.00
169.58	.00	.00	700.1	.143E+01	1.65	9.64	1.65	.00
172.46	.00	.00	721.9	.139E+01	1.69	9.73	1.69	.00
175.34	.00	.00	744.4	.134E+01	1.73	9.82	1.73	.00
178.23	.00	.00	767.7	.130E+01	1.76	9.91	1.76	.00
181.11	.00	.00	791.7	.126E+01	1.80	10.00	1.80	.00
183.99	.00	.00	816.5	.122E+01	1.84	10.09	1.84	.00
186.87	.00	.00	842.0	.119E+01	1.88	10.17	1.88	.00
189.76	.00	.00	868.4	.115E+01	1.93	10.26	1.93	.00
192.64	.00	.00	895.5	.112E+01	1.97	10.34	1.97	.00
195.52	.00	.00	923.4	.108E+01	2.02	10.43	2.02	.00

198.41	.00	.00	952.1	.105E+01	2.06	10.51	2.06	.00
201.29	.00	.00	981.6	.102E+01	2.11	10.59	2.11	.00
204.17	.00	.00	1011.8	.988E+00	2.16	10.68	2.16	.00
207.06	.00	.00	1042.9	.959E+00	2.21	10.76	2.21	.00
209.94	.00	.00	1074.7	.931E+00	2.26	10.84	2.26	.00
212.82	.00	.00	1107.2	.903E+00	2.31	10.92	2.31	.00
215.71	.00	.00	1140.5	.877E+00	2.36	11.00	2.36	.00

Cumulative travel time = 733. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
215.71	11.00	.00	1140.5	.877E+00	2.36	22.00	2.36	.00
231.39	11.00	.00	1295.5	.772E+00	2.66	22.22	2.66	.00
247.08	11.00	.00	1459.4	.685E+00	2.96	22.43	2.96	.00
262.76	11.00	.00	1629.4	.614E+00	3.28	22.64	3.28	.00
278.45	11.00	.00	1803.0	.555E+00	3.59	22.85	3.59	.00
294.14	11.00	.00	1978.4	.505E+00	3.91	23.06	3.91	.00
309.82	11.00	.00	2154.1	.464E+00	4.22	23.26	4.22	.00
325.51	11.00	.00	2329.4	.429E+00	4.52	23.47	4.52	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

341.19	11.00	.00	2359.9	.424E+00	4.54	23.67	4.54	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 344.33 m.

356.88	11.00	.00	2379.9	.420E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

372.57	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
388.25	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
403.94	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
419.62	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
435.31	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
450.99	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
466.68	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
482.37	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
498.05	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
513.74	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
529.42	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
545.11	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
560.80	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
576.48	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
592.17	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
607.85	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
623.54	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
639.23	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
654.91	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00

670.60	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
686.28	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
701.97	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
717.65	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
733.34	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
749.03	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
764.71	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
780.40	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
796.08	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
811.77	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
827.46	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
843.14	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
858.83	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
874.51	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
890.20	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
905.88	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
921.57	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
937.26	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
952.94	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
968.63	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
984.31	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00
1000.00	11.00	.00	2363.9	.423E+00	4.54	23.71	4.54	.00

Cumulative travel time = 3465. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^4^-^PORT^1^MAXIMUM^FLOW
 FILE NAME:               cormix\sim\MAC4-1X1.cx1
 Time of Fortran run:     01/13/20--20:38:34

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     38.11  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .354 F     =       .058 USTAR = .3016E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.00
 D0    =       .076 A0    =       .005 H0    =       .56
 THETA =     30.00  SIGMA =       .00
 U0    =      5.487 Q0    =       .025       = .2502E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .2502E-01  M0    = .1373E+00  J0    =-.3662E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .07  LM    =      3.73  Lm    =      1.05  Lb    =       .08
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     51.96  R     =     15.50

FLOW CLASSIFICATION
 1111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .100E+04    .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:             THETAE=     28.82  SIGMAE=        .00
  LE    =        .34  XE    =        .30  YE    =        .00  ZE    =        .73

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .100E+04    .04
       .30      .00      .73     1.0  .100E+04    .04
       .69      .00      .93     2.2  .457E+03    .09
      1.09      .00     1.10     3.7  .273E+03    .14
      1.51      .00     1.24     5.2  .191E+03    .19
      1.93      .00     1.37     6.9  .146E+03    .23
      2.36      .00     1.47     8.4  .118E+03    .27
      2.80      .00     1.56    10.0  .996E+02    .30
      3.23      .00     1.64    11.5  .867E+02    .33
      3.67      .00     1.70    13.0  .772E+02    .36
      4.10      .00     1.76    14.3  .699E+02    .39
      4.54      .00     1.81    15.6  .642E+02    .41
      4.99      .00     1.85    16.8  .595E+02    .43
      5.43      .00     1.88    17.9  .557E+02    .45
      5.87      .00     1.91    19.0  .527E+02    .47
      6.30      .00     1.94    20.0  .501E+02    .48
      6.74      .00     1.96    20.9  .479E+02    .49
      7.19      .00     1.97    21.7  .460E+02    .51
      7.63      .00     1.98    22.5  .445E+02    .52
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      8.07      .00    1.99    23.2  .431E+02    .53
      8.51      .00    1.99    23.8  .420E+02    .54
  Maximum jet height has been reached.
      8.95      .00    1.99    24.4  .409E+02    .54
      9.40      .00    1.98    25.1  .398E+02    .55
      9.84      .00    1.97    25.8  .387E+02    .56
     10.28      .00    1.96    26.6  .375E+02    .57
     10.72      .00    1.95    27.5  .364E+02    .58
     11.16      .00    1.93    28.4  .352E+02    .60
     11.61      .00    1.91    29.4  .341E+02    .61
     12.05      .00    1.89    30.4  .329E+02    .62
     12.49      .00    1.86    31.4  .318E+02    .63
     12.93      .00    1.83    32.6  .307E+02    .65
     13.36      .00    1.80    33.7  .297E+02    .66
     13.81      .00    1.77    35.0  .286E+02    .67
     14.25      .00    1.74    36.2  .276E+02    .69
     14.69      .00    1.70    37.5  .267E+02    .70
     15.13      .00    1.66    38.9  .257E+02    .72
     15.57      .00    1.63    40.3  .248E+02    .73
     16.01      .00    1.59    41.7  .240E+02    .74
     16.45      .00    1.55    43.2  .232E+02    .76
     16.89      .00    1.50    44.7  .224E+02    .77
     17.33      .00    1.46    46.2  .216E+02    .79
     17.76      .00    1.42    47.8  .209E+02    .80
     18.20      .00    1.37    49.4  .202E+02    .82
     18.65      .00    1.33    51.1  .196E+02    .83
     19.09      .00    1.28    52.8  .189E+02    .85
     19.52      .00    1.24    54.5  .184E+02    .87
     19.96      .00    1.19    56.2  .178E+02    .88
     20.40      .00    1.15    58.0  .172E+02    .90
     20.85      .00    1.10    59.8  .167E+02    .91
     21.28      .00    1.05    61.6  .162E+02    .93
     21.72      .00    1.00    63.5  .158E+02    .94
     22.16      .00     .96    65.3  .153E+02    .96
 Cumulative travel time =          36. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B
    22.16      .00     .96    65.3  .153E+02    .96

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
21.20	.00	.00	65.3	.153E+02	.00	.00	.00	.00
21.49	.00	.00	65.3	.153E+02	1.25	.63	1.25	.00
21.77	.00	.00	65.3	.153E+02	1.48	.89	1.48	.00
22.06	.00	.00	65.3	.153E+02	1.63	1.09	1.63	.00
22.35	.00	.00	67.1	.149E+02	1.73	1.25	1.73	.00
22.63	.00	.00	75.5	.133E+02	1.82	1.40	1.82	.00
22.92	.00	.00	87.0	.115E+02	1.88	1.53	1.88	.00
23.21	.00	.00	97.4	.103E+02	1.92	1.66	1.92	.00
23.50	.00	.00	104.6	.956E+01	1.96	1.77	1.96	.00
23.78	.00	.00	108.5	.921E+01	1.98	1.88	1.98	.00
24.07	.00	.00	111.1	.900E+01	1.98	1.98	1.98	.00

Cumulative travel time = 42. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
24.07	.00	.00	111.1	.900E+01	1.98	1.98	1.98	.00
25.06	.00	.00	112.9	.886E+01	1.92	2.08	1.92	.00
26.05	.00	.00	114.6	.873E+01	1.86	2.18	1.86	.00
27.04	.00	.00	116.3	.860E+01	1.81	2.27	1.81	.00
28.03	.00	.00	118.0	.847E+01	1.76	2.37	1.76	.00
29.02	.00	.00	119.7	.835E+01	1.72	2.46	1.72	.00
30.01	.00	.00	121.4	.824E+01	1.68	2.55	1.68	.00
31.00	.00	.00	123.1	.813E+01	1.65	2.64	1.65	.00
31.99	.00	.00	124.8	.801E+01	1.62	2.72	1.62	.00
32.98	.00	.00	126.5	.791E+01	1.59	2.81	1.59	.00
33.97	.00	.00	128.2	.780E+01	1.57	2.89	1.57	.00
34.96	.00	.00	130.0	.770E+01	1.54	2.98	1.54	.00
35.95	.00	.00	131.7	.759E+01	1.52	3.06	1.52	.00
36.94	.00	.00	133.5	.749E+01	1.50	3.14	1.50	.00
37.93	.00	.00	135.3	.739E+01	1.49	3.22	1.49	.00
38.92	.00	.00	137.2	.729E+01	1.47	3.30	1.47	.00
39.91	.00	.00	139.1	.719E+01	1.46	3.37	1.46	.00

40.90	.00	.00	141.0	.709E+01	1.44	3.45	1.44	.00
41.89	.00	.00	142.9	.700E+01	1.43	3.53	1.43	.00
42.88	.00	.00	144.9	.690E+01	1.42	3.60	1.42	.00
43.87	.00	.00	146.9	.681E+01	1.41	3.68	1.41	.00
44.86	.00	.00	149.0	.671E+01	1.40	3.75	1.40	.00
45.85	.00	.00	151.1	.662E+01	1.40	3.82	1.40	.00
46.84	.00	.00	153.3	.652E+01	1.39	3.90	1.39	.00
47.83	.00	.00	155.5	.643E+01	1.38	3.97	1.38	.00
48.83	.00	.00	157.7	.634E+01	1.38	4.04	1.38	.00
49.82	.00	.00	160.0	.625E+01	1.38	4.11	1.38	.00
50.81	.00	.00	162.3	.616E+01	1.37	4.18	1.37	.00
51.80	.00	.00	164.7	.607E+01	1.37	4.25	1.37	.00
52.79	.00	.00	167.2	.598E+01	1.37	4.32	1.37	.00
53.78	.00	.00	169.7	.589E+01	1.37	4.38	1.37	.00
54.77	.00	.00	172.2	.581E+01	1.37	4.45	1.37	.00
55.76	.00	.00	174.8	.572E+01	1.37	4.52	1.37	.00
56.75	.00	.00	177.4	.564E+01	1.37	4.59	1.37	.00
57.74	.00	.00	180.1	.555E+01	1.37	4.65	1.37	.00
58.73	.00	.00	182.9	.547E+01	1.37	4.72	1.37	.00
59.72	.00	.00	185.7	.538E+01	1.37	4.78	1.37	.00
60.71	.00	.00	188.6	.530E+01	1.37	4.85	1.37	.00
61.70	.00	.00	191.5	.522E+01	1.38	4.91	1.38	.00
62.69	.00	.00	194.5	.514E+01	1.38	4.98	1.38	.00
63.68	.00	.00	197.5	.506E+01	1.39	5.04	1.39	.00
64.67	.00	.00	200.6	.498E+01	1.39	5.10	1.39	.00
65.66	.00	.00	203.8	.491E+01	1.39	5.16	1.39	.00
66.65	.00	.00	207.0	.483E+01	1.40	5.23	1.40	.00
67.64	.00	.00	210.3	.475E+01	1.41	5.29	1.41	.00
68.63	.00	.00	213.7	.468E+01	1.41	5.35	1.41	.00
69.62	.00	.00	217.1	.461E+01	1.42	5.41	1.42	.00
70.61	.00	.00	220.6	.453E+01	1.42	5.47	1.42	.00
71.60	.00	.00	224.1	.446E+01	1.43	5.53	1.43	.00
72.59	.00	.00	227.7	.439E+01	1.44	5.59	1.44	.00
73.58	.00	.00	231.4	.432E+01	1.45	5.65	1.45	.00

Cumulative travel time = 181. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .274E-01 m^2/s
Horizontal diffusivity (initial value) = .685E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)

ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
73.58	.00	.00	231.4	.432E+01	1.45	5.65	1.45	.00
76.51	.00	.00	240.4	.416E+01	1.46	5.81	1.46	.00
79.44	.00	.00	249.5	.401E+01	1.48	5.96	1.48	.00
82.38	.00	.00	258.7	.387E+01	1.50	6.11	1.50	.00
85.31	.00	.00	268.1	.373E+01	1.52	6.25	1.52	.00
88.24	.00	.00	277.7	.360E+01	1.54	6.39	1.54	.00
91.17	.00	.00	287.4	.348E+01	1.56	6.53	1.56	.00
94.10	.00	.00	297.4	.336E+01	1.58	6.66	1.58	.00
97.03	.00	.00	307.5	.325E+01	1.60	6.80	1.60	.00
99.97	.00	.00	317.9	.315E+01	1.62	6.93	1.62	.00
102.90	.00	.00	328.6	.304E+01	1.65	7.05	1.65	.00
105.83	.00	.00	339.5	.295E+01	1.67	7.18	1.67	.00
108.76	.00	.00	350.7	.285E+01	1.70	7.30	1.70	.00
111.69	.00	.00	362.2	.276E+01	1.72	7.42	1.72	.00
114.62	.00	.00	374.0	.267E+01	1.75	7.54	1.75	.00
117.56	.00	.00	386.2	.259E+01	1.78	7.66	1.78	.00
120.49	.00	.00	398.6	.251E+01	1.81	7.77	1.81	.00
123.42	.00	.00	411.5	.243E+01	1.84	7.89	1.84	.00
126.35	.00	.00	424.6	.236E+01	1.88	8.00	1.88	.00
129.28	.00	.00	438.2	.228E+01	1.91	8.11	1.91	.00
132.21	.00	.00	452.1	.221E+01	1.94	8.22	1.94	.00
135.15	.00	.00	466.4	.214E+01	1.98	8.33	1.98	.00
138.08	.00	.00	481.2	.208E+01	2.02	8.43	2.02	.00
141.01	.00	.00	496.3	.201E+01	2.05	8.54	2.05	.00
143.94	.00	.00	511.8	.195E+01	2.09	8.64	2.09	.00
146.87	.00	.00	527.8	.189E+01	2.13	8.75	2.13	.00
149.80	.00	.00	544.2	.184E+01	2.17	8.85	2.17	.00
152.73	.00	.00	561.1	.178E+01	2.22	8.95	2.22	.00
155.67	.00	.00	578.3	.173E+01	2.26	9.05	2.26	.00
158.60	.00	.00	596.0	.168E+01	2.30	9.14	2.30	.00
161.53	.00	.00	614.2	.163E+01	2.35	9.24	2.35	.00
164.46	.00	.00	632.8	.158E+01	2.40	9.34	2.40	.00
167.39	.00	.00	651.8	.153E+01	2.44	9.43	2.44	.00
170.32	.00	.00	671.2	.149E+01	2.49	9.52	2.49	.00
173.26	.00	.00	691.1	.145E+01	2.54	9.62	2.54	.00
176.19	.00	.00	711.4	.141E+01	2.59	9.71	2.59	.00
179.12	.00	.00	732.1	.137E+01	2.64	9.80	2.64	.00
182.05	.00	.00	753.3	.133E+01	2.69	9.89	2.69	.00
184.98	.00	.00	774.8	.129E+01	2.74	9.98	2.74	.00
187.91	.00	.00	796.7	.126E+01	2.80	10.07	2.80	.00
190.85	.00	.00	819.0	.122E+01	2.85	10.16	2.85	.00
193.78	.00	.00	841.7	.119E+01	2.90	10.25	2.90	.00
196.71	.00	.00	864.8	.116E+01	2.96	10.33	2.96	.00
199.64	.00	.00	888.2	.113E+01	3.01	10.42	3.01	.00

202.57	.00	.00	911.9	.110E+01	3.07	10.50	3.07	.00
205.50	.00	.00	936.0	.107E+01	3.12	10.59	3.12	.00
208.44	.00	.00	960.5	.104E+01	3.18	10.67	3.18	.00
211.37	.00	.00	985.2	.102E+01	3.24	10.75	3.24	.00
214.30	.00	.00	1010.2	.990E+00	3.29	10.84	3.29	.00
217.23	.00	.00	1035.5	.966E+00	3.35	10.92	3.35	.00
220.16	.00	.00	1061.1	.942E+00	3.41	11.00	3.41	.00

Cumulative travel time = 595. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
220.16	11.00	.00	1061.1	.942E+00	3.41	22.00	3.41	.00
235.76	11.00	.00	1167.7	.856E+00	3.72	22.21	3.72	.00
251.36	11.00	.00	1275.4	.784E+00	4.02	22.43	4.02	.00
266.95	11.00	.00	1383.4	.723E+00	4.32	22.64	4.32	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

282.55	11.00	.00	1467.4	.681E+00	4.54	22.85	4.54	.00
298.15	11.00	.00	1480.7	.675E+00	4.54	23.05	4.54	.00
313.74	11.00	.00	1493.8	.669E+00	4.54	23.26	4.54	.00
329.34	11.00	.00	1506.8	.664E+00	4.54	23.46	4.54	.00
344.94	11.00	.00	1519.8	.658E+00	4.54	23.66	4.54	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.
The x-coordinate of bank attachment is 348.83 m.

360.53	11.00	.00	1532.6	.653E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

376.13	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
391.73	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
407.32	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
422.92	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
438.52	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
454.11	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
469.71	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
485.31	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
500.90	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
516.50	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
532.10	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
547.69	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
563.29	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
578.89	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
594.48	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
610.08	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
625.68	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
641.27	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
656.87	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00

672.47	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
688.06	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
703.66	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
719.26	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
734.85	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
750.45	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
766.05	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
781.64	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
797.24	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
812.84	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
828.44	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
844.03	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
859.63	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
875.23	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
890.82	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
906.42	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
922.02	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
937.61	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
953.21	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
968.81	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
984.40	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00
1000.00	11.00	.00	1523.0	.657E+00	4.54	23.71	4.54	.00

Cumulative travel time = 2797. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:          MACH^BIG^MUDDY^RIVER
 Design case:              CASE^4^-^PORT^3^NORMAL^FLOW
 FILE NAME:                cormix\sim\MAC4-3N1.cx1
 Time of Fortran run:      01/13/20--20:09:41

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     30.89  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .287 F     =       .058 USTAR = .2445E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.00
 D0    =       .102 A0    =       .008 H0    =       .55
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .023       = .2324E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .2324E-01  M0    = .6659E-01  J0    =-.3400E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .09  LM    =      2.25  Lm    =       .90  Lb    =       .14
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     23.50  R     =      9.98

FLOW CLASSIFICATION
 1111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 1111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y       Z        S       C       B
       .00      .00     .55     1.0  .100E+04    .05

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:             THETAE=     28.17  SIGMAE=        .00
  LE    =        .43  XE    =        .37  YE    =        .00  ZE    =        .76

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
       .00      .00     .55     1.0  .100E+04    .05
       .37      .00     .76     1.0  .100E+04    .05
       .57      .00     .86     1.4  .720E+03    .08
       .78      .00     .95     1.9  .516E+03    .10
       .99      .00    1.03     2.5  .398E+03    .13
      1.21      .00    1.11     3.1  .320E+03    .15
      1.42      .00    1.17     3.7  .270E+03    .18
      1.64      .00    1.23     4.3  .233E+03    .20
      1.87      .00    1.28     4.9  .205E+03    .22
      2.09      .00    1.32     5.4  .184E+03    .23
      2.31      .00    1.36     6.0  .168E+03    .25
      2.53      .00    1.40     6.5  .155E+03    .26
      2.77      .00    1.42     7.0  .144E+03    .28
      2.99      .00    1.45     7.4  .135E+03    .29
      3.21      .00    1.47     7.8  .128E+03    .30
      3.45      .00    1.49     8.2  .121E+03    .31
      3.67      .00    1.50     8.6  .116E+03    .32
      3.90      .00    1.51     8.9  .112E+03    .33
      4.13      .00    1.52     9.3  .108E+03    .34
```

```
      4.35      .00    1.52     9.5  .105E+03    .34
  Maximum jet height has been reached.
      4.58      .00    1.52     9.8  .102E+03    .35
      4.80      .00    1.52    10.1  .994E+02    .36
      5.04      .00    1.51    10.4  .964E+02    .36
      5.26      .00    1.50    10.7  .935E+02    .37
      5.49      .00    1.49    11.0  .905E+02    .38
      5.72      .00    1.48    11.4  .874E+02    .39
      5.94      .00    1.46    11.8  .844E+02    .39
      6.17      .00    1.45    12.3  .815E+02    .40
      6.39      .00    1.43    12.7  .786E+02    .41
      6.62      .00    1.41    13.2  .756E+02    .42
      6.85      .00    1.38    13.7  .728E+02    .43
      7.07      .00    1.36    14.3  .701E+02    .44
      7.30      .00    1.33    14.8  .674E+02    .45
      7.53      .00    1.30    15.4  .649E+02    .46
      7.75      .00    1.27    16.0  .625E+02    .47
      7.98      .00    1.24    16.6  .601E+02    .49
      8.20      .00    1.21    17.3  .578E+02    .50
      8.43      .00    1.18    17.9  .557E+02    .51
      8.65      .00    1.15    18.6  .537E+02    .52
      8.88      .00    1.11    19.4  .517E+02    .53
      9.10      .00    1.08    20.1  .498E+02    .54
      9.32      .00    1.04    20.8  .481E+02    .55
      9.56      .00    1.01    21.6  .463E+02    .56
      9.78      .00     .97    22.4  .447E+02    .58
     10.00      .00     .93    23.1  .432E+02    .59
     10.23      .00     .90    24.0  .417E+02    .60
     10.45      .00     .86    24.8  .403E+02    .61
     10.67      .00     .82    25.6  .390E+02    .62
     10.89      .00     .79    26.5  .378E+02    .63
     11.13      .00     .75    27.4  .365E+02    .65
     11.35      .00     .71    28.2  .354E+02    .66
     11.57      .00     .67    29.1  .343E+02    .67
 Cumulative travel time =          20. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B
    11.57      .00     .67    29.1  .343E+02    .67

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.90	.00	.00	29.1	.343E+02	.00	.00	.00	.00
11.10	.00	.00	29.1	.343E+02	.89	.45	.89	.00
11.30	.00	.00	29.1	.343E+02	1.06	.63	1.06	.00
11.50	.00	.00	29.1	.343E+02	1.16	.78	1.16	.00
11.70	.00	.00	29.9	.334E+02	1.24	.90	1.24	.00
11.90	.00	.00	33.6	.297E+02	1.30	1.00	1.30	.00
12.10	.00	.00	38.8	.258E+02	1.34	1.10	1.34	.00
12.30	.00	.00	43.4	.230E+02	1.38	1.18	1.38	.00
12.51	.00	.00	46.6	.214E+02	1.40	1.27	1.40	.00
12.71	.00	.00	48.4	.207E+02	1.41	1.34	1.41	.00
12.91	.00	.00	49.5	.202E+02	1.42	1.42	1.42	.00

Cumulative travel time = 25. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
12.91	.00	.00	49.5	.202E+02	1.42	1.42	1.42	.00
15.13	.00	.00	52.5	.190E+02	1.21	1.75	1.21	.00
17.36	.00	.00	55.1	.182E+02	1.08	2.06	1.08	.00
19.59	.00	.00	57.4	.174E+02	.99	2.34	.99	.00
21.82	.00	.00	59.7	.168E+02	.93	2.61	.93	.00
24.04	.00	.00	61.9	.162E+02	.87	2.86	.87	.00
26.27	.00	.00	64.2	.156E+02	.84	3.11	.84	.00
28.50	.00	.00	66.5	.150E+02	.80	3.34	.80	.00
30.73	.00	.00	68.9	.145E+02	.78	3.57	.78	.00
32.95	.00	.00	71.4	.140E+02	.76	3.79	.76	.00
35.18	.00	.00	74.1	.135E+02	.75	4.00	.75	.00
37.41	.00	.00	76.9	.130E+02	.74	4.21	.74	.00
39.64	.00	.00	79.8	.125E+02	.73	4.41	.73	.00
41.86	.00	.00	82.9	.121E+02	.73	4.61	.73	.00
44.09	.00	.00	86.2	.116E+02	.73	4.81	.73	.00
46.32	.00	.00	89.7	.111E+02	.73	5.00	.73	.00
48.55	.00	.00	93.4	.107E+02	.73	5.18	.73	.00

50.77	.00	.00	97.2	.103E+02	.73	5.37	.73	.00
53.00	.00	.00	101.3	.987E+01	.74	5.55	.74	.00
55.23	.00	.00	105.6	.947E+01	.75	5.72	.75	.00
57.45	.00	.00	110.0	.909E+01	.76	5.90	.76	.00
59.68	.00	.00	114.8	.871E+01	.77	6.07	.77	.00
61.91	.00	.00	119.7	.835E+01	.78	6.24	.78	.00
64.14	.00	.00	124.9	.801E+01	.79	6.41	.79	.00
66.36	.00	.00	130.3	.768E+01	.80	6.57	.80	.00
68.59	.00	.00	135.9	.736E+01	.82	6.74	.82	.00
70.82	.00	.00	141.8	.705E+01	.83	6.90	.83	.00
73.05	.00	.00	147.9	.676E+01	.85	7.06	.85	.00
75.27	.00	.00	154.3	.648E+01	.87	7.21	.87	.00
77.50	.00	.00	160.9	.621E+01	.88	7.37	.88	.00
79.73	.00	.00	167.8	.596E+01	.90	7.52	.90	.00
81.96	.00	.00	175.0	.571E+01	.92	7.68	.92	.00
84.18	.00	.00	182.4	.548E+01	.94	7.83	.94	.00
86.41	.00	.00	190.1	.526E+01	.96	7.98	.96	.00
88.64	.00	.00	198.1	.505E+01	.99	8.13	.99	.00
90.87	.00	.00	206.3	.485E+01	1.01	8.27	1.01	.00
93.09	.00	.00	214.8	.466E+01	1.03	8.42	1.03	.00
95.32	.00	.00	223.6	.447E+01	1.06	8.56	1.06	.00
97.55	.00	.00	232.7	.430E+01	1.08	8.71	1.08	.00
99.78	.00	.00	242.0	.413E+01	1.11	8.85	1.11	.00
102.00	.00	.00	251.7	.397E+01	1.13	8.99	1.13	.00
104.23	.00	.00	261.6	.382E+01	1.16	9.13	1.16	.00
106.46	.00	.00	271.8	.368E+01	1.19	9.27	1.19	.00
108.69	.00	.00	282.4	.354E+01	1.22	9.41	1.22	.00
110.91	.00	.00	293.2	.341E+01	1.24	9.54	1.24	.00
113.14	.00	.00	304.3	.329E+01	1.27	9.68	1.27	.00
115.37	.00	.00	315.7	.317E+01	1.30	9.81	1.30	.00
117.60	.00	.00	327.5	.305E+01	1.33	9.95	1.33	.00
119.82	.00	.00	339.5	.295E+01	1.36	10.08	1.36	.00
122.05	.00	.00	351.8	.284E+01	1.39	10.21	1.39	.00
124.28	.00	.00	364.5	.274E+01	1.43	10.34	1.43	.00

Cumulative travel time = 412. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .222E-01 m^2/s
Horizontal diffusivity (initial value) = .555E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)

ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
124.28	.00	.00	364.5	.274E+01	1.43	10.34	1.43	.00
124.74	.00	.00	365.6	.274E+01	1.43	10.36	1.43	.00
125.20	.00	.00	366.8	.273E+01	1.43	10.37	1.43	.00
125.66	.00	.00	367.9	.272E+01	1.43	10.38	1.43	.00
126.12	.00	.00	369.1	.271E+01	1.44	10.40	1.44	.00
126.58	.00	.00	370.2	.270E+01	1.44	10.41	1.44	.00
127.04	.00	.00	371.4	.269E+01	1.44	10.42	1.44	.00
127.51	.00	.00	372.5	.268E+01	1.44	10.44	1.44	.00
127.97	.00	.00	373.7	.268E+01	1.45	10.45	1.45	.00
128.43	.00	.00	374.9	.267E+01	1.45	10.46	1.45	.00
128.89	.00	.00	376.0	.266E+01	1.45	10.48	1.45	.00
129.35	.00	.00	377.2	.265E+01	1.46	10.49	1.46	.00
129.81	.00	.00	378.4	.264E+01	1.46	10.50	1.46	.00
130.27	.00	.00	379.6	.263E+01	1.46	10.52	1.46	.00
130.73	.00	.00	380.8	.263E+01	1.46	10.53	1.46	.00
131.19	.00	.00	381.9	.262E+01	1.47	10.54	1.47	.00
131.66	.00	.00	383.1	.261E+01	1.47	10.56	1.47	.00
132.12	.00	.00	384.3	.260E+01	1.47	10.57	1.47	.00
132.58	.00	.00	385.6	.259E+01	1.47	10.58	1.47	.00
133.04	.00	.00	386.8	.259E+01	1.48	10.60	1.48	.00
133.50	.00	.00	388.0	.258E+01	1.48	10.61	1.48	.00
133.96	.00	.00	389.2	.257E+01	1.48	10.62	1.48	.00
134.42	.00	.00	390.4	.256E+01	1.49	10.64	1.49	.00
134.88	.00	.00	391.6	.255E+01	1.49	10.65	1.49	.00
135.34	.00	.00	392.9	.255E+01	1.49	10.66	1.49	.00
135.81	.00	.00	394.1	.254E+01	1.49	10.68	1.49	.00
136.27	.00	.00	395.4	.253E+01	1.50	10.69	1.50	.00
136.73	.00	.00	396.6	.252E+01	1.50	10.70	1.50	.00
137.19	.00	.00	397.9	.251E+01	1.50	10.72	1.50	.00
137.65	.00	.00	399.1	.251E+01	1.51	10.73	1.51	.00
138.11	.00	.00	400.4	.250E+01	1.51	10.74	1.51	.00
138.57	.00	.00	401.6	.249E+01	1.51	10.76	1.51	.00
139.03	.00	.00	402.9	.248E+01	1.51	10.77	1.51	.00
139.49	.00	.00	404.2	.247E+01	1.52	10.78	1.52	.00
139.96	.00	.00	405.5	.247E+01	1.52	10.79	1.52	.00
140.42	.00	.00	406.7	.246E+01	1.52	10.81	1.52	.00
140.88	.00	.00	408.0	.245E+01	1.53	10.82	1.53	.00
141.34	.00	.00	409.3	.244E+01	1.53	10.83	1.53	.00
141.80	.00	.00	410.6	.244E+01	1.53	10.85	1.53	.00
142.26	.00	.00	411.9	.243E+01	1.54	10.86	1.54	.00
142.72	.00	.00	413.2	.242E+01	1.54	10.87	1.54	.00
143.18	.00	.00	414.5	.241E+01	1.54	10.88	1.54	.00
143.65	.00	.00	415.8	.240E+01	1.54	10.90	1.54	.00
144.11	.00	.00	417.2	.240E+01	1.55	10.91	1.55	.00

144.57	.00	.00	418.5	.239E+01	1.55	10.92	1.55	.00
145.03	.00	.00	419.8	.238E+01	1.55	10.94	1.55	.00
145.49	.00	.00	421.2	.237E+01	1.56	10.95	1.56	.00
145.95	.00	.00	422.5	.237E+01	1.56	10.96	1.56	.00
146.41	.00	.00	423.9	.236E+01	1.56	10.97	1.56	.00
146.87	.00	.00	425.2	.235E+01	1.57	10.99	1.57	.00
147.33	.00	.00	426.6	.234E+01	1.57	11.00	1.57	.00

Cumulative travel time = 493. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
147.33	11.00	.00	426.6	.234E+01	1.57	22.00	1.57	.00
164.39	11.00	.00	465.4	.215E+01	1.69	22.23	1.69	.00
181.44	11.00	.00	509.1	.196E+01	1.83	22.47	1.83	.00
198.49	11.00	.00	558.2	.179E+01	1.99	22.70	1.99	.00
215.55	11.00	.00	612.9	.163E+01	2.16	22.92	2.16	.00
232.60	11.00	.00	673.4	.148E+01	2.36	23.15	2.36	.00
249.65	11.00	.00	739.7	.135E+01	2.56	23.37	2.56	.00
266.71	11.00	.00	811.6	.123E+01	2.79	23.59	2.79	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 276.00 m.

283.76	11.00	.00	888.7	.113E+01	3.02	23.71	3.02	.00
300.81	11.00	.00	957.3	.104E+01	3.27	23.71	3.27	.00
317.87	11.00	.00	1031.8	.969E+00	3.52	23.71	3.52	.00
334.92	11.00	.00	1107.7	.903E+00	3.78	23.71	3.78	.00
351.97	11.00	.00	1184.6	.844E+00	4.04	23.71	4.04	.00
369.03	11.00	.00	1261.9	.792E+00	4.31	23.71	4.31	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

386.08	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

403.13	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
420.19	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
437.24	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
454.29	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
471.35	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
488.40	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
505.45	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
522.51	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
539.56	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
556.61	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
573.67	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
590.72	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
607.77	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
624.83	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00

641.88	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
658.93	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
675.99	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
693.04	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
710.09	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
727.15	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
744.20	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
761.25	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
778.31	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
795.36	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
812.41	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
829.47	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
846.52	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
863.57	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
880.63	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
897.68	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
914.73	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
931.79	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
948.84	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
965.89	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
982.95	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00
1000.00	11.00	.00	1329.6	.752E+00	4.54	23.71	4.54	.00

Cumulative travel time = 3461. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^4^-^PORT^3^MAXIMUM^FLOW
 FILE NAME:               cormix\sim\MAC4-3X1.cx1
 Time of Fortran run:     01/13/20--20:35:48

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     38.11  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .354 F     =       .058 USTAR = .3016E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =    11.00
 D0    =       .102 A0    =       .008 H0    =       .55
 THETA =     30.00  SIGMA =       .00
 U0    =      5.487 Q0    =       .044       = .4448E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .4448E-01  M0    = .2441E+00  J0    =-.6510E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .09  LM    =      4.30  Lm    =      1.40  Lb    =       .15
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     44.99  R     =     15.50

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y       Z        S       C       B
       .00      .00     .55     1.0  .100E+04    .05

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:             THETAE=     28.82  SIGMAE=        .00
  LE    =        .46  XE    =        .40  YE    =        .00  ZE    =        .77

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
       .00      .00     .55     1.0  .100E+04    .05
       .40      .00     .77     1.0  .100E+04    .05
       .79      .00     .98     1.9  .538E+03    .10
      1.21      .00    1.17     3.0  .336E+03    .16
      1.63      .00    1.33     4.1  .242E+03    .21
      2.07      .00    1.47     5.4  .186E+03    .26
      2.50      .00    1.59     6.6  .152E+03    .30
      2.94      .00    1.70     7.8  .128E+03    .34
      3.38      .00    1.80     9.0  .111E+03    .38
      3.83      .00    1.88    10.2  .985E+02    .41
      4.28      .00    1.95    11.2  .890E+02    .44
      4.73      .00    2.02    12.3  .812E+02    .47
      5.19      .00    2.07    13.3  .750E+02    .49
      5.63      .00    2.12    14.3  .701E+02    .52
      6.09      .00    2.16    15.2  .660E+02    .54
      6.54      .00    2.19    16.0  .625E+02    .56
      7.00      .00    2.22    16.8  .596E+02    .57
      7.44      .00    2.24    17.5  .571E+02    .59
      7.90      .00    2.26    18.2  .550E+02    .60
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      8.35      .00    2.27    18.8  .532E+02    .62
      8.81      .00    2.28    19.4  .516E+02    .63
      9.26      .00    2.28    19.9  .502E+02    .64
  Maximum jet height has been reached.
      9.72      .00    2.28    20.4  .490E+02    .65
     10.18      .00    2.28    21.0  .477E+02    .66
     10.62      .00    2.27    21.5  .464E+02    .67
     11.08      .00    2.26    22.2  .451E+02    .68
     11.53      .00    2.24    22.8  .438E+02    .70
     11.99      .00    2.22    23.6  .424E+02    .71
     12.44      .00    2.20    24.3  .411E+02    .72
     12.90      .00    2.17    25.1  .398E+02    .74
     13.34      .00    2.14    26.0  .385E+02    .75
     13.80      .00    2.11    26.9  .372E+02    .77
     14.26      .00    2.07    27.8  .359E+02    .78
     14.71      .00    2.04    28.8  .348E+02    .80
     15.16      .00    2.00    29.8  .336E+02    .82
     15.61      .00    1.96    30.8  .324E+02    .83
     16.07      .00    1.91    31.9  .313E+02    .85
     16.51      .00    1.87    33.0  .303E+02    .87
     16.97      .00    1.82    34.2  .292E+02    .88
     17.41      .00    1.77    35.4  .283E+02    .90
     17.87      .00    1.72    36.6  .273E+02    .92
     18.32      .00    1.67    37.8  .264E+02    .94
     18.77      .00    1.62    39.1  .256E+02    .96
     19.23      .00    1.57    40.5  .247E+02    .97
     19.67      .00    1.52    41.8  .239E+02    .99
     20.13      .00    1.46    43.2  .232E+02   1.01
     20.57      .00    1.41    44.5  .225E+02   1.03
     21.03      .00    1.35    46.0  .217E+02   1.05
     21.47      .00    1.29    47.4  .211E+02   1.07
     21.93      .00    1.24    48.9  .204E+02   1.08
     22.37      .00    1.18    50.4  .199E+02   1.10
     22.83      .00    1.12    51.9  .193E+02   1.12
 Cumulative travel time =          34. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X         Y        Z         S        C        B
     22.83      .00    1.12    51.9  .193E+02   1.12

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
21.71	.00	.00	51.9	.193E+02	.00	.00	.00	.00
22.05	.00	.00	51.9	.193E+02	1.48	.74	1.48	.00
22.38	.00	.00	51.9	.193E+02	1.76	1.05	1.76	.00
22.72	.00	.00	51.9	.193E+02	1.93	1.29	1.93	.00
23.06	.00	.00	53.3	.188E+02	2.06	1.49	2.06	.00
23.39	.00	.00	59.9	.167E+02	2.16	1.66	2.16	.00
23.73	.00	.00	69.1	.145E+02	2.23	1.82	2.23	.00
24.07	.00	.00	77.4	.129E+02	2.29	1.97	2.29	.00
24.40	.00	.00	83.1	.120E+02	2.32	2.11	2.32	.00
24.74	.00	.00	86.2	.116E+02	2.35	2.23	2.35	.00
25.07	.00	.00	88.2	.113E+02	2.35	2.35	2.35	.00

Cumulative travel time = 41. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
25.07	.00	.00	88.2	.113E+02	2.35	2.35	2.35	.00
27.37	.00	.00	91.1	.110E+02	2.18	2.63	2.18	.00
29.66	.00	.00	93.9	.106E+02	2.04	2.90	2.04	.00
31.96	.00	.00	96.5	.104E+02	1.93	3.15	1.93	.00
34.25	.00	.00	99.1	.101E+02	1.84	3.39	1.84	.00
36.55	.00	.00	101.7	.984E+01	1.76	3.63	1.76	.00
38.84	.00	.00	104.2	.960E+01	1.70	3.85	1.70	.00
41.14	.00	.00	106.8	.936E+01	1.65	4.07	1.65	.00
43.43	.00	.00	109.4	.914E+01	1.60	4.29	1.60	.00
45.73	.00	.00	112.1	.892E+01	1.57	4.50	1.57	.00
48.02	.00	.00	114.9	.871E+01	1.54	4.70	1.54	.00
50.31	.00	.00	117.7	.850E+01	1.51	4.90	1.51	.00
52.61	.00	.00	120.7	.829E+01	1.49	5.10	1.49	.00
54.90	.00	.00	123.7	.808E+01	1.47	5.29	1.47	.00
57.20	.00	.00	126.9	.788E+01	1.45	5.48	1.45	.00
59.49	.00	.00	130.1	.769E+01	1.44	5.66	1.44	.00
61.79	.00	.00	133.5	.749E+01	1.43	5.85	1.43	.00

64.08	.00	.00	137.0	.730E+01	1.43	6.03	1.43	.00
66.38	.00	.00	140.7	.711E+01	1.42	6.20	1.42	.00
68.67	.00	.00	144.5	.692E+01	1.42	6.38	1.42	.00
70.97	.00	.00	148.4	.674E+01	1.42	6.55	1.42	.00
73.26	.00	.00	152.5	.656E+01	1.43	6.72	1.43	.00
75.56	.00	.00	156.7	.638E+01	1.43	6.89	1.43	.00
77.85	.00	.00	161.1	.621E+01	1.43	7.06	1.43	.00
80.14	.00	.00	165.7	.604E+01	1.44	7.22	1.44	.00
82.44	.00	.00	170.4	.587E+01	1.45	7.38	1.45	.00
84.73	.00	.00	175.3	.571E+01	1.46	7.54	1.46	.00
87.03	.00	.00	180.3	.555E+01	1.47	7.70	1.47	.00
89.32	.00	.00	185.5	.539E+01	1.48	7.86	1.48	.00
91.62	.00	.00	190.9	.524E+01	1.50	8.01	1.50	.00
93.91	.00	.00	196.5	.509E+01	1.51	8.17	1.51	.00
96.21	.00	.00	202.2	.495E+01	1.53	8.32	1.53	.00
98.50	.00	.00	208.1	.480E+01	1.54	8.47	1.54	.00
100.80	.00	.00	214.2	.467E+01	1.56	8.62	1.56	.00
103.09	.00	.00	220.5	.454E+01	1.58	8.77	1.58	.00
105.39	.00	.00	227.0	.441E+01	1.60	8.92	1.60	.00
107.68	.00	.00	233.6	.428E+01	1.62	9.06	1.62	.00
109.97	.00	.00	240.5	.416E+01	1.64	9.21	1.64	.00
112.27	.00	.00	247.5	.404E+01	1.66	9.35	1.66	.00
114.56	.00	.00	254.8	.393E+01	1.69	9.49	1.69	.00
116.86	.00	.00	262.2	.381E+01	1.71	9.64	1.71	.00
119.15	.00	.00	269.9	.371E+01	1.73	9.78	1.73	.00
121.45	.00	.00	277.7	.360E+01	1.76	9.92	1.76	.00
123.74	.00	.00	285.7	.350E+01	1.79	10.06	1.79	.00
126.04	.00	.00	294.0	.340E+01	1.81	10.19	1.81	.00
128.33	.00	.00	302.4	.331E+01	1.84	10.33	1.84	.00
130.63	.00	.00	311.1	.321E+01	1.87	10.47	1.87	.00
132.92	.00	.00	320.0	.313E+01	1.90	10.60	1.90	.00
135.21	.00	.00	329.0	.304E+01	1.93	10.73	1.93	.00
137.51	.00	.00	338.3	.296E+01	1.96	10.87	1.96	.00
139.80	.00	.00	347.8	.287E+01	1.99	11.00	1.99	.00

Cumulative travel time = 364. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

Discharge is non-buoyant or weakly buoyant.
Therefore BUOYANT SPREADING REGIME is ABSENT.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .274E-01 m^2/s
Horizontal diffusivity (initial value) = .685E-01 m^2/s

Profile definitions:
  BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
     = or equal to layer depth, if fully mixed
  BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
       measured horizontally in Y-direction
  ZU = upper plume boundary (Z-coordinate)
  ZL = lower plume boundary (Z-coordinate)
  S = hydrodynamic centerline dilution
  C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
139.80	11.00	.00	347.8	.287E+01	1.99	22.00	1.99	.00
157.01	11.00	.00	380.8	.263E+01	2.15	22.24	2.15	.00
174.21	11.00	.00	417.3	.240E+01	2.33	22.47	2.33	.00
191.42	11.00	.00	457.3	.219E+01	2.53	22.70	2.53	.00
208.62	11.00	.00	500.8	.200E+01	2.74	22.93	2.74	.00
225.82	11.00	.00	547.7	.183E+01	2.97	23.16	2.97	.00
243.03	11.00	.00	597.5	.167E+01	3.21	23.38	3.21	.00
260.23	11.00	.00	650.0	.154E+01	3.46	23.60	3.46	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel
    width during the current prediction interval.
The x-coordinate of bank attachment is 268.54 m.

277.44	11.00	.00	704.7	.142E+01	3.72	23.71	3.72	.00
294.64	11.00	.00	750.6	.133E+01	3.98	23.71	3.98	.00
311.84	11.00	.00	800.2	.125E+01	4.24	23.71	4.24	.00
329.05	11.00	.00	849.9	.118E+01	4.50	23.71	4.50	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
  prediction interval.

346.25	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are
    NO FURTHER CHANGES with downstream direction.

363.46	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
380.66	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
397.86	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
415.07	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
432.27	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
449.47	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
466.68	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
483.88	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
501.09	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
518.29	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
535.49	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
552.70	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
569.90	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
587.11	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
604.31	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00

621.51	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
638.72	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
655.92	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
673.13	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
690.33	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
707.53	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
724.74	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
741.94	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
759.15	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
776.35	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
793.55	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
810.76	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
827.96	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
845.16	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
862.37	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
879.57	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
896.78	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
913.98	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
931.18	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
948.39	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
965.59	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
982.80	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00
1000.00	11.00	.00	856.7	.117E+01	4.54	23.71	4.54	.00

Cumulative travel time = 2791. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^4^-^PORT^4^NORMAL^FLOW
 FILE NAME:               cormix\sim\MAC4-4N1.cx1
 Time of Fortran run:     01/13/20--20:05:56

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     30.89  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .287 F     =       .058 USTAR = .2445E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.00
 D0    =       .152 A0    =       .018 H0    =       .53
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .052       = .5228E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .5228E-01  M0    = .1498E+00  J0    =-.7651E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .14  LM    =      2.75  Lm    =      1.35  Lb    =       .32
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     19.19  R     =      9.98

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
       .00      .00      .53     1.0  .100E+04    .08

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:             THETAE=     28.17  SIGMAE=        .00
  LE    =       .64  XE    =       .56  YE    =       .00  ZE    =        .84

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
       .00      .00      .53     1.0  .100E+04    .08
       .56      .00      .84     1.0  .100E+04    .08
       .76      .00      .94     1.2  .820E+03    .10
       .97      .00     1.04     1.6  .633E+03    .13
      1.19      .00     1.13     2.0  .506E+03    .16
      1.41      .00     1.22     2.4  .424E+03    .18
      1.64      .00     1.29     2.8  .361E+03    .21
      1.86      .00     1.36     3.2  .317E+03    .23
      2.09      .00     1.43     3.6  .280E+03    .26
      2.31      .00     1.48     3.9  .253E+03    .28
      2.55      .00     1.54     4.3  .231E+03    .30
      2.77      .00     1.58     4.7  .213E+03    .32
      3.01      .00     1.62     5.1  .198E+03    .33
      3.24      .00     1.66     5.4  .186E+03    .35
      3.48      .00     1.69     5.7  .175E+03    .37
      3.71      .00     1.71     6.0  .166E+03    .38
      3.95      .00     1.74     6.3  .158E+03    .39
      4.18      .00     1.75     6.6  .152E+03    .40
      4.42      .00     1.77     6.8  .146E+03    .41
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      4.65      .00    1.78     7.1  .141E+03    .42
      4.89      .00    1.78     7.3  .137E+03    .43
      5.12      .00    1.79     7.5  .133E+03    .44
  Maximum jet height has been reached.
      5.36      .00    1.79     7.7  .130E+03    .45
      5.59      .00    1.78     7.9  .127E+03    .46
      5.84      .00    1.78     8.1  .123E+03    .47
      6.07      .00    1.77     8.4  .120E+03    .47
      6.31      .00    1.75     8.6  .116E+03    .48
      6.54      .00    1.74     8.9  .112E+03    .49
      6.78      .00    1.72     9.2  .109E+03    .50
      7.01      .00    1.70     9.5  .105E+03    .51
      7.25      .00    1.67     9.8  .102E+03    .53
      7.48      .00    1.65    10.2  .982E+02    .54
      7.70      .00    1.62    10.5  .949E+02    .55
      7.94      .00    1.59    10.9  .915E+02    .56
      8.17      .00    1.56    11.3  .884E+02    .57
      8.41      .00    1.52    11.7  .851E+02    .59
      8.64      .00    1.49    12.2  .822E+02    .60
      8.88      .00    1.45    12.6  .792E+02    .61
      9.10      .00    1.41    13.1  .765E+02    .63
      9.34      .00    1.37    13.6  .737E+02    .64
      9.57      .00    1.33    14.1  .712E+02    .66
      9.81      .00    1.28    14.6  .686E+02    .67
     10.03      .00    1.24    15.1  .663E+02    .68
     10.27      .00    1.20    15.6  .640E+02    .70
     10.50      .00    1.15    16.2  .618E+02    .71
     10.73      .00    1.10    16.8  .597E+02    .73
     10.96      .00    1.06    17.3  .577E+02    .74
     11.20      .00    1.01    17.9  .558E+02    .76
     11.42      .00     .96    18.5  .540E+02    .77
     11.66      .00     .91    19.1  .522E+02    .79
     11.88      .00     .87    19.8  .506E+02    .80
     12.12      .00     .82    20.4  .491E+02    .82
 Cumulative travel time =          18. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B
     12.12      .00     .82    20.4  .491E+02    .82

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
11.31	.00	.00	20.4	.491E+02	.00	.00	.00	.00
11.55	.00	.00	20.4	.491E+02	1.12	.56	1.12	.00
11.79	.00	.00	20.4	.491E+02	1.32	.79	1.32	.00
12.04	.00	.00	20.4	.491E+02	1.46	.97	1.46	.00
12.28	.00	.00	20.9	.478E+02	1.56	1.12	1.56	.00
12.53	.00	.00	23.5	.425E+02	1.63	1.26	1.63	.00
12.77	.00	.00	27.1	.369E+02	1.68	1.38	1.68	.00
13.02	.00	.00	30.4	.329E+02	1.73	1.49	1.73	.00
13.26	.00	.00	32.6	.306E+02	1.75	1.59	1.75	.00
13.51	.00	.00	33.9	.295E+02	1.77	1.69	1.77	.00
13.75	.00	.00	34.7	.289E+02	1.78	1.78	1.78	.00

Cumulative travel time = 23. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
13.75	.00	.00	34.7	.289E+02	1.78	1.78	1.78	.00
15.36	.00	.00	36.2	.276E+02	1.57	2.10	1.57	.00
16.97	.00	.00	37.5	.266E+02	1.42	2.41	1.42	.00
18.57	.00	.00	38.7	.258E+02	1.31	2.69	1.31	.00
20.18	.00	.00	39.8	.251E+02	1.22	2.96	1.22	.00
21.79	.00	.00	40.8	.245E+02	1.15	3.22	1.15	.00
23.39	.00	.00	41.7	.240E+02	1.09	3.47	1.09	.00
25.00	.00	.00	42.6	.235E+02	1.05	3.71	1.05	.00
26.61	.00	.00	43.5	.230E+02	1.00	3.95	1.00	.00
28.22	.00	.00	44.4	.225E+02	.97	4.17	.97	.00
29.82	.00	.00	45.2	.221E+02	.94	4.39	.94	.00
31.43	.00	.00	46.1	.217E+02	.91	4.61	.91	.00
33.04	.00	.00	46.9	.213E+02	.89	4.82	.89	.00
34.64	.00	.00	47.8	.209E+02	.87	5.02	.87	.00
36.25	.00	.00	48.7	.205E+02	.85	5.22	.85	.00
37.86	.00	.00	49.6	.202E+02	.83	5.42	.83	.00
39.46	.00	.00	50.5	.198E+02	.82	5.61	.82	.00

41.07	.00	.00	51.4	.194E+02	.81	5.81	.81	.00
42.68	.00	.00	52.4	.191E+02	.80	5.99	.80	.00
44.29	.00	.00	53.4	.187E+02	.79	6.18	.79	.00
45.89	.00	.00	54.4	.184E+02	.78	6.36	.78	.00
47.50	.00	.00	55.4	.181E+02	.77	6.54	.77	.00
49.11	.00	.00	56.4	.177E+02	.77	6.72	.77	.00
50.71	.00	.00	57.5	.174E+02	.76	6.89	.76	.00
52.32	.00	.00	58.6	.171E+02	.76	7.06	.76	.00
53.93	.00	.00	59.8	.167E+02	.75	7.23	.75	.00
55.53	.00	.00	61.0	.164E+02	.75	7.40	.75	.00
57.14	.00	.00	62.2	.161E+02	.75	7.57	.75	.00
58.75	.00	.00	63.4	.158E+02	.75	7.73	.75	.00
60.36	.00	.00	64.7	.155E+02	.75	7.89	.75	.00
61.96	.00	.00	66.0	.151E+02	.75	8.05	.75	.00
63.57	.00	.00	67.4	.148E+02	.75	8.21	.75	.00
65.18	.00	.00	68.8	.145E+02	.75	8.37	.75	.00
66.78	.00	.00	70.2	.142E+02	.75	8.53	.75	.00
68.39	.00	.00	71.7	.140E+02	.75	8.68	.75	.00
70.00	.00	.00	73.2	.137E+02	.75	8.84	.75	.00
71.60	.00	.00	74.7	.134E+02	.76	8.99	.76	.00
73.21	.00	.00	76.3	.131E+02	.76	9.14	.76	.00
74.82	.00	.00	77.9	.128E+02	.76	9.29	.76	.00
76.43	.00	.00	79.6	.126E+02	.77	9.44	.77	.00
78.03	.00	.00	81.3	.123E+02	.77	9.59	.77	.00
79.64	.00	.00	83.1	.120E+02	.78	9.73	.78	.00
81.25	.00	.00	84.9	.118E+02	.78	9.88	.78	.00
82.85	.00	.00	86.7	.115E+02	.79	10.02	.79	.00
84.46	.00	.00	88.6	.113E+02	.79	10.16	.79	.00
86.07	.00	.00	90.6	.110E+02	.80	10.31	.80	.00
87.67	.00	.00	92.6	.108E+02	.81	10.45	.81	.00
89.28	.00	.00	94.6	.106E+02	.81	10.59	.81	.00
90.89	.00	.00	96.7	.103E+02	.82	10.73	.82	.00
92.50	.00	.00	98.8	.101E+02	.83	10.86	.83	.00
94.10	.00	.00	101.0	.991E+01	.84	11.00	.84	.00

Cumulative travel time = 303. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
94.10	11.00	.00	101.0	.991E+01	.84	22.00	.84	.00
94.51	11.00	.00	101.5	.985E+01	.84	22.03	.84	.00
94.92	11.00	.00	102.0	.980E+01	.84	22.07	.84	.00
95.33	11.00	.00	102.5	.975E+01	.84	22.10	.84	.00
95.74	11.00	.00	103.0	.970E+01	.85	22.14	.85	.00
96.16	11.00	.00	103.6	.965E+01	.85	22.17	.85	.00
96.57	11.00	.00	104.1	.961E+01	.85	22.21	.85	.00
96.98	11.00	.00	104.6	.956E+01	.86	22.24	.86	.00

97.39	11.00	.00	105.2	.951E+01	.86	22.28	.86	.00
97.80	11.00	.00	105.7	.946E+01	.86	22.31	.86	.00
98.21	11.00	.00	106.2	.941E+01	.87	22.35	.87	.00
98.62	11.00	.00	106.8	.937E+01	.87	22.38	.87	.00
99.03	11.00	.00	107.3	.932E+01	.87	22.42	.87	.00
99.44	11.00	.00	107.9	.927E+01	.87	22.45	.87	.00
99.85	11.00	.00	108.4	.923E+01	.88	22.49	.88	.00
100.26	11.00	.00	108.9	.918E+01	.88	22.52	.88	.00
100.67	11.00	.00	109.5	.913E+01	.88	22.55	.88	.00
101.08	11.00	.00	110.0	.909E+01	.89	22.59	.89	.00
101.49	11.00	.00	110.6	.904E+01	.89	22.62	.89	.00
101.90	11.00	.00	111.1	.900E+01	.89	22.66	.89	.00
102.31	11.00	.00	111.7	.895E+01	.90	22.69	.90	.00
102.72	11.00	.00	112.2	.891E+01	.90	22.73	.90	.00
103.14	11.00	.00	112.8	.887E+01	.90	22.76	.90	.00
103.55	11.00	.00	113.3	.882E+01	.91	22.79	.91	.00
103.96	11.00	.00	113.9	.878E+01	.91	22.83	.91	.00
104.37	11.00	.00	114.5	.874E+01	.91	22.86	.91	.00
104.78	11.00	.00	115.0	.869E+01	.91	22.90	.91	.00
105.19	11.00	.00	115.6	.865E+01	.92	22.93	.92	.00
105.60	11.00	.00	116.2	.861E+01	.92	22.97	.92	.00
106.01	11.00	.00	116.7	.857E+01	.92	23.00	.92	.00
106.42	11.00	.00	117.3	.853E+01	.93	23.03	.93	.00
106.83	11.00	.00	117.9	.848E+01	.93	23.07	.93	.00
107.24	11.00	.00	118.4	.844E+01	.93	23.10	.93	.00
107.65	11.00	.00	119.0	.840E+01	.94	23.14	.94	.00
108.06	11.00	.00	119.6	.836E+01	.94	23.17	.94	.00
108.47	11.00	.00	120.2	.832E+01	.94	23.20	.94	.00
108.88	11.00	.00	120.7	.828E+01	.95	23.24	.95	.00
109.29	11.00	.00	121.3	.824E+01	.95	23.27	.95	.00
109.71	11.00	.00	121.9	.820E+01	.95	23.31	.95	.00
110.12	11.00	.00	122.5	.816E+01	.96	23.34	.96	.00
110.53	11.00	.00	123.1	.813E+01	.96	23.37	.96	.00
110.94	11.00	.00	123.7	.809E+01	.96	23.41	.96	.00
111.35	11.00	.00	124.3	.805E+01	.97	23.44	.97	.00
111.76	11.00	.00	124.8	.801E+01	.97	23.47	.97	.00
112.17	11.00	.00	125.4	.797E+01	.97	23.51	.97	.00
112.58	11.00	.00	126.0	.793E+01	.97	23.54	.97	.00
112.99	11.00	.00	126.6	.790E+01	.98	23.58	.98	.00
113.40	11.00	.00	127.2	.786E+01	.98	23.61	.98	.00
113.81	11.00	.00	127.8	.782E+01	.98	23.64	.98	.00
114.22	11.00	.00	128.4	.779E+01	.99	23.68	.99	.00
114.63	11.00	.00	129.0	.775E+01	.99	23.71	.99	.00

Cumulative travel time = 374. sec

Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .222E-01 m^2/s
Horizontal diffusivity (initial value) = .555E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
114.63	11.00	.00	129.0	.775E+01	.99	23.71	.99	.00
132.34	11.00	.00	131.8	.759E+01	1.01	23.71	1.01	.00
150.05	11.00	.00	134.7	.742E+01	1.03	23.71	1.03	.00
167.75	11.00	.00	137.7	.726E+01	1.06	23.71	1.06	.00
185.46	11.00	.00	140.9	.710E+01	1.08	23.71	1.08	.00
203.17	11.00	.00	144.2	.693E+01	1.11	23.71	1.11	.00
220.88	11.00	.00	147.6	.677E+01	1.13	23.71	1.13	.00
238.58	11.00	.00	151.2	.661E+01	1.16	23.71	1.16	.00
256.29	11.00	.00	155.0	.645E+01	1.19	23.71	1.19	.00
274.00	11.00	.00	158.9	.629E+01	1.22	23.71	1.22	.00
291.71	11.00	.00	163.0	.614E+01	1.25	23.71	1.25	.00
309.41	11.00	.00	167.3	.598E+01	1.28	23.71	1.28	.00
327.12	11.00	.00	171.8	.582E+01	1.32	23.71	1.32	.00
344.83	11.00	.00	176.5	.567E+01	1.36	23.71	1.36	.00
362.54	11.00	.00	181.5	.551E+01	1.39	23.71	1.39	.00
380.24	11.00	.00	186.7	.536E+01	1.43	23.71	1.43	.00
397.95	11.00	.00	192.1	.521E+01	1.48	23.71	1.48	.00
415.66	11.00	.00	197.9	.505E+01	1.52	23.71	1.52	.00
433.36	11.00	.00	203.9	.490E+01	1.57	23.71	1.57	.00
451.07	11.00	.00	210.2	.476E+01	1.61	23.71	1.61	.00
468.78	11.00	.00	216.9	.461E+01	1.67	23.71	1.67	.00
486.49	11.00	.00	224.0	.446E+01	1.72	23.71	1.72	.00
504.19	11.00	.00	231.4	.432E+01	1.78	23.71	1.78	.00
521.90	11.00	.00	239.2	.418E+01	1.84	23.71	1.84	.00
539.61	11.00	.00	247.5	.404E+01	1.90	23.71	1.90	.00
557.32	11.00	.00	256.2	.390E+01	1.97	23.71	1.97	.00
575.02	11.00	.00	265.4	.377E+01	2.04	23.71	2.04	.00
592.73	11.00	.00	275.1	.364E+01	2.11	23.71	2.11	.00
610.44	11.00	.00	285.3	.351E+01	2.19	23.71	2.19	.00
628.15	11.00	.00	296.0	.338E+01	2.27	23.71	2.27	.00
645.85	11.00	.00	307.4	.325E+01	2.36	23.71	2.36	.00
663.56	11.00	.00	319.3	.313E+01	2.45	23.71	2.45	.00
681.27	11.00	.00	331.9	.301E+01	2.55	23.71	2.55	.00
698.97	11.00	.00	345.1	.290E+01	2.65	23.71	2.65	.00

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   716.68    11.00     .00   358.9  .279E+01   2.76    23.71    2.76     .00
   734.39    11.00     .00   373.5  .268E+01   2.87    23.71    2.87     .00
   752.10    11.00     .00   388.7  .257E+01   2.99    23.71    2.99     .00
   769.80    11.00     .00   404.5  .247E+01   3.11    23.71    3.11     .00
   787.51    11.00     .00   421.1  .237E+01   3.23    23.71    3.23     .00
   805.22    11.00     .00   438.3  .228E+01   3.37    23.71    3.37     .00
   822.93    11.00     .00   456.2  .219E+01   3.50    23.71    3.50     .00
   840.63    11.00     .00   474.7  .211E+01   3.65    23.71    3.65     .00
   858.34    11.00     .00   493.9  .202E+01   3.79    23.71    3.79     .00
   876.05    11.00     .00   513.6  .195E+01   3.95    23.71    3.95     .00
   893.76    11.00     .00   533.9  .187E+01   4.10    23.71    4.10     .00
   911.46    11.00     .00   554.7  .180E+01   4.26    23.71    4.26     .00
   929.17    11.00     .00   576.0  .174E+01   4.42    23.71    4.42     .00
 Plume interacts with SURFACE.
 The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
   prediction interval.
   946.88    11.00     .00   591.1  .169E+01   4.54    23.71    4.54     .00
 Effluent is FULLY MIXED over the entire channel cross-section.
 Except for possible far-field decay or reaction processes, there are
     NO FURTHER CHANGES with downstream direction.
   964.58    11.00     .00   591.1  .169E+01   4.54    23.71    4.54     .00
   982.29    11.00     .00   591.1  .169E+01   4.54    23.71    4.54     .00
  1000.00    11.00     .00   591.1  .169E+01   4.54    23.71    4.54     .00
 Cumulative travel time =        3454. sec

 Simulation limit based on maximum specified distance =   1000.00 m.
   This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
CORMIX1: Submerged Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^4^-^PORT^4^MAXIMUM^FLOW
 FILE NAME:               cormix\sim\MAC4-4X1.cx1
 Time of Fortran run:     01/13/20--20:40:50

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     38.11  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .354 F     =       .058 USTAR = .3016E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.00
 D0    =       .152 A0    =       .018 H0    =       .53
 THETA =     30.00  SIGMA =       .00
 U0    =      5.487 Q0    =       .100       = .1001E+00
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .1001E+00  M0    = .5492E+00  J0    =-.1465E-01  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .14  LM    =      5.27  Lm    =      2.09  Lb    =       .33
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     36.74  R     =     15.50

FLOW CLASSIFICATION
 11111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1000.00  XMAX  =   1000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
      .00      .00      .53     1.0  .100E+04     .08

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:              THETAE=     28.82  SIGMAE=        .00
  LE    =        .68  XE    =        .59  YE    =        .00  ZE    =        .86

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
      .00      .00      .53     1.0  .100E+04     .08
      .59      .00      .86     1.0  .100E+04     .08
     1.00      .00     1.07     1.5  .650E+03     .13
     1.44      .00     1.28     2.3  .438E+03     .19
     1.88      .00     1.47     3.1  .325E+03     .24
     2.33      .00     1.64     3.9  .256E+03     .30
     2.79      .00     1.79     4.7  .211E+03     .35
     3.25      .00     1.93     5.6  .179E+03     .40
     3.71      .00     2.06     6.4  .156E+03     .44
     4.18      .00     2.17     7.3  .138E+03     .48
     4.65      .00     2.27     8.1  .124E+03     .52
     5.13      .00     2.35     8.9  .113E+03     .56
     5.60      .00     2.43     9.6  .104E+03     .59
     6.08      .00     2.50    10.3  .967E+02     .62
     6.56      .00     2.56    11.0  .906E+02     .65
     7.03      .00     2.61    11.7  .855E+02     .68
     7.51      .00     2.66    12.3  .811E+02     .70
     7.99      .00     2.70    12.9  .774E+02     .73
     8.47      .00     2.73    13.5  .742E+02     .75
```

8.96	.00	2.75	14.0	.715E+02	.77
9.44	.00	2.77	14.5	.691E+02	.78
9.92	.00	2.79	14.9	.670E+02	.80
10.40	.00	2.79	15.3	.652E+02	.81
10.88	.00	2.80	15.7	.636E+02	.83

Maximum jet height has been reached.

11.36	.00	2.79	16.1	.621E+02	.84
11.84	.00	2.79	16.5	.605E+02	.85
12.32	.00	2.77	17.0	.589E+02	.87
12.81	.00	2.76	17.5	.572E+02	.88
13.29	.00	2.73	18.0	.556E+02	.90
13.77	.00	2.71	18.5	.540E+02	.92
14.25	.00	2.67	19.1	.523E+02	.94
14.73	.00	2.64	19.7	.507E+02	.95
15.21	.00	2.60	20.4	.491E+02	.97
15.69	.00	2.56	21.1	.475E+02	.99
16.17	.00	2.51	21.8	.460E+02	1.01
16.65	.00	2.46	22.5	.445E+02	1.03
17.12	.00	2.41	23.3	.430E+02	1.05
17.60	.00	2.36	24.1	.416E+02	1.08
18.08	.00	2.30	24.9	.402E+02	1.10
18.56	.00	2.24	25.7	.389E+02	1.12
19.04	.00	2.18	26.6	.376E+02	1.14
19.51	.00	2.12	27.5	.363E+02	1.17
19.99	.00	2.05	28.4	.352E+02	1.19
20.47	.00	1.98	29.4	.340E+02	1.21
20.94	.00	1.92	30.4	.329E+02	1.24
21.42	.00	1.85	31.4	.319E+02	1.26
21.90	.00	1.78	32.4	.309E+02	1.28
22.37	.00	1.70	33.5	.299E+02	1.31
22.85	.00	1.63	34.5	.290E+02	1.33
23.32	.00	1.56	35.6	.281E+02	1.36
23.80	.00	1.48	36.7	.272E+02	1.38
24.28	.00	1.40	37.8	.264E+02	1.40

Cumulative travel time = 32. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
24.28	.00	1.40	37.8	.264E+02	1.40

Profile definitions:

BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
22.87	.00	.00	37.8	.264E+02	.00	.00	.00	.00
23.29	.00	.00	37.8	.264E+02	1.90	.95	1.90	.00
23.71	.00	.00	37.8	.264E+02	2.25	1.35	2.25	.00
24.14	.00	.00	37.8	.264E+02	2.48	1.65	2.48	.00
24.56	.00	.00	38.9	.257E+02	2.64	1.91	2.64	.00
24.98	.00	.00	43.7	.229E+02	2.77	2.13	2.77	.00
25.40	.00	.00	50.4	.199E+02	2.86	2.34	2.86	.00
25.82	.00	.00	56.4	.177E+02	2.93	2.52	2.93	.00
26.24	.00	.00	60.6	.165E+02	2.98	2.70	2.98	.00
26.66	.00	.00	62.9	.159E+02	3.01	2.86	3.01	.00
27.08	.00	.00	64.3	.155E+02	3.02	3.02	3.02	.00

Cumulative travel time = 40. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
27.08	.00	.00	64.3	.155E+02	3.02	3.02	3.02	.00
28.54	.00	.00	65.6	.152E+02	2.85	3.25	2.85	.00
30.00	.00	.00	66.9	.150E+02	2.72	3.48	2.72	.00
31.45	.00	.00	68.0	.147E+02	2.60	3.70	2.60	.00
32.91	.00	.00	69.1	.145E+02	2.50	3.91	2.50	.00
34.37	.00	.00	70.1	.143E+02	2.41	4.12	2.41	.00
35.82	.00	.00	71.2	.141E+02	2.33	4.32	2.33	.00
37.28	.00	.00	72.1	.139E+02	2.25	4.52	2.25	.00
38.74	.00	.00	73.1	.137E+02	2.19	4.72	2.19	.00
40.19	.00	.00	74.0	.135E+02	2.13	4.91	2.13	.00
41.65	.00	.00	74.9	.133E+02	2.08	5.09	2.08	.00
43.10	.00	.00	75.8	.132E+02	2.03	5.28	2.03	.00
44.56	.00	.00	76.7	.130E+02	1.99	5.46	1.99	.00
46.02	.00	.00	77.6	.129E+02	1.95	5.63	1.95	.00
47.47	.00	.00	78.5	.127E+02	1.91	5.81	1.91	.00
48.93	.00	.00	79.4	.126E+02	1.88	5.98	1.88	.00
50.39	.00	.00	80.3	.125E+02	1.85	6.15	1.85	.00

51.84	.00	.00	81.2	.123E+02	1.82	6.32	1.82	.00
53.30	.00	.00	82.1	.122E+02	1.79	6.48	1.79	.00
54.76	.00	.00	82.9	.121E+02	1.77	6.64	1.77	.00
56.21	.00	.00	83.8	.119E+02	1.74	6.80	1.74	.00
57.67	.00	.00	84.8	.118E+02	1.72	6.96	1.72	.00
59.13	.00	.00	85.7	.117E+02	1.70	7.12	1.70	.00
60.58	.00	.00	86.6	.115E+02	1.68	7.28	1.68	.00
62.04	.00	.00	87.5	.114E+02	1.67	7.43	1.67	.00
63.50	.00	.00	88.5	.113E+02	1.65	7.58	1.65	.00
64.95	.00	.00	89.4	.112E+02	1.64	7.73	1.64	.00
66.41	.00	.00	90.4	.111E+02	1.62	7.88	1.62	.00
67.87	.00	.00	91.4	.109E+02	1.61	8.03	1.61	.00
69.32	.00	.00	92.4	.108E+02	1.60	8.17	1.60	.00
70.78	.00	.00	93.4	.107E+02	1.59	8.32	1.59	.00
72.24	.00	.00	94.4	.106E+02	1.58	8.46	1.58	.00
73.69	.00	.00	95.5	.105E+02	1.57	8.61	1.57	.00
75.15	.00	.00	96.5	.104E+02	1.56	8.75	1.56	.00
76.61	.00	.00	97.6	.102E+02	1.55	8.89	1.55	.00
78.06	.00	.00	98.7	.101E+02	1.55	9.03	1.55	.00
79.52	.00	.00	99.8	.100E+02	1.54	9.17	1.54	.00
80.97	.00	.00	100.9	.991E+01	1.53	9.30	1.53	.00
82.43	.00	.00	102.1	.980E+01	1.53	9.44	1.53	.00
83.89	.00	.00	103.2	.969E+01	1.52	9.57	1.52	.00
85.34	.00	.00	104.4	.958E+01	1.52	9.71	1.52	.00
86.80	.00	.00	105.6	.947E+01	1.52	9.84	1.52	.00
88.26	.00	.00	106.9	.936E+01	1.51	9.97	1.51	.00
89.71	.00	.00	108.1	.925E+01	1.51	10.10	1.51	.00
91.17	.00	.00	109.4	.914E+01	1.51	10.24	1.51	.00
92.63	.00	.00	110.7	.904E+01	1.51	10.37	1.51	.00
94.08	.00	.00	112.0	.893E+01	1.51	10.49	1.51	.00
95.54	.00	.00	113.3	.883E+01	1.51	10.62	1.51	.00
97.00	.00	.00	114.7	.872E+01	1.51	10.75	1.51	.00
98.45	.00	.00	116.0	.862E+01	1.51	10.88	1.51	.00
99.91	.00	.00	117.4	.852E+01	1.51	11.00	1.51	.00

Cumulative travel time = 245. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
99.91	11.00	.00	117.4	.852E+01	1.51	22.00	1.51	.00
100.32	11.00	.00	117.8	.849E+01	1.51	22.03	1.51	.00
100.72	11.00	.00	118.1	.847E+01	1.51	22.07	1.51	.00
101.13	11.00	.00	118.5	.844E+01	1.52	22.10	1.52	.00
101.53	11.00	.00	118.8	.842E+01	1.52	22.14	1.52	.00
101.94	11.00	.00	119.2	.839E+01	1.52	22.17	1.52	.00
102.35	11.00	.00	119.5	.837E+01	1.52	22.21	1.52	.00
102.75	11.00	.00	119.9	.834E+01	1.52	22.24	1.52	.00

103.16	11.00	.00	120.2	.832E+01	1.53	22.28	1.53	.00
103.56	11.00	.00	120.6	.829E+01	1.53	22.31	1.53	.00
103.97	11.00	.00	120.9	.827E+01	1.53	22.35	1.53	.00
104.37	11.00	.00	121.3	.824E+01	1.53	22.38	1.53	.00
104.78	11.00	.00	121.7	.822E+01	1.53	22.42	1.53	.00
105.19	11.00	.00	122.0	.820E+01	1.54	22.45	1.54	.00
105.59	11.00	.00	122.4	.817E+01	1.54	22.49	1.54	.00
106.00	11.00	.00	122.7	.815E+01	1.54	22.52	1.54	.00
106.40	11.00	.00	123.1	.812E+01	1.54	22.55	1.54	.00
106.81	11.00	.00	123.5	.810E+01	1.54	22.59	1.54	.00
107.22	11.00	.00	123.8	.808E+01	1.55	22.62	1.55	.00
107.62	11.00	.00	124.2	.805E+01	1.55	22.66	1.55	.00
108.03	11.00	.00	124.5	.803E+01	1.55	22.69	1.55	.00
108.43	11.00	.00	124.9	.801E+01	1.55	22.73	1.55	.00
108.84	11.00	.00	125.3	.798E+01	1.56	22.76	1.56	.00
109.24	11.00	.00	125.6	.796E+01	1.56	22.80	1.56	.00
109.65	11.00	.00	126.0	.794E+01	1.56	22.83	1.56	.00
110.06	11.00	.00	126.4	.791E+01	1.56	22.86	1.56	.00
110.46	11.00	.00	126.8	.789E+01	1.56	22.90	1.56	.00
110.87	11.00	.00	127.1	.787E+01	1.57	22.93	1.57	.00
111.27	11.00	.00	127.5	.784E+01	1.57	22.97	1.57	.00
111.68	11.00	.00	127.9	.782E+01	1.57	23.00	1.57	.00
112.09	11.00	.00	128.2	.780E+01	1.57	23.03	1.57	.00
112.49	11.00	.00	128.6	.777E+01	1.58	23.07	1.58	.00
112.90	11.00	.00	129.0	.775E+01	1.58	23.10	1.58	.00
113.30	11.00	.00	129.4	.773E+01	1.58	23.14	1.58	.00
113.71	11.00	.00	129.8	.771E+01	1.58	23.17	1.58	.00
114.11	11.00	.00	130.1	.768E+01	1.59	23.20	1.59	.00
114.52	11.00	.00	130.5	.766E+01	1.59	23.24	1.59	.00
114.93	11.00	.00	130.9	.764E+01	1.59	23.27	1.59	.00
115.33	11.00	.00	131.3	.762E+01	1.59	23.31	1.59	.00
115.74	11.00	.00	131.7	.759E+01	1.59	23.34	1.59	.00
116.14	11.00	.00	132.1	.757E+01	1.60	23.37	1.60	.00
116.55	11.00	.00	132.4	.755E+01	1.60	23.41	1.60	.00
116.96	11.00	.00	132.8	.753E+01	1.60	23.44	1.60	.00
117.36	11.00	.00	133.2	.751E+01	1.60	23.48	1.60	.00
117.77	11.00	.00	133.6	.748E+01	1.61	23.51	1.61	.00
118.17	11.00	.00	134.0	.746E+01	1.61	23.54	1.61	.00
118.58	11.00	.00	134.4	.744E+01	1.61	23.58	1.61	.00
118.98	11.00	.00	134.8	.742E+01	1.61	23.61	1.61	.00
119.39	11.00	.00	135.2	.740E+01	1.62	23.64	1.62	.00
119.80	11.00	.00	135.6	.738E+01	1.62	23.68	1.62	.00
120.20	11.00	.00	136.0	.736E+01	1.62	23.71	1.62	.00

Cumulative travel time = 302. sec
Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .274E-01 m^2/s
Horizontal diffusivity (initial value) = .685E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
120.20	11.00	.00	136.0	.736E+01	1.62	23.71	1.62	.00
137.80	11.00	.00	140.1	.714E+01	1.67	23.71	1.67	.00
155.39	11.00	.00	144.6	.692E+01	1.72	23.71	1.72	.00
172.99	11.00	.00	149.2	.670E+01	1.78	23.71	1.78	.00
190.59	11.00	.00	154.1	.649E+01	1.84	23.71	1.84	.00
208.18	11.00	.00	159.2	.628E+01	1.90	23.71	1.90	.00
225.78	11.00	.00	164.6	.608E+01	1.96	23.71	1.96	.00
243.37	11.00	.00	170.3	.587E+01	2.03	23.71	2.03	.00
260.97	11.00	.00	176.3	.567E+01	2.10	23.71	2.10	.00
278.57	11.00	.00	182.6	.548E+01	2.18	23.71	2.18	.00
296.16	11.00	.00	189.3	.528E+01	2.26	23.71	2.26	.00
313.76	11.00	.00	196.3	.510E+01	2.34	23.71	2.34	.00
331.35	11.00	.00	203.6	.491E+01	2.43	23.71	2.43	.00
348.95	11.00	.00	211.4	.473E+01	2.52	23.71	2.52	.00
366.55	11.00	.00	219.5	.456E+01	2.62	23.71	2.62	.00
384.14	11.00	.00	228.0	.439E+01	2.72	23.71	2.72	.00
401.74	11.00	.00	236.9	.422E+01	2.82	23.71	2.82	.00
419.33	11.00	.00	246.3	.406E+01	2.94	23.71	2.94	.00
436.93	11.00	.00	256.0	.391E+01	3.05	23.71	3.05	.00
454.53	11.00	.00	266.2	.376E+01	3.17	23.71	3.17	.00
472.12	11.00	.00	276.8	.361E+01	3.30	23.71	3.30	.00
489.72	11.00	.00	287.8	.347E+01	3.43	23.71	3.43	.00
507.31	11.00	.00	299.2	.334E+01	3.57	23.71	3.57	.00
524.91	11.00	.00	311.0	.322E+01	3.71	23.71	3.71	.00
542.51	11.00	.00	323.2	.309E+01	3.85	23.71	3.85	.00
560.10	11.00	.00	335.7	.298E+01	4.00	23.71	4.00	.00
577.70	11.00	.00	348.6	.287E+01	4.16	23.71	4.16	.00
595.29	11.00	.00	361.8	.276E+01	4.31	23.71	4.31	.00
612.89	11.00	.00	375.3	.266E+01	4.47	23.71	4.47	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

630.48	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are
NO FURTHER CHANGES with downstream direction.

648.08	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
665.68	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
683.27	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
700.87	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
718.46	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
736.06	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
753.66	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
771.25	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
788.85	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
806.44	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
824.04	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
841.64	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
859.23	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
876.83	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
894.42	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
912.02	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
929.62	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
947.21	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
964.81	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
982.40	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00
1000.00	11.00	.00	380.8	.263E+01	4.54	23.71	4.54	.00

Cumulative travel time = 2781. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^5^-^PORT^1^-^NORMAL^FLOW
 FILE NAME:               cormix\sim\MAC5-1N1.cx1
 Time of Fortran run:     01/09/20--13:10:35

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     25.76  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .239 F     =       .058 USTAR = .2039E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.80
 D0    =       .076 A0    =       .005 H0    =       .56
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .013       = .1300E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .1300E-01  M0    = .3726E-01  J0    =-.1903E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .07  LM    =      1.94  Lm    =       .81  Lb    =       .14
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     27.17  R     =     11.97

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
```

```
 REGMZ =  0
 XINT  =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y       Z        S       C       B
       .00      .00     .56     1.0  .100E+04    .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.47  SIGMAE=       .00
  LE    =       .33  XE    =       .29  YE    =       .00  ZE    =       .72

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
       .00      .00     .56     1.0  .100E+04    .04
       .29      .00     .72     1.0  .100E+04    .04
       .47      .00     .82     1.5  .678E+03    .06
       .65      .00     .90     2.1  .471E+03    .09
       .84      .00     .97     2.8  .357E+03    .11
      1.03      .00    1.04     3.5  .286E+03    .13
      1.22      .00    1.10     4.2  .238E+03    .15
      1.42      .00    1.15     4.9  .204E+03    .17
      1.62      .00    1.20     5.6  .178E+03    .19
      1.82      .00    1.24     6.3  .159E+03    .20
      2.02      .00    1.27     6.9  .145E+03    .22
      2.22      .00    1.30     7.5  .133E+03    .23
      2.42      .00    1.33     8.1  .123E+03    .24
      2.62      .00    1.35     8.6  .116E+03    .26
      2.82      .00    1.37     9.2  .109E+03    .27
      3.03      .00    1.39     9.6  .104E+03    .27
      3.23      .00    1.40    10.1  .992E+02    .28
      3.43      .00    1.40    10.5  .953E+02    .29
      3.63      .00    1.41    10.9  .921E+02    .30
```

```
      3.83      .00    1.41    11.2  .893E+02    .30
  Maximum jet height has been reached.
      4.04      .00    1.41    11.5  .868E+02    .31
      4.24      .00    1.41    11.9  .843E+02    .32
      4.44      .00    1.40    12.2  .816E+02    .32
      4.65      .00    1.39    12.7  .790E+02    .33
      4.85      .00    1.38    13.1  .763E+02    .34
      5.05      .00    1.37    13.6  .736E+02    .34
      5.26      .00    1.36    14.1  .708E+02    .35
      5.46      .00    1.34    14.7  .682E+02    .36
      5.66      .00    1.32    15.2  .656E+02    .37
      5.86      .00    1.30    15.8  .631E+02    .38
      6.06      .00    1.28    16.5  .607E+02    .39
      6.26      .00    1.25    17.1  .583E+02    .40
      6.46      .00    1.23    17.8  .561E+02    .41
      6.67      .00    1.20    18.6  .538E+02    .42
      6.87      .00    1.17    19.3  .517E+02    .43
      7.07      .00    1.14    20.1  .497E+02    .44
      7.27      .00    1.11    20.9  .478E+02    .45
      7.47      .00    1.08    21.8  .460E+02    .46
      7.67      .00    1.05    22.6  .442E+02    .47
      7.87      .00    1.02    23.5  .425E+02    .48
      8.07      .00     .99    24.4  .410E+02    .49
      8.27      .00     .95    25.3  .395E+02    .50
      8.47      .00     .92    26.3  .380E+02    .51
      8.67      .00     .89    27.2  .367E+02    .52
      8.87      .00     .85    28.2  .354E+02    .53
      9.07      .00     .82    29.3  .342E+02    .54
      9.27      .00     .78    30.3  .330E+02    .55
      9.47      .00     .75    31.4  .319E+02    .56
      9.67      .00     .71    32.4  .309E+02    .57
      9.87      .00     .68    33.5  .299E+02    .58
     10.07      .00     .64    34.6  .289E+02    .60
     10.27      .00     .61    35.7  .280E+02    .61
 Cumulative travel time =          21. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
--------------------------------------------------------------------------------
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BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X         Y       Z         S        C        B
     10.27      .00     .61    35.7  .280E+02    .61

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
9.67	.00	.00	35.7	.280E+02	.00	.00	.00	.00
9.85	.00	.00	35.7	.280E+02	.81	.41	.81	.00
10.03	.00	.00	35.7	.280E+02	.96	.57	.96	.00
10.21	.00	.00	35.7	.280E+02	1.05	.70	1.05	.00
10.40	.00	.00	36.7	.273E+02	1.12	.81	1.12	.00
10.58	.00	.00	41.2	.243E+02	1.18	.91	1.18	.00
10.76	.00	.00	47.5	.210E+02	1.22	.99	1.22	.00
10.94	.00	.00	53.2	.188E+02	1.25	1.07	1.25	.00
11.12	.00	.00	57.2	.175E+02	1.27	1.15	1.27	.00
11.30	.00	.00	59.3	.169E+02	1.28	1.22	1.28	.00
11.49	.00	.00	60.7	.165E+02	1.28	1.28	1.28	.00

Cumulative travel time = 26. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
11.49	.00	.00	60.7	.165E+02	1.28	1.28	1.28	.00
13.64	.00	.00	64.7	.155E+02	1.09	1.62	1.09	.00
15.80	.00	.00	68.0	.147E+02	.96	1.92	.96	.00
17.96	.00	.00	71.1	.141E+02	.88	2.20	.88	.00
20.12	.00	.00	74.0	.135E+02	.82	2.46	.82	.00
22.28	.00	.00	76.9	.130E+02	.77	2.71	.77	.00
24.44	.00	.00	79.9	.125E+02	.74	2.95	.74	.00
26.60	.00	.00	83.0	.121E+02	.71	3.18	.71	.00
28.75	.00	.00	86.1	.116E+02	.69	3.40	.69	.00
30.91	.00	.00	89.5	.112E+02	.67	3.62	.67	.00
33.07	.00	.00	93.0	.107E+02	.66	3.82	.66	.00
35.23	.00	.00	96.8	.103E+02	.65	4.03	.65	.00
37.39	.00	.00	100.7	.993E+01	.65	4.22	.65	.00
39.55	.00	.00	104.9	.953E+01	.65	4.42	.65	.00
41.71	.00	.00	109.4	.914E+01	.65	4.61	.65	.00
43.86	.00	.00	114.1	.877E+01	.65	4.79	.65	.00
46.02	.00	.00	119.0	.840E+01	.65	4.97	.65	.00

48.18	.00	.00	124.3	.804E+01	.66	5.15	.66	.00
50.34	.00	.00	129.8	.770E+01	.66	5.33	.66	.00
52.50	.00	.00	135.7	.737E+01	.67	5.50	.67	.00
54.66	.00	.00	141.8	.705E+01	.68	5.67	.68	.00
56.82	.00	.00	148.3	.674E+01	.69	5.83	.69	.00
58.97	.00	.00	155.0	.645E+01	.70	6.00	.70	.00
61.13	.00	.00	162.1	.617E+01	.71	6.16	.71	.00
63.29	.00	.00	169.6	.590E+01	.73	6.32	.73	.00
65.45	.00	.00	177.3	.564E+01	.74	6.48	.74	.00
67.61	.00	.00	185.4	.539E+01	.76	6.64	.76	.00
69.77	.00	.00	193.9	.516E+01	.78	6.79	.78	.00
71.93	.00	.00	202.7	.493E+01	.79	6.94	.79	.00
74.08	.00	.00	211.8	.472E+01	.81	7.10	.81	.00
76.24	.00	.00	221.4	.452E+01	.83	7.25	.83	.00
78.40	.00	.00	231.2	.432E+01	.85	7.39	.85	.00
80.56	.00	.00	241.5	.414E+01	.87	7.54	.87	.00
82.72	.00	.00	252.1	.397E+01	.89	7.69	.89	.00
84.88	.00	.00	263.2	.380E+01	.91	7.83	.91	.00
87.04	.00	.00	274.6	.364E+01	.94	7.97	.94	.00
89.19	.00	.00	286.3	.349E+01	.96	8.11	.96	.00
91.35	.00	.00	298.5	.335E+01	.98	8.25	.98	.00
93.51	.00	.00	311.1	.321E+01	1.01	8.39	1.01	.00
95.67	.00	.00	324.1	.309E+01	1.03	8.53	1.03	.00
97.83	.00	.00	337.5	.296E+01	1.06	8.67	1.06	.00
99.99	.00	.00	351.2	.285E+01	1.08	8.80	1.08	.00
102.14	.00	.00	365.4	.274E+01	1.11	8.94	1.11	.00
104.30	.00	.00	380.1	.263E+01	1.14	9.07	1.14	.00
106.46	.00	.00	395.1	.253E+01	1.17	9.20	1.17	.00
108.62	.00	.00	410.5	.244E+01	1.19	9.33	1.19	.00
110.78	.00	.00	426.4	.235E+01	1.22	9.47	1.22	.00
112.94	.00	.00	442.7	.226E+01	1.25	9.60	1.25	.00
115.10	.00	.00	459.5	.218E+01	1.28	9.72	1.28	.00
117.25	.00	.00	476.6	.210E+01	1.31	9.85	1.31	.00
119.41	.00	.00	494.2	.202E+01	1.35	9.98	1.35	.00

Cumulative travel time = 477. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .185E-01 m^2/s
Horizontal diffusivity (initial value) = .463E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)

ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
119.41	.00	.00	494.2	.202E+01	1.35	9.98	1.35	.00
120.72	.00	.00	498.7	.201E+01	1.35	10.02	1.35	.00
122.02	.00	.00	503.1	.199E+01	1.36	10.06	1.36	.00
123.33	.00	.00	507.6	.197E+01	1.37	10.10	1.37	.00
124.63	.00	.00	512.2	.195E+01	1.37	10.14	1.37	.00
125.93	.00	.00	516.8	.193E+01	1.38	10.18	1.38	.00
127.24	.00	.00	521.5	.192E+01	1.39	10.22	1.39	.00
128.54	.00	.00	526.2	.190E+01	1.39	10.25	1.39	.00
129.85	.00	.00	530.9	.188E+01	1.40	10.29	1.40	.00
131.15	.00	.00	535.7	.187E+01	1.41	10.33	1.41	.00
132.46	.00	.00	540.5	.185E+01	1.42	10.37	1.42	.00
133.76	.00	.00	545.4	.183E+01	1.42	10.41	1.42	.00
135.07	.00	.00	550.4	.182E+01	1.43	10.45	1.43	.00
136.37	.00	.00	555.4	.180E+01	1.44	10.48	1.44	.00
137.67	.00	.00	560.4	.178E+01	1.45	10.52	1.45	.00
138.98	.00	.00	565.5	.177E+01	1.45	10.56	1.45	.00
140.28	.00	.00	570.7	.175E+01	1.46	10.60	1.46	.00
141.59	.00	.00	575.9	.174E+01	1.47	10.63	1.47	.00
142.89	.00	.00	581.2	.172E+01	1.48	10.67	1.48	.00
144.20	.00	.00	586.5	.171E+01	1.49	10.71	1.49	.00
145.50	.00	.00	591.9	.169E+01	1.50	10.75	1.50	.00
146.81	.00	.00	597.3	.167E+01	1.50	10.78	1.50	.00
148.11	.00	.00	602.8	.166E+01	1.51	10.82	1.51	.00
149.41	.00	.00	608.4	.164E+01	1.52	10.86	1.52	.00
150.72	.00	.00	614.0	.163E+01	1.53	10.89	1.53	.00
152.02	.00	.00	619.7	.161E+01	1.54	10.93	1.54	.00
153.33	.00	.00	625.4	.160E+01	1.55	10.96	1.55	.00
154.63	.00	.00	631.2	.158E+01	1.56	11.00	1.56	.00
155.94	.00	.00	637.1	.157E+01	1.57	11.04	1.57	.00
157.24	.00	.00	643.0	.156E+01	1.58	11.07	1.58	.00
158.54	.00	.00	649.0	.154E+01	1.59	11.11	1.59	.00
159.85	.00	.00	655.1	.153E+01	1.60	11.14	1.60	.00
161.15	.00	.00	661.2	.151E+01	1.61	11.18	1.61	.00
162.46	.00	.00	667.5	.150E+01	1.62	11.21	1.62	.00
163.76	.00	.00	673.7	.148E+01	1.63	11.25	1.63	.00
165.07	.00	.00	680.1	.147E+01	1.64	11.28	1.64	.00
166.37	.00	.00	686.5	.146E+01	1.65	11.32	1.65	.00
167.68	.00	.00	693.0	.144E+01	1.66	11.35	1.66	.00
168.98	.00	.00	699.5	.143E+01	1.67	11.39	1.67	.00
170.28	.00	.00	706.2	.142E+01	1.68	11.42	1.68	.00
171.59	.00	.00	712.9	.140E+01	1.69	11.46	1.69	.00
172.89	.00	.00	719.6	.139E+01	1.70	11.49	1.70	.00
174.20	.00	.00	726.5	.138E+01	1.71	11.53	1.71	.00
175.50	.00	.00	733.4	.136E+01	1.72	11.56	1.72	.00

176.81	.00	.00	740.4	.135E+01	1.73	11.60	1.73	.00
178.11	.00	.00	747.5	.134E+01	1.75	11.63	1.75	.00
179.41	.00	.00	754.7	.133E+01	1.76	11.66	1.76	.00
180.72	.00	.00	762.0	.131E+01	1.77	11.70	1.77	.00
182.02	.00	.00	769.3	.130E+01	1.78	11.73	1.78	.00
183.33	.00	.00	776.7	.129E+01	1.79	11.77	1.79	.00
184.63	.00	.00	784.2	.128E+01	1.81	11.80	1.81	.00

Cumulative travel time = 749. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
184.63	11.80	.00	784.2	.128E+01	1.81	23.60	1.81	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 193.20 m.

204.94	11.80	.00	882.2	.113E+01	2.01	23.71	2.01	.00
225.25	11.80	.00	976.6	.102E+01	2.24	23.71	2.24	.00
245.55	11.80	.00	1086.9	.920E+00	2.49	23.71	2.49	.00
265.86	11.80	.00	1206.4	.829E+00	2.76	23.71	2.76	.00
286.17	11.80	.00	1333.5	.750E+00	3.06	23.71	3.06	.00
306.48	11.80	.00	1466.5	.682E+00	3.36	23.71	3.36	.00
326.78	11.80	.00	1603.3	.624E+00	3.67	23.71	3.67	.00
347.09	11.80	.00	1742.4	.574E+00	3.99	23.71	3.99	.00
367.40	11.80	.00	1882.2	.531E+00	4.31	23.71	4.31	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

387.71	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

408.01	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
428.32	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
448.63	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
468.94	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
489.24	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
509.55	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
529.86	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
550.16	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
570.47	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
590.78	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
611.09	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
631.39	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
651.70	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
672.01	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
692.32	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
712.62	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
732.93	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
753.24	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00

773.55	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
793.85	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
814.16	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
834.47	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
854.78	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
875.08	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
895.39	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
915.70	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
936.00	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
956.31	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
976.62	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
996.93	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1017.23	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1037.54	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1057.85	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1078.16	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1098.46	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1118.77	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1139.08	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1159.39	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1179.69	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00
1200.00	11.80	.00	1981.4	.505E+00	4.54	23.71	4.54	.00

Cumulative travel time = 4990. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^5^-^PORT^1^-^MAXIMUM^FLOW
 FILE NAME:               cormix\sim\MAC5-1X1.cx1
 Time of Fortran run:     01/09/20--13:28:45

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     84.50  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .785 F     =       .058 USTAR = .6688E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.80
 D0    =       .076 A0    =       .005 H0    =       .56
 THETA =     30.00  SIGMA =       .00
 U0    =      5.487 Q0    =       .025       = .2489E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .2489E-01  M0    = .1366E+00  J0    =-.3643E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .07  LM    =      3.72  Lm    =       .47  Lb    =       .01
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     52.02  R     =      6.98

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .100E+04     .04

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:             THETAE=     27.38  SIGMAE=       .00
  LE    =       .29  XE    =       .26  YE    =       .00  ZE    =       .70

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
       .00      .00      .56     1.0  .100E+04     .04
       .26      .00      .70     1.0  .100E+04     .04
       .95      .00      .96     3.5  .282E+03     .12
      1.67      .00     1.11     6.3  .160E+03     .17
      2.40      .00     1.22     8.7  .115E+03     .21
      3.14      .00     1.29    10.9  .919E+02     .25
      3.88      .00     1.35    12.8  .779E+02     .27
      4.62      .00     1.40    14.6  .685E+02     .29
      5.35      .00     1.44    16.2  .618E+02     .31
      6.09      .00     1.47    17.6  .567E+02     .33
      6.83      .00     1.49    19.0  .528E+02     .34
      7.57      .00     1.51    20.2  .496E+02     .35
      8.31      .00     1.53    21.2  .471E+02     .36
      9.05      .00     1.54    22.2  .450E+02     .37
      9.79      .00     1.55    23.1  .433E+02     .38
     10.53      .00     1.55    23.9  .419E+02     .39
  Maximum jet height has been reached.
     11.27      .00     1.55    24.6  .407E+02     .39
     12.01      .00     1.55    25.3  .396E+02     .40
```

12.75	.00	1.55	26.0	.384E+02	.41
13.49	.00	1.54	26.9	.372E+02	.41
14.23	.00	1.53	27.8	.360E+02	.42
14.97	.00	1.52	28.8	.348E+02	.43
15.71	.00	1.51	29.8	.336E+02	.44
16.45	.00	1.49	30.9	.324E+02	.44
17.19	.00	1.47	32.0	.312E+02	.45
17.94	.00	1.45	33.3	.301E+02	.46
18.67	.00	1.43	34.5	.290E+02	.47
19.41	.00	1.41	35.8	.279E+02	.48
20.15	.00	1.39	37.2	.269E+02	.49
20.89	.00	1.36	38.6	.259E+02	.50
21.63	.00	1.34	40.0	.250E+02	.51
22.37	.00	1.31	41.5	.241E+02	.52
23.11	.00	1.29	43.0	.232E+02	.53
23.85	.00	1.26	44.6	.224E+02	.54
24.59	.00	1.23	46.2	.217E+02	.55
25.33	.00	1.20	47.8	.209E+02	.56
26.07	.00	1.18	49.4	.202E+02	.57
26.81	.00	1.15	51.1	.196E+02	.58
27.55	.00	1.12	52.8	.189E+02	.59
28.29	.00	1.09	54.6	.183E+02	.60
29.03	.00	1.06	56.3	.178E+02	.61
29.77	.00	1.03	58.1	.172E+02	.62
30.51	.00	1.00	59.9	.167E+02	.63
31.24	.00	.97	61.7	.162E+02	.64
31.99	.00	.94	63.6	.157E+02	.65
32.73	.00	.91	65.5	.153E+02	.66
33.46	.00	.88	67.4	.148E+02	.67
34.20	.00	.84	69.3	.144E+02	.68
34.95	.00	.81	71.2	.140E+02	.69
35.68	.00	.78	73.2	.137E+02	.70
36.42	.00	.75	75.1	.133E+02	.71
37.16	.00	.72	77.1	.130E+02	.72

Cumulative travel time = 37. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

Control volume inflow:

X	Y	Z	S	C	B
37.16	.00	.72	77.1	.130E+02	.72

Profile definitions:

BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
36.44	.00	.00	77.1	.130E+02	.00	.00	.00	.00
36.66	.00	.00	77.1	.130E+02	.91	.46	.91	.00
36.87	.00	.00	77.1	.130E+02	1.07	.64	1.07	.00
37.09	.00	.00	77.1	.130E+02	1.18	.79	1.18	.00
37.31	.00	.00	79.2	.126E+02	1.26	.91	1.26	.00
37.52	.00	.00	89.1	.112E+02	1.32	1.02	1.32	.00
37.74	.00	.00	102.6	.974E+01	1.37	1.12	1.37	.00
37.95	.00	.00	115.0	.869E+01	1.40	1.21	1.40	.00
38.17	.00	.00	123.5	.810E+01	1.42	1.29	1.42	.00
38.39	.00	.00	128.1	.781E+01	1.44	1.37	1.44	.00
38.60	.00	.00	131.1	.763E+01	1.44	1.44	1.44	.00

Cumulative travel time = 39. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Discharge is non-buoyant or weakly buoyant.
Therefore BUOYANT SPREADING REGIME is ABSENT.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .607E-01 m^2/s
Horizontal diffusivity (initial value) = .152E+00 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
38.60	.00	.00	131.1	.763E+01	1.44	1.44	1.44	.00
43.12	.00	.00	213.7	.468E+01	1.54	2.20	1.54	.00
47.63	.00	.00	290.5	.344E+01	1.67	2.75	1.67	.00
52.15	.00	.00	369.9	.270E+01	1.83	3.21	1.83	.00

56.66	.00	.00	453.4	.221E+01	1.99	3.61	1.99	.00
61.18	.00	.00	541.2	.185E+01	2.16	3.97	2.16	.00
65.69	.00	.00	632.6	.158E+01	2.33	4.31	2.33	.00
70.21	.00	.00	726.9	.138E+01	2.50	4.61	2.50	.00
74.72	.00	.00	823.7	.121E+01	2.66	4.90	2.66	.00
79.24	.00	.00	922.4	.108E+01	2.83	5.17	2.83	.00
83.75	.00	.00	1022.6	.978E+00	2.98	5.43	2.98	.00
88.27	.00	.00	1124.0	.890E+00	3.14	5.68	3.14	.00
92.78	.00	.00	1226.5	.815E+00	3.29	5.92	3.29	.00
97.30	.00	.00	1329.8	.752E+00	3.43	6.14	3.43	.00
101.81	.00	.00	1433.8	.697E+00	3.57	6.36	3.57	.00
106.33	.00	.00	1538.3	.650E+00	3.71	6.57	3.71	.00
110.84	.00	.00	1643.4	.609E+00	3.84	6.78	3.84	.00
115.36	.00	.00	1748.8	.572E+00	3.97	6.98	3.97	.00
119.88	.00	.00	1854.6	.539E+00	4.10	7.17	4.10	.00
124.39	.00	.00	1960.7	.510E+00	4.22	7.36	4.22	.00
128.91	.00	.00	2067.1	.484E+00	4.34	7.55	4.34	.00
133.42	.00	.00	2173.7	.460E+00	4.46	7.73	4.46	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

137.94	.00	.00	2262.8	.442E+00	4.54	7.90	4.54	.00
142.45	.00	.00	2312.0	.433E+00	4.54	8.07	4.54	.00
146.97	.00	.00	2360.1	.424E+00	4.54	8.24	4.54	.00
151.48	.00	.00	2407.3	.415E+00	4.54	8.41	4.54	.00
156.00	.00	.00	2453.6	.408E+00	4.54	8.57	4.54	.00
160.51	.00	.00	2499.0	.400E+00	4.54	8.73	4.54	.00
165.03	.00	.00	2543.6	.393E+00	4.54	8.88	4.54	.00
169.54	.00	.00	2587.5	.386E+00	4.54	9.04	4.54	.00
174.06	.00	.00	2630.6	.380E+00	4.54	9.19	4.54	.00
178.57	.00	.00	2673.0	.374E+00	4.54	9.33	4.54	.00
183.09	.00	.00	2714.8	.368E+00	4.54	9.48	4.54	.00
187.60	.00	.00	2755.9	.363E+00	4.54	9.62	4.54	.00
192.12	.00	.00	2796.4	.358E+00	4.54	9.76	4.54	.00
196.63	.00	.00	2836.4	.353E+00	4.54	9.90	4.54	.00
201.15	.00	.00	2875.8	.348E+00	4.54	10.04	4.54	.00
205.66	.00	.00	2914.6	.343E+00	4.54	10.18	4.54	.00
210.18	.00	.00	2953.0	.339E+00	4.54	10.31	4.54	.00
214.69	.00	.00	2990.8	.334E+00	4.54	10.44	4.54	.00
219.21	.00	.00	3028.2	.330E+00	4.54	10.57	4.54	.00
223.72	.00	.00	3065.1	.326E+00	4.54	10.70	4.54	.00
228.24	.00	.00	3101.6	.322E+00	4.54	10.83	4.54	.00
232.75	.00	.00	3137.7	.319E+00	4.54	10.96	4.54	.00
237.27	.00	.00	3173.3	.315E+00	4.54	11.08	4.54	.00
241.78	.00	.00	3208.6	.312E+00	4.54	11.20	4.54	.00
246.30	.00	.00	3243.4	.308E+00	4.54	11.33	4.54	.00
250.81	.00	.00	3277.9	.305E+00	4.54	11.45	4.54	.00
255.33	.00	.00	3312.1	.302E+00	4.54	11.57	4.54	.00
259.84	.00	.00	3345.9	.299E+00	4.54	11.68	4.54	.00
264.36	.00	.00	3379.3	.296E+00	4.54	11.80	4.54	.00

Cumulative travel time = 327. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
264.36	11.80	.00	3379.3	.296E+00	4.54	23.60	4.54	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 272.92 m.

283.07	11.80	.00	3413.6	.293E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

301.78	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
320.50	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
339.21	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
357.92	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
376.63	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
395.35	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
414.06	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
432.77	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
451.49	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
470.20	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
488.91	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
507.62	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
526.34	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
545.05	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
563.76	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
582.48	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
601.19	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
619.90	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
638.61	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
657.33	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
676.04	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
694.75	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
713.47	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
732.18	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
750.89	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
769.60	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
788.32	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
807.03	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
825.74	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
844.46	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
863.17	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
881.88	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
900.59	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
919.31	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
938.02	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
956.73	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
975.45	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00

994.16	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1012.87	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1031.58	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1050.30	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1069.01	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1087.72	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1106.44	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1125.15	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1143.86	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1162.57	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1181.29	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00
1200.00	11.80	.00	3395.1	.295E+00	4.54	23.71	4.54	.00

Cumulative travel time = 1518. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^5^-^PORT^3^-^NORMAL^FLOW
 FILE NAME:               cormix\sim\MAC5-3N1.cx1
 Time of Fortran run:     01/09/20--13:06:58

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     25.76  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .239 F     =       .058 USTAR = .2039E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.80
 D0    =       .102 A0    =       .008 H0    =       .55
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .023       = .2342E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .2342E-01  M0    = .6712E-01  J0    =-.3427E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .09  LM    =      2.25  Lm    =      1.08  Lb    =       .25
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     23.45  R     =     11.97

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
```

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 REGMZ =  0
 XINT  =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y       Z        S       C       B
       .00      .00     .55     1.0  .100E+04    .05

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.47  SIGMAE=        .00
  LE    =        .44  XE    =        .39  YE    =        .00  ZE    =        .77

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
       .00      .00     .55     1.0  .100E+04    .05
       .39      .00     .77     1.0  .100E+04    .05
       .57      .00     .86     1.3  .754E+03    .08
       .75      .00     .95     1.8  .554E+03    .10
       .94      .00    1.03     2.3  .434E+03    .12
      1.14      .00    1.10     2.8  .355E+03    .15
      1.33      .00    1.17     3.3  .299E+03    .17
      1.53      .00    1.23     3.9  .259E+03    .19
      1.74      .00    1.29     4.4  .227E+03    .21
      1.94      .00    1.33     4.9  .203E+03    .23
      2.14      .00    1.38     5.4  .185E+03    .25
      2.34      .00    1.42     5.9  .170E+03    .26
      2.54      .00    1.45     6.4  .157E+03    .28
      2.74      .00    1.48     6.8  .147E+03    .29
      2.96      .00    1.50     7.2  .138E+03    .30
      3.16      .00    1.53     7.6  .131E+03    .31
      3.37      .00    1.54     8.0  .125E+03    .33
      3.57      .00    1.56     8.4  .120E+03    .34
      3.78      .00    1.57     8.7  .115E+03    .34
```

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      3.99      .00    1.57     9.0  .111E+03    .35
      4.20      .00    1.58     9.3  .108E+03    .36
  Maximum jet height has been reached.
      4.41      .00    1.58     9.5  .105E+03    .37
      4.61      .00    1.58     9.8  .102E+03    .37
      4.82      .00    1.57    10.1  .994E+02    .38
      5.02      .00    1.56    10.4  .964E+02    .39
      5.23      .00    1.55    10.7  .934E+02    .40
      5.45      .00    1.54    11.1  .902E+02    .40
      5.65      .00    1.52    11.5  .871E+02    .41
      5.86      .00    1.50    11.9  .841E+02    .42
      6.06      .00    1.48    12.3  .812E+02    .43
      6.27      .00    1.46    12.8  .783E+02    .44
      6.47      .00    1.44    13.3  .754E+02    .45
      6.67      .00    1.41    13.8  .727E+02    .46
      6.89      .00    1.38    14.3  .698E+02    .48
      7.09      .00    1.35    14.9  .673E+02    .49
      7.29      .00    1.32    15.4  .648E+02    .50
      7.50      .00    1.29    16.0  .624E+02    .51
      7.70      .00    1.25    16.6  .601E+02    .52
      7.90      .00    1.22    17.3  .579E+02    .53
      8.12      .00    1.18    18.0  .556E+02    .55
      8.32      .00    1.14    18.6  .536E+02    .56
      8.52      .00    1.11    19.3  .517E+02    .57
      8.72      .00    1.07    20.1  .499E+02    .58
      8.93      .00    1.03    20.8  .481E+02    .59
      9.13      .00     .99    21.5  .464E+02    .61
      9.34      .00     .95    22.3  .448E+02    .62
      9.54      .00     .91    23.1  .432E+02    .63
      9.74      .00     .87    23.9  .418E+02    .65
      9.94      .00     .82    24.7  .404E+02    .66
     10.15      .00     .78    25.6  .391E+02    .67
     10.35      .00     .74    26.4  .378E+02    .68
     10.56      .00     .70    27.3  .366E+02    .70
 Cumulative travel time =          19. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X         Y        Z         S        C        B
     10.56      .00      .70     27.3  .366E+02     .70

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
9.86	.00	.00	27.3	.366E+02	.00	.00	.00	.00
10.07	.00	.00	27.3	.366E+02	.95	.48	.95	.00
10.28	.00	.00	27.3	.366E+02	1.12	.67	1.12	.00
10.49	.00	.00	27.3	.366E+02	1.24	.83	1.24	.00
10.70	.00	.00	28.0	.357E+02	1.32	.95	1.32	.00
10.91	.00	.00	31.5	.317E+02	1.38	1.07	1.38	.00
11.12	.00	.00	36.3	.275E+02	1.43	1.17	1.43	.00
11.33	.00	.00	40.7	.246E+02	1.46	1.26	1.46	.00
11.53	.00	.00	43.7	.229E+02	1.49	1.35	1.49	.00
11.74	.00	.00	45.3	.221E+02	1.50	1.43	1.50	.00
11.95	.00	.00	46.4	.216E+02	1.51	1.51	1.51	.00

Cumulative travel time = 25. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
11.95	.00	.00	46.4	.216E+02	1.51	1.51	1.51	.00
14.02	.00	.00	49.3	.203E+02	1.27	1.90	1.27	.00
16.09	.00	.00	51.7	.193E+02	1.12	2.26	1.12	.00
18.17	.00	.00	53.8	.186E+02	1.02	2.59	1.02	.00
20.24	.00	.00	55.7	.179E+02	.94	2.91	.94	.00
22.31	.00	.00	57.6	.174E+02	.88	3.20	.88	.00
24.38	.00	.00	59.3	.169E+02	.83	3.48	.83	.00
26.45	.00	.00	61.1	.164E+02	.80	3.76	.80	.00
28.52	.00	.00	62.9	.159E+02	.77	4.02	.77	.00
30.59	.00	.00	64.7	.155E+02	.74	4.27	.74	.00
32.67	.00	.00	66.5	.150E+02	.72	4.52	.72	.00
34.74	.00	.00	68.4	.146E+02	.70	4.76	.70	.00
36.81	.00	.00	70.4	.142E+02	.69	4.99	.69	.00
38.88	.00	.00	72.5	.138E+02	.68	5.22	.68	.00
40.95	.00	.00	74.6	.134E+02	.67	5.44	.67	.00
43.02	.00	.00	76.9	.130E+02	.66	5.66	.66	.00
45.09	.00	.00	79.2	.126E+02	.66	5.88	.66	.00

47.17	.00	.00	81.6	.123E+02	.66	6.09	.66	.00
49.24	.00	.00	84.2	.119E+02	.65	6.30	.65	.00
51.31	.00	.00	86.8	.115E+02	.65	6.50	.65	.00
53.38	.00	.00	89.6	.112E+02	.65	6.70	.65	.00
55.45	.00	.00	92.5	.108E+02	.66	6.90	.66	.00
57.52	.00	.00	95.5	.105E+02	.66	7.09	.66	.00
59.59	.00	.00	98.7	.101E+02	.66	7.28	.66	.00
61.67	.00	.00	101.9	.981E+01	.67	7.47	.67	.00
63.74	.00	.00	105.3	.949E+01	.67	7.66	.67	.00
65.81	.00	.00	108.9	.918E+01	.68	7.85	.68	.00
67.88	.00	.00	112.6	.888E+01	.69	8.03	.69	.00
69.95	.00	.00	116.4	.859E+01	.69	8.21	.69	.00
72.02	.00	.00	120.3	.831E+01	.70	8.39	.70	.00
74.09	.00	.00	124.4	.804E+01	.71	8.57	.71	.00
76.16	.00	.00	128.7	.777E+01	.72	8.74	.72	.00
78.24	.00	.00	133.1	.751E+01	.73	8.92	.73	.00
80.31	.00	.00	137.7	.726E+01	.74	9.09	.74	.00
82.38	.00	.00	142.4	.702E+01	.75	9.26	.75	.00
84.45	.00	.00	147.2	.679E+01	.76	9.43	.76	.00
86.52	.00	.00	152.3	.657E+01	.78	9.59	.78	.00
88.59	.00	.00	157.4	.635E+01	.79	9.76	.79	.00
90.66	.00	.00	162.8	.614E+01	.80	9.92	.80	.00
92.74	.00	.00	168.3	.594E+01	.82	10.09	.82	.00
94.81	.00	.00	173.9	.575E+01	.83	10.25	.83	.00
96.88	.00	.00	179.8	.556E+01	.85	10.41	.85	.00
98.95	.00	.00	185.8	.538E+01	.86	10.57	.86	.00
101.02	.00	.00	192.0	.521E+01	.88	10.73	.88	.00
103.09	.00	.00	198.3	.504E+01	.89	10.88	.89	.00
105.16	.00	.00	204.8	.488E+01	.91	11.04	.91	.00
107.24	.00	.00	211.5	.473E+01	.92	11.19	.92	.00
109.31	.00	.00	218.3	.458E+01	.94	11.35	.94	.00
111.38	.00	.00	225.4	.444E+01	.96	11.50	.96	.00
113.45	.00	.00	232.6	.430E+01	.98	11.65	.98	.00
115.52	.00	.00	240.0	.417E+01	1.00	11.80	1.00	.00

Cumulative travel time = 457. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
115.52	11.80	.00	240.0	.417E+01	1.00	23.60	1.00	.00
115.55	11.80	.00	240.1	.417E+01	1.00	23.60	1.00	.00
115.58	11.80	.00	240.2	.416E+01	1.00	23.60	1.00	.00
115.61	11.80	.00	240.3	.416E+01	1.00	23.61	1.00	.00
115.64	11.80	.00	240.4	.416E+01	1.00	23.61	1.00	.00
115.67	11.80	.00	240.5	.416E+01	1.00	23.61	1.00	.00
115.70	11.80	.00	240.6	.416E+01	1.00	23.61	1.00	.00
115.74	11.80	.00	240.7	.415E+01	1.00	23.62	1.00	.00

115.77	11.80	.00	240.8	.415E+01	1.00	23.62	1.00	.00
115.80	11.80	.00	240.9	.415E+01	1.00	23.62	1.00	.00
115.83	11.80	.00	241.0	.415E+01	1.00	23.62	1.00	.00
115.86	11.80	.00	241.1	.415E+01	1.00	23.62	1.00	.00
115.89	11.80	.00	241.2	.415E+01	1.00	23.63	1.00	.00
115.92	11.80	.00	241.3	.414E+01	1.00	23.63	1.00	.00
115.95	11.80	.00	241.5	.414E+01	1.00	23.63	1.00	.00
115.98	11.80	.00	241.6	.414E+01	1.00	23.63	1.00	.00
116.01	11.80	.00	241.7	.414E+01	1.00	23.64	1.00	.00
116.04	11.80	.00	241.8	.414E+01	1.00	23.64	1.00	.00
116.07	11.80	.00	241.9	.413E+01	1.00	23.64	1.00	.00
116.10	11.80	.00	242.0	.413E+01	1.00	23.64	1.00	.00
116.13	11.80	.00	242.1	.413E+01	1.00	23.64	1.00	.00
116.16	11.80	.00	242.2	.413E+01	1.00	23.65	1.00	.00
116.19	11.80	.00	242.3	.413E+01	1.00	23.65	1.00	.00
116.22	11.80	.00	242.4	.413E+01	1.00	23.65	1.00	.00
116.26	11.80	.00	242.5	.412E+01	1.00	23.65	1.00	.00
116.29	11.80	.00	242.6	.412E+01	1.00	23.66	1.00	.00
116.32	11.80	.00	242.7	.412E+01	1.00	23.66	1.00	.00
116.35	11.80	.00	242.8	.412E+01	1.00	23.66	1.00	.00
116.38	11.80	.00	242.9	.412E+01	1.00	23.66	1.00	.00
116.41	11.80	.00	243.0	.411E+01	1.01	23.66	1.01	.00
116.44	11.80	.00	243.1	.411E+01	1.01	23.67	1.01	.00
116.47	11.80	.00	243.2	.411E+01	1.01	23.67	1.01	.00
116.50	11.80	.00	243.3	.411E+01	1.01	23.67	1.01	.00
116.53	11.80	.00	243.5	.411E+01	1.01	23.67	1.01	.00
116.56	11.80	.00	243.6	.411E+01	1.01	23.67	1.01	.00
116.59	11.80	.00	243.7	.410E+01	1.01	23.68	1.01	.00
116.62	11.80	.00	243.8	.410E+01	1.01	23.68	1.01	.00
116.65	11.80	.00	243.9	.410E+01	1.01	23.68	1.01	.00
116.68	11.80	.00	244.0	.410E+01	1.01	23.68	1.01	.00
116.71	11.80	.00	244.1	.410E+01	1.01	23.69	1.01	.00
116.75	11.80	.00	244.2	.410E+01	1.01	23.69	1.01	.00
116.78	11.80	.00	244.3	.409E+01	1.01	23.69	1.01	.00
116.81	11.80	.00	244.4	.409E+01	1.01	23.69	1.01	.00
116.84	11.80	.00	244.5	.409E+01	1.01	23.69	1.01	.00
116.87	11.80	.00	244.6	.409E+01	1.01	23.70	1.01	.00
116.90	11.80	.00	244.7	.409E+01	1.01	23.70	1.01	.00
116.93	11.80	.00	244.8	.408E+01	1.01	23.70	1.01	.00
116.96	11.80	.00	244.9	.408E+01	1.01	23.70	1.01	.00
116.99	11.80	.00	245.0	.408E+01	1.01	23.71	1.01	.00
117.02	11.80	.00	245.1	.408E+01	1.01	23.71	1.01	.00
117.05	11.80	.00	245.3	.408E+01	1.01	23.71	1.01	.00

Cumulative travel time = 464. sec
Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .185E-01 m^2/s
Horizontal diffusivity (initial value) = .463E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
117.05	11.80	.00	245.3	.408E+01	1.01	23.71	1.01	.00
138.71	11.80	.00	254.9	.392E+01	1.05	23.71	1.05	.00
160.37	11.80	.00	265.4	.377E+01	1.10	23.71	1.10	.00
182.03	11.80	.00	276.5	.362E+01	1.14	23.71	1.14	.00
203.69	11.80	.00	288.6	.347E+01	1.19	23.71	1.19	.00
225.35	11.80	.00	301.6	.332E+01	1.24	23.71	1.24	.00
247.00	11.80	.00	315.7	.317E+01	1.30	23.71	1.30	.00
268.66	11.80	.00	330.9	.302E+01	1.37	23.71	1.37	.00
290.32	11.80	.00	347.4	.288E+01	1.43	23.71	1.43	.00
311.98	11.80	.00	365.3	.274E+01	1.51	23.71	1.51	.00
333.64	11.80	.00	384.8	.260E+01	1.59	23.71	1.59	.00
355.30	11.80	.00	405.9	.246E+01	1.68	23.71	1.68	.00
376.96	11.80	.00	428.9	.233E+01	1.77	23.71	1.77	.00
398.62	11.80	.00	454.0	.220E+01	1.87	23.71	1.87	.00
420.28	11.80	.00	481.2	.208E+01	1.99	23.71	1.99	.00
441.94	11.80	.00	510.8	.196E+01	2.11	23.71	2.11	.00
463.59	11.80	.00	542.9	.184E+01	2.24	23.71	2.24	.00
485.25	11.80	.00	577.6	.173E+01	2.38	23.71	2.38	.00
506.91	11.80	.00	615.1	.163E+01	2.54	23.71	2.54	.00
528.57	11.80	.00	655.3	.153E+01	2.70	23.71	2.70	.00
550.23	11.80	.00	698.3	.143E+01	2.88	23.71	2.88	.00
571.89	11.80	.00	744.0	.134E+01	3.07	23.71	3.07	.00
593.55	11.80	.00	792.4	.126E+01	3.27	23.71	3.27	.00
615.21	11.80	.00	843.2	.119E+01	3.48	23.71	3.48	.00
636.87	11.80	.00	896.3	.112E+01	3.70	23.71	3.70	.00
658.53	11.80	.00	951.4	.105E+01	3.93	23.71	3.93	.00
680.18	11.80	.00	1008.2	.992E+00	4.16	23.71	4.16	.00
701.84	11.80	.00	1066.5	.938E+00	4.40	23.71	4.40	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

723.50	11.80	.00	1100.0	.909E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are

```
     NO FURTHER CHANGES with downstream direction.
    745.16    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
    766.82    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
    788.48    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
    810.14    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
    831.80    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
    853.46    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
    875.12    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
    896.77    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
    918.43    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
    940.09    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
    961.75    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
    983.41    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
   1005.07    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
   1026.73    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
   1048.39    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
   1070.05    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
   1091.71    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
   1113.36    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
   1135.02    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
   1156.68    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
   1178.34    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
   1200.00    11.80     .00  1100.0  .909E+00   4.54    23.71    4.54     .00
 Cumulative travel time =        4985. sec

 Simulation limit based on maximum specified distance =   1200.00 m.
   This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
CORMIX1: Submerged Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:          MACH^BIG^MUDDY^RIVER
 Design case:              CASE^5^-^PORT^3^-^MAXIMUM^FLOW
 FILE NAME:                cormix\sim\MAC5-3X1.cx1
 Time of Fortran run:      01/09/20--13:34:43

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     84.50  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .785 F     =       .058 USTAR = .6688E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.80
 D0    =       .102 A0    =       .008 H0    =       .55
 THETA =     30.00  SIGMA =       .00
 U0    =      5.487 Q0    =       .045       = .4483E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .4483E-01  M0    = .2460E+00  J0    =-.6561E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .09  LM    =      4.31  Lm    =       .63  Lb    =       .01
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     44.91  R     =      6.98

FLOW CLASSIFICATION
 1111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y       Z        S       C       B
       .00      .00     .55     1.0  .100E+04    .05

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     27.38  SIGMAE=        .00
  LE    =        .39  XE    =        .34  YE    =        .00  ZE    =        .74

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
       .00      .00     .55     1.0  .100E+04    .05
       .34      .00     .74     1.0  .100E+04    .05
      1.02      .00    1.01     2.8  .355E+03    .13
      1.73      .00    1.19     4.9  .206E+03    .20
      2.45      .00    1.32     6.8  .148E+03    .25
      3.18      .00    1.42     8.5  .117E+03    .28
      3.91      .00    1.49    10.1  .988E+02    .32
      4.64      .00    1.55    11.6  .864E+02    .34
      5.37      .00    1.60    12.9  .775E+02    .37
      6.10      .00    1.65    14.1  .708E+02    .38
      6.84      .00    1.68    15.2  .656E+02    .40
      7.57      .00    1.71    16.3  .615E+02    .42
      8.31      .00    1.73    17.2  .581E+02    .43
      9.04      .00    1.75    18.1  .554E+02    .44
      9.77      .00    1.76    18.8  .531E+02    .45
     10.51      .00    1.77    19.5  .512E+02    .46
     11.24      .00    1.78    20.2  .496E+02    .47
     11.97      .00    1.78    20.7  .482E+02    .48
  Maximum jet height has been reached.
```

```
     12.71      .00    1.78    21.3  .470E+02    .49
     13.44      .00    1.77    21.9  .458E+02    .49
     14.18      .00    1.77    22.5  .444E+02    .50
     14.91      .00    1.76    23.2  .431E+02    .51
     15.64      .00    1.74    23.9  .418E+02    .52
     16.37      .00    1.73    24.7  .404E+02    .53
     17.11      .00    1.71    25.6  .391E+02    .54
     17.84      .00    1.69    26.5  .378E+02    .55
     18.58      .00    1.67    27.4  .365E+02    .56
     19.31      .00    1.65    28.4  .352E+02    .57
     20.04      .00    1.62    29.4  .340E+02    .58
     20.78      .00    1.60    30.5  .328E+02    .59
     21.51      .00    1.57    31.5  .317E+02    .60
     22.24      .00    1.54    32.7  .306E+02    .62
     22.97      .00    1.51    33.8  .296E+02    .63
     23.71      .00    1.48    35.0  .286E+02    .64
     24.44      .00    1.45    36.2  .276E+02    .65
     25.18      .00    1.42    37.5  .267E+02    .66
     25.91      .00    1.39    38.8  .258E+02    .67
     26.64      .00    1.35    40.1  .250E+02    .69
     27.37      .00    1.32    41.4  .242E+02    .70
     28.11      .00    1.29    42.7  .234E+02    .71
     28.84      .00    1.25    44.1  .227E+02    .72
     29.57      .00    1.22    45.5  .220E+02    .73
     30.30      .00    1.18    46.9  .213E+02    .75
     31.03      .00    1.14    48.4  .207E+02    .76
     31.77      .00    1.11    49.8  .201E+02    .77
     32.50      .00    1.07    51.3  .195E+02    .78
     33.24      .00    1.04    52.8  .189E+02    .79
     33.97      .00    1.00    54.3  .184E+02    .81
     34.70      .00     .96    55.8  .179E+02    .82
     35.43      .00     .93    57.4  .174E+02    .83
     36.16      .00     .89    58.9  .170E+02    .84
     36.90      .00     .85    60.5  .165E+02    .85
 Cumulative travel time =          35. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
--------------------------------------------------------------------------------
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BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B
    36.90      .00     .85    60.5  .165E+02    .85

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
36.05	.00	.00	60.5	.165E+02	.00	.00	.00	.00
36.31	.00	.00	60.5	.165E+02	1.08	.54	1.08	.00
36.56	.00	.00	60.5	.165E+02	1.28	.77	1.28	.00
36.82	.00	.00	60.5	.165E+02	1.41	.94	1.41	.00
37.07	.00	.00	62.2	.161E+02	1.50	1.08	1.50	.00
37.33	.00	.00	69.9	.143E+02	1.57	1.21	1.57	.00
37.58	.00	.00	80.5	.124E+02	1.63	1.33	1.63	.00
37.84	.00	.00	90.2	.111E+02	1.66	1.43	1.66	.00
38.10	.00	.00	96.9	.103E+02	1.69	1.53	1.69	.00
38.35	.00	.00	100.5	.995E+01	1.71	1.63	1.71	.00
38.61	.00	.00	102.8	.972E+01	1.71	1.71	1.71	.00

Cumulative travel time = 38. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Discharge is non-buoyant or weakly buoyant.
Therefore BUOYANT SPREADING REGIME is ABSENT.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .607E-01 m^2/s
Horizontal diffusivity (initial value) = .152E+00 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
38.61	.00	.00	102.8	.972E+01	1.71	1.71	1.71	.00
43.10	.00	.00	148.9	.671E+01	1.79	2.38	1.79	.00
47.58	.00	.00	190.8	.524E+01	1.88	2.90	1.88	.00
52.07	.00	.00	232.4	.430E+01	1.99	3.33	1.99	.00

56.56	.00	.00	275.1	.363E+01	2.11	3.72	2.11	.00
61.05	.00	.00	319.4	.313E+01	2.24	4.07	2.24	.00
65.54	.00	.00	365.4	.274E+01	2.38	4.39	2.38	.00
70.02	.00	.00	413.0	.242E+01	2.51	4.69	2.51	.00
74.51	.00	.00	462.1	.216E+01	2.65	4.97	2.65	.00
79.00	.00	.00	512.6	.195E+01	2.79	5.24	2.79	.00
83.49	.00	.00	564.2	.177E+01	2.93	5.50	2.93	.00
87.98	.00	.00	616.8	.162E+01	3.07	5.74	3.07	.00
92.46	.00	.00	670.2	.149E+01	3.21	5.97	3.21	.00
96.95	.00	.00	724.4	.138E+01	3.34	6.19	3.34	.00
101.44	.00	.00	779.2	.128E+01	3.47	6.41	3.47	.00
105.93	.00	.00	834.6	.120E+01	3.60	6.62	3.60	.00
110.41	.00	.00	890.4	.112E+01	3.73	6.82	3.73	.00
114.90	.00	.00	946.6	.106E+01	3.85	7.02	3.85	.00
119.39	.00	.00	1003.2	.997E+00	3.97	7.21	3.97	.00
123.88	.00	.00	1060.1	.943E+00	4.09	7.40	4.09	.00
128.37	.00	.00	1117.3	.895E+00	4.21	7.58	4.21	.00
132.85	.00	.00	1174.7	.851E+00	4.32	7.76	4.32	.00
137.34	.00	.00	1232.3	.811E+00	4.44	7.93	4.44	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

141.83	.00	.00	1288.0	.776E+00	4.54	8.10	4.54	.00
146.32	.00	.00	1314.5	.761E+00	4.54	8.27	4.54	.00
150.81	.00	.00	1340.4	.746E+00	4.54	8.43	4.54	.00
155.29	.00	.00	1365.9	.732E+00	4.54	8.59	4.54	.00
159.78	.00	.00	1390.9	.719E+00	4.54	8.75	4.54	.00
164.27	.00	.00	1415.4	.706E+00	4.54	8.90	4.54	.00
168.76	.00	.00	1439.6	.695E+00	4.54	9.05	4.54	.00
173.25	.00	.00	1463.3	.683E+00	4.54	9.20	4.54	.00
177.73	.00	.00	1486.7	.673E+00	4.54	9.35	4.54	.00
182.22	.00	.00	1509.7	.662E+00	4.54	9.50	4.54	.00
186.71	.00	.00	1532.3	.653E+00	4.54	9.64	4.54	.00
191.20	.00	.00	1554.6	.643E+00	4.54	9.78	4.54	.00
195.68	.00	.00	1576.6	.634E+00	4.54	9.92	4.54	.00
200.17	.00	.00	1598.3	.626E+00	4.54	10.05	4.54	.00
204.66	.00	.00	1619.7	.617E+00	4.54	10.19	4.54	.00
209.15	.00	.00	1640.9	.609E+00	4.54	10.32	4.54	.00
213.64	.00	.00	1661.7	.602E+00	4.54	10.45	4.54	.00
218.12	.00	.00	1682.3	.594E+00	4.54	10.58	4.54	.00
222.61	.00	.00	1702.7	.587E+00	4.54	10.71	4.54	.00
227.10	.00	.00	1722.8	.580E+00	4.54	10.84	4.54	.00
231.59	.00	.00	1742.7	.574E+00	4.54	10.96	4.54	.00
236.08	.00	.00	1762.3	.567E+00	4.54	11.09	4.54	.00
240.56	.00	.00	1781.8	.561E+00	4.54	11.21	4.54	.00
245.05	.00	.00	1801.0	.555E+00	4.54	11.33	4.54	.00
249.54	.00	.00	1820.0	.549E+00	4.54	11.45	4.54	.00
254.03	.00	.00	1838.9	.544E+00	4.54	11.57	4.54	.00
258.51	.00	.00	1857.5	.538E+00	4.54	11.68	4.54	.00
263.00	.00	.00	1876.0	.533E+00	4.54	11.80	4.54	.00

Cumulative travel time = 323. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
263.00	11.80	.00	1876.0	.533E+00	4.54	23.60	4.54	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 271.57 m.

281.74	11.80	.00	1895.0	.528E+00	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

300.48	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
319.22	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
337.96	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
356.70	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
375.44	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
394.18	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
412.92	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
431.66	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
450.40	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
469.14	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
487.88	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
506.62	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
525.36	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
544.10	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
562.84	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
581.58	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
600.32	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
619.06	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
637.80	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
656.54	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
675.28	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
694.02	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
712.76	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
731.50	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
750.24	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
768.98	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
787.72	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
806.46	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
825.20	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
843.94	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
862.68	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
881.42	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
900.16	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
918.90	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
937.64	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
956.38	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
975.12	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00

993.86	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1012.60	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1031.34	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1050.08	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1068.82	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1087.56	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1106.30	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1125.04	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1143.78	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1162.52	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1181.26	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00
1200.00	11.80	.00	1884.7	.531E+00	4.54	23.71	4.54	.00

Cumulative travel time = 1516. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^5^-^PORT^4^-^NORMAL^FLOW
 FILE NAME:               cormix\sim\MAC5-4N1.cx1
 Time of Fortran run:     01/09/20--13:02:58

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     25.76  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .239 F     =       .058 USTAR = .2039E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.80
 D0    =       .152 A0    =       .018 H0    =       .53
 THETA =     30.00  SIGMA =       .00
 U0    =      2.866 Q0    =       .052       = .5200E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .5200E-01  M0    = .1490E+00  J0    =-.7611E-02  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .13  LM    =      2.75  Lm    =      1.61  Lb    =       .56
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     19.21  R     =     11.97

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y       Z        S       C       B
       .00      .00     .53     1.0  .100E+04    .08

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.47  SIGMAE=        .00
  LE    =        .66  XE    =        .57  YE    =        .00  ZE    =        .85

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
       .00      .00     .53     1.0  .100E+04    .08
       .57      .00     .85     1.0  .100E+04    .08
       .76      .00     .94     1.2  .847E+03    .10
       .96      .00    1.04     1.5  .657E+03    .13
      1.15      .00    1.13     1.9  .540E+03    .15
      1.36      .00    1.22     2.2  .452E+03    .18
      1.56      .00    1.29     2.6  .391E+03    .20
      1.77      .00    1.37     2.9  .341E+03    .23
      1.97      .00    1.43     3.3  .305E+03    .25
      2.19      .00    1.49     3.6  .274E+03    .27
      2.39      .00    1.55     4.0  .251E+03    .29
      2.61      .00    1.60     4.3  .230E+03    .31
      2.82      .00    1.64     4.7  .214E+03    .33
      3.04      .00    1.68     5.0  .200E+03    .35
      3.24      .00    1.72     5.3  .188E+03    .36
      3.47      .00    1.75     5.6  .178E+03    .38
      3.69      .00    1.78     5.9  .169E+03    .39
      3.90      .00    1.80     6.2  .162E+03    .41
      4.13      .00    1.82     6.5  .155E+03    .42
```

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      4.34      .00    1.83     6.7  .150E+03    .43
      4.56      .00    1.84     6.9  .144E+03    .44
      4.77      .00    1.85     7.1  .140E+03    .45
      5.00      .00    1.85     7.3  .136E+03    .46
  Maximum jet height has been reached.
      5.21      .00    1.85     7.5  .133E+03    .47
      5.43      .00    1.85     7.7  .129E+03    .47
      5.64      .00    1.84     7.9  .126E+03    .48
      5.87      .00    1.83     8.2  .122E+03    .49
      6.08      .00    1.82     8.4  .119E+03    .50
      6.30      .00    1.80     8.7  .115E+03    .51
      6.53      .00    1.78     9.0  .111E+03    .52
      6.74      .00    1.76     9.3  .108E+03    .54
      6.96      .00    1.73     9.6  .104E+03    .55
      7.17      .00    1.70     9.9  .101E+03    .56
      7.39      .00    1.67    10.3  .971E+02    .57
      7.60      .00    1.64    10.7  .938E+02    .59
      7.82      .00    1.60    11.1  .904E+02    .60
      8.03      .00    1.57    11.4  .874E+02    .61
      8.25      .00    1.53    11.9  .842E+02    .63
      8.46      .00    1.49    12.3  .813E+02    .64
      8.68      .00    1.44    12.8  .784E+02    .66
      8.88      .00    1.40    13.2  .757E+02    .67
      9.10      .00    1.35    13.7  .730E+02    .69
      9.32      .00    1.31    14.2  .703E+02    .70
      9.53      .00    1.26    14.7  .680E+02    .72
      9.75      .00    1.21    15.3  .656E+02    .73
      9.95      .00    1.16    15.8  .634E+02    .75
     10.17      .00    1.11    16.3  .612E+02    .76
     10.38      .00    1.06    16.9  .592E+02    .78
     10.60      .00    1.00    17.5  .572E+02    .79
     10.80      .00     .95    18.1  .554E+02    .81
     11.02      .00     .90    18.7  .535E+02    .83
     11.22      .00     .85    19.3  .519E+02    .84
 Cumulative travel time =          17. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y        Z        S        C        B
    11.22      .00      .85    19.3  .519E+02    .84

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.38	.00	.00	19.3	.519E+02	.00	.00	.00	.00
10.63	.00	.00	19.3	.519E+02	1.19	.60	1.19	.00
10.88	.00	.00	19.3	.519E+02	1.41	.84	1.41	.00
11.14	.00	.00	19.3	.519E+02	1.55	1.03	1.55	.00
11.39	.00	.00	19.8	.505E+02	1.65	1.19	1.65	.00
11.64	.00	.00	22.3	.449E+02	1.73	1.33	1.73	.00
11.89	.00	.00	25.6	.390E+02	1.79	1.46	1.79	.00
12.15	.00	.00	28.7	.348E+02	1.83	1.58	1.83	.00
12.40	.00	.00	30.9	.324E+02	1.86	1.69	1.86	.00
12.65	.00	.00	32.0	.312E+02	1.88	1.79	1.88	.00
12.91	.00	.00	32.8	.305E+02	1.89	1.89	1.89	.00

Cumulative travel time = 24. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
12.91	.00	.00	32.8	.305E+02	1.89	1.89	1.89	.00
14.27	.00	.00	34.2	.292E+02	1.66	2.24	1.66	.00
15.64	.00	.00	35.5	.282E+02	1.50	2.57	1.50	.00
17.00	.00	.00	36.5	.274E+02	1.38	2.88	1.38	.00
18.37	.00	.00	37.5	.267E+02	1.29	3.17	1.29	.00
19.73	.00	.00	38.3	.261E+02	1.21	3.45	1.21	.00
21.10	.00	.00	39.2	.255E+02	1.15	3.71	1.15	.00
22.46	.00	.00	39.9	.251E+02	1.09	3.97	1.09	.00
23.83	.00	.00	40.6	.246E+02	1.05	4.22	1.05	.00
25.19	.00	.00	41.3	.242E+02	1.01	4.47	1.01	.00
26.56	.00	.00	42.0	.238E+02	.97	4.70	.97	.00
27.92	.00	.00	42.7	.234E+02	.94	4.93	.94	.00
29.29	.00	.00	43.3	.231E+02	.91	5.16	.91	.00
30.65	.00	.00	43.9	.228E+02	.89	5.38	.89	.00
32.02	.00	.00	44.6	.224E+02	.87	5.60	.87	.00
33.38	.00	.00	45.2	.221E+02	.85	5.81	.85	.00
34.75	.00	.00	45.8	.218E+02	.83	6.02	.83	.00

36.11	.00	.00	46.5	.215E+02	.81	6.22	.81	.00
37.48	.00	.00	47.1	.212E+02	.80	6.42	.80	.00
38.85	.00	.00	47.7	.210E+02	.78	6.62	.78	.00
40.21	.00	.00	48.4	.207E+02	.77	6.82	.77	.00
41.58	.00	.00	49.0	.204E+02	.76	7.01	.76	.00
42.94	.00	.00	49.7	.201E+02	.75	7.20	.75	.00
44.31	.00	.00	50.3	.199E+02	.74	7.39	.74	.00
45.67	.00	.00	51.0	.196E+02	.73	7.57	.73	.00
47.04	.00	.00	51.7	.193E+02	.72	7.75	.72	.00
48.40	.00	.00	52.4	.191E+02	.72	7.93	.72	.00
49.77	.00	.00	53.1	.188E+02	.71	8.11	.71	.00
51.13	.00	.00	53.8	.186E+02	.71	8.29	.71	.00
52.50	.00	.00	54.6	.183E+02	.70	8.46	.70	.00
53.86	.00	.00	55.3	.181E+02	.70	8.64	.70	.00
55.23	.00	.00	56.1	.178E+02	.69	8.81	.69	.00
56.59	.00	.00	56.9	.176E+02	.69	8.98	.69	.00
57.96	.00	.00	57.6	.173E+02	.68	9.15	.68	.00
59.32	.00	.00	58.5	.171E+02	.68	9.31	.68	.00
60.69	.00	.00	59.3	.169E+02	.68	9.48	.68	.00
62.06	.00	.00	60.1	.166E+02	.68	9.64	.68	.00
63.42	.00	.00	61.0	.164E+02	.68	9.80	.68	.00
64.79	.00	.00	61.9	.162E+02	.67	9.96	.67	.00
66.15	.00	.00	62.8	.159E+02	.67	10.12	.67	.00
67.52	.00	.00	63.7	.157E+02	.67	10.28	.67	.00
68.88	.00	.00	64.6	.155E+02	.67	10.44	.67	.00
70.25	.00	.00	65.6	.153E+02	.67	10.59	.67	.00
71.61	.00	.00	66.5	.150E+02	.67	10.75	.67	.00
72.98	.00	.00	67.5	.148E+02	.67	10.90	.67	.00
74.34	.00	.00	68.6	.146E+02	.67	11.05	.67	.00
75.71	.00	.00	69.6	.144E+02	.67	11.21	.67	.00
77.07	.00	.00	70.6	.142E+02	.68	11.36	.68	.00
78.44	.00	.00	71.7	.139E+02	.68	11.51	.68	.00
79.80	.00	.00	72.8	.137E+02	.68	11.65	.68	.00
81.17	.00	.00	73.9	.135E+02	.68	11.80	.68	.00

Cumulative travel time = 309. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
81.17	11.80	.00	73.9	.135E+02	.68	23.60	.68	.00
81.19	11.80	.00	73.9	.135E+02	.68	23.60	.68	.00
81.21	11.80	.00	74.0	.135E+02	.68	23.60	.68	.00
81.23	11.80	.00	74.0	.135E+02	.68	23.61	.68	.00
81.25	11.80	.00	74.0	.135E+02	.68	23.61	.68	.00
81.27	11.80	.00	74.0	.135E+02	.68	23.61	.68	.00
81.29	11.80	.00	74.0	.135E+02	.68	23.61	.68	.00
81.31	11.80	.00	74.0	.135E+02	.68	23.62	.68	.00

81.33	11.80	.00	74.1	.135E+02	.68	23.62	.68	.00
81.35	11.80	.00	74.1	.135E+02	.68	23.62	.68	.00
81.38	11.80	.00	74.1	.135E+02	.68	23.62	.68	.00
81.40	11.80	.00	74.1	.135E+02	.68	23.62	.68	.00
81.42	11.80	.00	74.1	.135E+02	.68	23.63	.68	.00
81.44	11.80	.00	74.1	.135E+02	.68	23.63	.68	.00
81.46	11.80	.00	74.1	.135E+02	.68	23.63	.68	.00
81.48	11.80	.00	74.2	.135E+02	.68	23.63	.68	.00
81.50	11.80	.00	74.2	.135E+02	.68	23.64	.68	.00
81.52	11.80	.00	74.2	.135E+02	.68	23.64	.68	.00
81.54	11.80	.00	74.2	.135E+02	.68	23.64	.68	.00
81.56	11.80	.00	74.2	.135E+02	.68	23.64	.68	.00
81.58	11.80	.00	74.2	.135E+02	.68	23.64	.68	.00
81.60	11.80	.00	74.2	.135E+02	.68	23.65	.68	.00
81.62	11.80	.00	74.3	.135E+02	.68	23.65	.68	.00
81.64	11.80	.00	74.3	.135E+02	.68	23.65	.68	.00
81.66	11.80	.00	74.3	.135E+02	.68	23.65	.68	.00
81.69	11.80	.00	74.3	.135E+02	.68	23.66	.68	.00
81.71	11.80	.00	74.3	.135E+02	.68	23.66	.68	.00
81.73	11.80	.00	74.3	.135E+02	.68	23.66	.68	.00
81.75	11.80	.00	74.4	.134E+02	.68	23.66	.68	.00
81.77	11.80	.00	74.4	.134E+02	.68	23.66	.68	.00
81.79	11.80	.00	74.4	.134E+02	.68	23.67	.68	.00
81.81	11.80	.00	74.4	.134E+02	.68	23.67	.68	.00
81.83	11.80	.00	74.4	.134E+02	.68	23.67	.68	.00
81.85	11.80	.00	74.4	.134E+02	.68	23.67	.68	.00
81.87	11.80	.00	74.4	.134E+02	.68	23.68	.68	.00
81.89	11.80	.00	74.5	.134E+02	.68	23.68	.68	.00
81.91	11.80	.00	74.5	.134E+02	.68	23.68	.68	.00
81.93	11.80	.00	74.5	.134E+02	.68	23.68	.68	.00
81.95	11.80	.00	74.5	.134E+02	.68	23.68	.68	.00
81.97	11.80	.00	74.5	.134E+02	.68	23.69	.68	.00
81.99	11.80	.00	74.5	.134E+02	.68	23.69	.68	.00
82.02	11.80	.00	74.6	.134E+02	.68	23.69	.68	.00
82.04	11.80	.00	74.6	.134E+02	.68	23.69	.68	.00
82.06	11.80	.00	74.6	.134E+02	.68	23.69	.68	.00
82.08	11.80	.00	74.6	.134E+02	.68	23.70	.68	.00
82.10	11.80	.00	74.6	.134E+02	.68	23.70	.68	.00
82.12	11.80	.00	74.6	.134E+02	.68	23.70	.68	.00
82.14	11.80	.00	74.6	.134E+02	.68	23.70	.68	.00
82.16	11.80	.00	74.7	.134E+02	.68	23.71	.68	.00
82.18	11.80	.00	74.7	.134E+02	.68	23.71	.68	.00
82.20	11.80	.00	74.7	.134E+02	.68	23.71	.68	.00

Cumulative travel time = 313. sec

Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .185E-01 m^2/s
Horizontal diffusivity (initial value) = .463E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
82.20	11.80	.00	74.7	.134E+02	.68	23.71	.68	.00
104.56	11.80	.00	75.3	.133E+02	.69	23.71	.69	.00
126.91	11.80	.00	76.0	.132E+02	.70	23.71	.70	.00
149.27	11.80	.00	76.7	.130E+02	.70	23.71	.70	.00
171.63	11.80	.00	77.4	.129E+02	.71	23.71	.71	.00
193.98	11.80	.00	78.1	.128E+02	.72	23.71	.72	.00
216.34	11.80	.00	78.8	.127E+02	.72	23.71	.72	.00
238.69	11.80	.00	79.5	.126E+02	.73	23.71	.73	.00
261.05	11.80	.00	80.2	.125E+02	.74	23.71	.74	.00
283.41	11.80	.00	81.0	.123E+02	.74	23.71	.74	.00
305.76	11.80	.00	81.8	.122E+02	.75	23.71	.75	.00
328.12	11.80	.00	82.5	.121E+02	.76	23.71	.76	.00
350.47	11.80	.00	83.3	.120E+02	.76	23.71	.76	.00
372.83	11.80	.00	84.1	.119E+02	.77	23.71	.77	.00
395.18	11.80	.00	85.0	.118E+02	.78	23.71	.78	.00
417.54	11.80	.00	85.8	.117E+02	.79	23.71	.79	.00
439.90	11.80	.00	86.7	.115E+02	.79	23.71	.79	.00
462.25	11.80	.00	87.5	.114E+02	.80	23.71	.80	.00
484.61	11.80	.00	88.4	.113E+02	.81	23.71	.81	.00
506.96	11.80	.00	89.3	.112E+02	.82	23.71	.82	.00
529.32	11.80	.00	90.3	.111E+02	.83	23.71	.83	.00
551.68	11.80	.00	91.2	.110E+02	.84	23.71	.84	.00
574.03	11.80	.00	92.2	.108E+02	.84	23.71	.84	.00
596.39	11.80	.00	93.2	.107E+02	.85	23.71	.85	.00
618.74	11.80	.00	94.2	.106E+02	.86	23.71	.86	.00
641.10	11.80	.00	95.2	.105E+02	.87	23.71	.87	.00
663.46	11.80	.00	96.2	.104E+02	.88	23.71	.88	.00
685.81	11.80	.00	97.3	.103E+02	.89	23.71	.89	.00
708.17	11.80	.00	98.4	.102E+02	.90	23.71	.90	.00
730.52	11.80	.00	99.5	.100E+02	.91	23.71	.91	.00
752.88	11.80	.00	100.7	.993E+01	.92	23.71	.92	.00
775.24	11.80	.00	101.8	.982E+01	.93	23.71	.93	.00
797.59	11.80	.00	103.0	.971E+01	.94	23.71	.94	.00
819.95	11.80	.00	104.2	.959E+01	.96	23.71	.96	.00

842.30	11.80	.00	105.5	.948E+01	.97	23.71	.97	.00
864.66	11.80	.00	106.8	.937E+01	.98	23.71	.98	.00
887.02	11.80	.00	108.1	.925E+01	.99	23.71	.99	.00
909.37	11.80	.00	109.4	.914E+01	1.00	23.71	1.00	.00
931.73	11.80	.00	110.8	.903E+01	1.02	23.71	1.02	.00
954.08	11.80	.00	112.2	.891E+01	1.03	23.71	1.03	.00
976.44	11.80	.00	113.6	.880E+01	1.04	23.71	1.04	.00
998.80	11.80	.00	115.1	.869E+01	1.06	23.71	1.06	.00
1021.15	11.80	.00	116.6	.857E+01	1.07	23.71	1.07	.00
1043.51	11.80	.00	118.2	.846E+01	1.08	23.71	1.08	.00
1065.86	11.80	.00	119.8	.835E+01	1.10	23.71	1.10	.00
1088.22	11.80	.00	121.4	.824E+01	1.11	23.71	1.11	.00
1110.58	11.80	.00	123.1	.812E+01	1.13	23.71	1.13	.00
1132.93	11.80	.00	124.8	.801E+01	1.14	23.71	1.14	.00
1155.29	11.80	.00	126.6	.790E+01	1.16	23.71	1.16	.00
1177.64	11.80	.00	128.4	.779E+01	1.18	23.71	1.18	.00
1200.00	11.80	.00	130.3	.768E+01	1.19	23.71	1.19	.00

Cumulative travel time = 4975. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^5^-^PORT^4^-^MAXIMUM^FLOW
 FILE NAME:               cormix\sim\MAC5-4X1.cx1
 Time of Fortran run:     01/09/20--13:38:06

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     84.50  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .785 F     =       .058 USTAR = .6688E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.80
 D0    =       .152 A0    =       .018 H0    =       .53
 THETA =     30.00  SIGMA =       .00
 U0    =      5.487 Q0    =       .100       = .9956E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .9956E-01  M0    = .5463E+00  J0    =-.1457E-01  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .13  LM    =      5.26  Lm    =       .94  Lb    =       .03
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     36.79  R     =      6.98

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y        Z        S        C        B
       .00      .00      .53     1.0  .100E+04     .08

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:              THETAE=     27.38  SIGMAE=        .00
  LE    =        .58  XE    =        .51  YE    =        .00  ZE    =        .81

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y        Z        S        C        B
       .00      .00      .53     1.0  .100E+04     .08
       .51      .00      .81     1.0  .100E+04     .08
      1.19      .00     1.10     2.1  .466E+03     .16
      1.89      .00     1.32     3.5  .285E+03     .23
      2.61      .00     1.48     4.9  .205E+03     .29
      3.33      .00     1.61     6.2  .163E+03     .34
      4.07      .00     1.72     7.4  .136E+03     .39
      4.80      .00     1.80     8.5  .118E+03     .42
      5.54      .00     1.88     9.5  .105E+03     .45
      6.27      .00     1.94    10.5  .957E+02     .48
      7.01      .00     1.99    11.3  .882E+02     .50
      7.75      .00     2.03    12.2  .823E+02     .53
      8.49      .00     2.06    12.9  .774E+02     .54
      9.22      .00     2.09    13.6  .735E+02     .56
      9.97      .00     2.12    14.3  .701E+02     .58
     10.70      .00     2.14    14.8  .673E+02     .59
     11.45      .00     2.15    15.4  .650E+02     .60
     12.18      .00     2.16    15.9  .630E+02     .61
     12.92      .00     2.17    16.3  .612E+02     .62
```

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  Maximum jet height has been reached.
     13.66      .00    2.17    16.7  .598E+02    .63
     14.40      .00    2.16    17.1  .584E+02    .64
     15.14      .00    2.16    17.6  .569E+02    .65
     15.88      .00    2.15    18.1  .554E+02    .66
     16.61      .00    2.14    18.6  .538E+02    .67
     17.36      .00    2.12    19.1  .522E+02    .68
     18.09      .00    2.10    19.7  .507E+02    .70
     18.84      .00    2.08    20.4  .491E+02    .71
     19.57      .00    2.05    21.0  .475E+02    .72
     20.31      .00    2.03    21.7  .460E+02    .73
     21.05      .00    2.00    22.5  .445E+02    .75
     21.79      .00    1.97    23.2  .431E+02    .76
     22.52      .00    1.94    24.0  .417E+02    .77
     23.27      .00    1.90    24.8  .403E+02    .79
     24.00      .00    1.86    25.7  .390E+02    .80
     24.73      .00    1.83    26.5  .377E+02    .82
     25.48      .00    1.79    27.4  .365E+02    .83
     26.21      .00    1.75    28.3  .353E+02    .85
     26.95      .00    1.71    29.2  .342E+02    .86
     27.69      .00    1.67    30.2  .331E+02    .88
     28.43      .00    1.62    31.2  .321E+02    .89
     29.16      .00    1.58    32.2  .311E+02    .91
     29.90      .00    1.54    33.2  .301E+02    .92
     30.64      .00    1.49    34.2  .292E+02    .94
     31.38      .00    1.45    35.3  .284E+02    .95
     32.11      .00    1.40    36.3  .275E+02    .97
     32.86      .00    1.36    37.4  .267E+02    .99
     33.59      .00    1.31    38.5  .260E+02   1.00
     34.33      .00    1.27    39.6  .252E+02   1.02
     35.06      .00    1.22    40.7  .245E+02   1.03
     35.81      .00    1.17    41.9  .239E+02   1.05
     36.54      .00    1.12    43.0  .232E+02   1.06
     37.28      .00    1.08    44.2  .226E+02   1.08
 Cumulative travel time =          33. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B
     37.28      .00    1.08    44.2  .226E+02   1.08

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
36.20	.00	.00	44.2	.226E+02	.00	.00	.00	.00
36.53	.00	.00	44.2	.226E+02	1.37	.69	1.37	.00
36.85	.00	.00	44.2	.226E+02	1.63	.98	1.63	.00
37.17	.00	.00	44.2	.226E+02	1.79	1.20	1.79	.00
37.50	.00	.00	45.4	.220E+02	1.91	1.38	1.91	.00
37.82	.00	.00	51.0	.196E+02	2.00	1.54	2.00	.00
38.14	.00	.00	58.8	.170E+02	2.07	1.69	2.07	.00
38.47	.00	.00	65.9	.152E+02	2.12	1.83	2.12	.00
38.79	.00	.00	70.8	.141E+02	2.16	1.95	2.16	.00
39.11	.00	.00	73.4	.136E+02	2.18	2.07	2.18	.00
39.44	.00	.00	75.1	.133E+02	2.18	2.18	2.18	.00

Cumulative travel time = 36. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Discharge is non-buoyant or weakly buoyant.
Therefore BUOYANT SPREADING REGIME is ABSENT.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .607E-01 m^2/s
Horizontal diffusivity (initial value) = .152E+00 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
39.44	.00	.00	75.1	.133E+02	2.18	2.18	2.18	.00
43.87	.00	.00	96.1	.104E+02	2.23	2.73	2.23	.00
48.30	.00	.00	115.1	.869E+01	2.29	3.18	2.29	.00
52.73	.00	.00	133.4	.750E+01	2.36	3.58	2.36	.00

57.16	.00	.00	151.4	.660E+01	2.44	3.94	2.44	.00
61.59	.00	.00	169.6	.590E+01	2.52	4.27	2.52	.00
66.02	.00	.00	188.0	.532E+01	2.61	4.57	2.61	.00
70.45	.00	.00	206.9	.483E+01	2.70	4.86	2.70	.00
74.88	.00	.00	226.1	.442E+01	2.80	5.13	2.80	.00
79.31	.00	.00	245.8	.407E+01	2.90	5.38	2.90	.00
83.74	.00	.00	266.0	.376E+01	3.00	5.63	3.00	.00
88.17	.00	.00	286.7	.349E+01	3.10	5.86	3.10	.00
92.60	.00	.00	307.7	.325E+01	3.21	6.09	3.21	.00
97.03	.00	.00	329.2	.304E+01	3.31	6.30	3.31	.00
101.46	.00	.00	351.1	.285E+01	3.42	6.51	3.42	.00
105.89	.00	.00	373.3	.268E+01	3.52	6.72	3.52	.00
110.32	.00	.00	395.8	.253E+01	3.63	6.91	3.63	.00
114.76	.00	.00	418.7	.239E+01	3.74	7.11	3.74	.00
119.19	.00	.00	441.8	.226E+01	3.84	7.29	3.84	.00
123.62	.00	.00	465.2	.215E+01	3.95	7.47	3.95	.00
128.05	.00	.00	488.8	.205E+01	4.05	7.65	4.05	.00
132.48	.00	.00	512.6	.195E+01	4.15	7.83	4.15	.00
136.91	.00	.00	536.6	.186E+01	4.26	8.00	4.26	.00
141.34	.00	.00	560.7	.178E+01	4.36	8.16	4.36	.00
145.77	.00	.00	585.1	.171E+01	4.46	8.33	4.46	.00

Plume interacts with SURFACE.

The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

150.20	.00	.00	607.5	.165E+01	4.54	8.49	4.54	.00
154.63	.00	.00	618.7	.162E+01	4.54	8.64	4.54	.00
159.06	.00	.00	629.8	.159E+01	4.54	8.80	4.54	.00
163.49	.00	.00	640.6	.156E+01	4.54	8.95	4.54	.00
167.92	.00	.00	651.3	.154E+01	4.54	9.10	4.54	.00
172.35	.00	.00	661.8	.151E+01	4.54	9.24	4.54	.00
176.78	.00	.00	672.1	.149E+01	4.54	9.39	4.54	.00
181.21	.00	.00	682.3	.147E+01	4.54	9.53	4.54	.00
185.64	.00	.00	692.3	.144E+01	4.54	9.67	4.54	.00
190.08	.00	.00	702.2	.142E+01	4.54	9.81	4.54	.00
194.51	.00	.00	712.0	.140E+01	4.54	9.94	4.54	.00
198.94	.00	.00	721.6	.139E+01	4.54	10.08	4.54	.00
203.37	.00	.00	731.1	.137E+01	4.54	10.21	4.54	.00
207.80	.00	.00	740.4	.135E+01	4.54	10.34	4.54	.00
212.23	.00	.00	749.7	.133E+01	4.54	10.47	4.54	.00
216.66	.00	.00	758.8	.132E+01	4.54	10.60	4.54	.00
221.09	.00	.00	767.9	.130E+01	4.54	10.73	4.54	.00
225.52	.00	.00	776.8	.129E+01	4.54	10.85	4.54	.00
229.95	.00	.00	785.6	.127E+01	4.54	10.97	4.54	.00
234.38	.00	.00	794.3	.126E+01	4.54	11.10	4.54	.00
238.81	.00	.00	803.0	.125E+01	4.54	11.22	4.54	.00
243.24	.00	.00	811.5	.123E+01	4.54	11.33	4.54	.00
247.67	.00	.00	819.9	.122E+01	4.54	11.45	4.54	.00
252.10	.00	.00	828.3	.121E+01	4.54	11.57	4.54	.00
256.53	.00	.00	836.6	.120E+01	4.54	11.69	4.54	.00
260.96	.00	.00	844.8	.118E+01	4.54	11.80	4.54	.00

Cumulative travel time = 318. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
260.96	11.80	.00	844.8	.118E+01	4.54	23.60	4.54	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 269.54 m.

279.75	11.80	.00	853.4	.117E+01	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

298.53	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
317.31	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
336.09	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
354.87	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
373.65	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
392.43	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
411.21	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
429.99	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
448.77	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
467.55	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
486.33	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
505.11	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
523.89	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
542.67	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
561.46	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
580.24	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
599.02	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
617.80	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
636.58	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
655.36	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
674.14	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
692.92	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
711.70	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
730.48	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
749.26	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
768.04	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
786.82	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
805.60	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
824.39	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
843.17	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
861.95	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
880.73	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
899.51	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
918.29	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
937.07	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
955.85	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
974.63	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00

993.41	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1012.19	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1030.97	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1049.75	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1068.53	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1087.32	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1106.10	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1124.88	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1143.66	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1162.44	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1181.22	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00
1200.00	11.80	.00	848.7	.118E+01	4.54	23.71	4.54	.00

Cumulative travel time = 1513. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:          MACH^BIG^MUDDY^RIVER
 Design case:              CASE^5^-^PORT^5^-^NORMAL^FLOW
 FILE NAME:                cormix\sim\MAC5-5N3.cx1
 Time of Fortran run:      01/09/20--12:56:44

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     25.76  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .239 F     =       .058 USTAR = .2039E-01
 UW    =     2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U          RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT       DISTB =     11.80
 D0    =       .203 A0    =       .032 H0    =       .50
 THETA =     30.00  SIGMA =       .00
 U0    =     2.866 Q0    =       .093       = .9276E-01
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .9276E-01  M0    = .2658E+00  J0    =-.1357E-01  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .18  LM    =      3.18  Lm    =      2.15  Lb    =       .99
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     16.62  R     =     11.97

FLOW CLASSIFICATION
 1111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 1111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
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 REGMZ =  0
 XINT  =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y       Z        S       C       B
       .00      .00     .50     1.0  .100E+04    .10

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     28.47  SIGMAE=        .00
  LE    =        .88  XE    =        .77  YE    =        .00  ZE    =        .93

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
       .00      .00     .50     1.0  .100E+04    .10
       .77      .00     .93     1.0  .100E+04    .10
       .96      .00    1.03     1.1  .902E+03    .13
      1.17      .00    1.13     1.4  .729E+03    .16
      1.36      .00    1.23     1.6  .617E+03    .18
      1.58      .00    1.32     1.9  .527E+03    .21
      1.80      .00    1.41     2.2  .459E+03    .24
      2.00      .00    1.48     2.4  .410E+03    .26
      2.23      .00    1.56     2.7  .367E+03    .29
      2.45      .00    1.63     3.0  .332E+03    .31
      2.66      .00    1.69     3.3  .306E+03    .33
      2.89      .00    1.76     3.5  .282E+03    .35
      3.12      .00    1.81     3.8  .262E+03    .38
      3.33      .00    1.86     4.1  .246E+03    .39
      3.56      .00    1.90     4.3  .231E+03    .41
      3.80      .00    1.94     4.6  .219E+03    .43
      4.01      .00    1.97     4.8  .209E+03    .45
      4.24      .00    2.01     5.0  .199E+03    .47
      4.48      .00    2.03     5.2  .191E+03    .48
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      4.69      .00    2.05     5.4  .184E+03    .49
      4.93      .00    2.07     5.6  .177E+03    .51
      5.17      .00    2.08     5.8  .172E+03    .52
      5.38      .00    2.09     6.0  .167E+03    .53
      5.62      .00    2.09     6.2  .163E+03    .54
  Maximum jet height has been reached.
      5.86      .00    2.09     6.3  .158E+03    .55
      6.07      .00    2.09     6.5  .155E+03    .56
      6.31      .00    2.08     6.6  .150E+03    .57
      6.54      .00    2.07     6.8  .146E+03    .58
      6.76      .00    2.05     7.0  .142E+03    .59
      7.00      .00    2.03     7.2  .138E+03    .61
      7.23      .00    2.01     7.5  .134E+03    .62
      7.45      .00    1.98     7.7  .130E+03    .63
      7.68      .00    1.95     8.0  .125E+03    .64
      7.92      .00    1.92     8.2  .121E+03    .66
      8.13      .00    1.89     8.5  .118E+03    .67
      8.36      .00    1.85     8.8  .114E+03    .69
      8.60      .00    1.81     9.1  .110E+03    .70
      8.81      .00    1.77     9.4  .106E+03    .72
      9.04      .00    1.72     9.8  .102E+03    .74
      9.27      .00    1.67    10.1  .988E+02    .75
      9.48      .00    1.62    10.5  .957E+02    .77
      9.71      .00    1.57    10.8  .923E+02    .79
      9.94      .00    1.51    11.2  .891E+02    .80
     10.15      .00    1.46    11.6  .863E+02    .82
     10.38      .00    1.40    12.0  .833E+02    .84
     10.61      .00    1.34    12.4  .804E+02    .86
     10.82      .00    1.29    12.8  .779E+02    .87
     11.05      .00    1.22    13.3  .752E+02    .89
     11.28      .00    1.16    13.8  .727E+02    .91
     11.48      .00    1.10    14.2  .704E+02    .93
     11.71      .00    1.03    14.7  .681E+02    .95
     11.94      .00     .97    15.1  .660E+02    .97
 Cumulative travel time =          16. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y        Z        S        C        B
    11.94      .00     .97    15.1  .660E+02    .97

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
10.97	.00	.00	15.1	.660E+02	.00	.00	.00	.00
11.26	.00	.00	15.1	.660E+02	1.40	.71	1.40	.00
11.55	.00	.00	15.1	.660E+02	1.67	1.00	1.67	.00
11.84	.00	.00	15.1	.660E+02	1.83	1.22	1.83	.00
12.13	.00	.00	15.6	.643E+02	1.96	1.41	1.96	.00
12.42	.00	.00	17.5	.572E+02	2.05	1.58	2.05	.00
12.71	.00	.00	20.2	.496E+02	2.12	1.73	2.12	.00
13.00	.00	.00	22.6	.443E+02	2.17	1.87	2.17	.00
13.29	.00	.00	24.3	.412E+02	2.21	2.00	2.21	.00
13.58	.00	.00	25.2	.398E+02	2.23	2.12	2.23	.00
13.87	.00	.00	25.7	.388E+02	2.23	2.23	2.23	.00

Cumulative travel time = 24. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
13.87	.00	.00	25.7	.388E+02	2.23	2.23	2.23	.00
14.87	.00	.00	26.6	.375E+02	2.02	2.56	2.02	.00
15.88	.00	.00	27.4	.365E+02	1.86	2.86	1.86	.00
16.88	.00	.00	28.1	.356E+02	1.73	3.14	1.73	.00
17.88	.00	.00	28.7	.349E+02	1.63	3.42	1.63	.00
18.89	.00	.00	29.2	.342E+02	1.54	3.68	1.54	.00
19.89	.00	.00	29.8	.336E+02	1.46	3.94	1.46	.00
20.89	.00	.00	30.2	.331E+02	1.40	4.18	1.40	.00
21.90	.00	.00	30.7	.326E+02	1.34	4.42	1.34	.00
22.90	.00	.00	31.1	.321E+02	1.30	4.66	1.30	.00
23.90	.00	.00	31.5	.317E+02	1.25	4.88	1.25	.00
24.91	.00	.00	31.9	.313E+02	1.21	5.11	1.21	.00
25.91	.00	.00	32.3	.310E+02	1.18	5.32	1.18	.00
26.91	.00	.00	32.7	.306E+02	1.14	5.54	1.14	.00
27.92	.00	.00	33.0	.303E+02	1.11	5.75	1.11	.00
28.92	.00	.00	33.4	.300E+02	1.09	5.95	1.09	.00
29.92	.00	.00	33.7	.297E+02	1.06	6.15	1.06	.00

30.93	.00	.00	34.0	.294E+02	1.04	6.35	1.04	.00
31.93	.00	.00	34.3	.291E+02	1.02	6.55	1.02	.00
32.93	.00	.00	34.7	.289E+02	1.00	6.74	1.00	.00
33.94	.00	.00	35.0	.286E+02	.98	6.93	.98	.00
34.94	.00	.00	35.3	.284E+02	.96	7.12	.96	.00
35.94	.00	.00	35.6	.281E+02	.94	7.30	.94	.00
36.95	.00	.00	35.9	.279E+02	.93	7.48	.93	.00
37.95	.00	.00	36.2	.276E+02	.91	7.66	.91	.00
38.95	.00	.00	36.5	.274E+02	.90	7.84	.90	.00
39.96	.00	.00	36.8	.272E+02	.89	8.02	.89	.00
40.96	.00	.00	37.1	.270E+02	.88	8.19	.88	.00
41.96	.00	.00	37.4	.268E+02	.87	8.37	.87	.00
42.97	.00	.00	37.7	.266E+02	.86	8.54	.86	.00
43.97	.00	.00	38.0	.263E+02	.85	8.70	.85	.00
44.97	.00	.00	38.3	.261E+02	.84	8.87	.84	.00
45.98	.00	.00	38.6	.259E+02	.83	9.04	.83	.00
46.98	.00	.00	38.8	.257E+02	.82	9.20	.82	.00
47.98	.00	.00	39.1	.255E+02	.81	9.36	.81	.00
48.99	.00	.00	39.4	.253E+02	.80	9.53	.80	.00
49.99	.00	.00	39.8	.252E+02	.80	9.69	.80	.00
50.99	.00	.00	40.1	.250E+02	.79	9.84	.79	.00
52.00	.00	.00	40.4	.248E+02	.78	10.00	.78	.00
53.00	.00	.00	40.7	.246E+02	.78	10.16	.78	.00
54.00	.00	.00	41.0	.244E+02	.77	10.31	.77	.00
55.00	.00	.00	41.3	.242E+02	.76	10.47	.76	.00
56.01	.00	.00	41.6	.240E+02	.76	10.62	.76	.00
57.01	.00	.00	41.9	.239E+02	.75	10.77	.75	.00
58.01	.00	.00	42.2	.237E+02	.75	10.92	.75	.00
59.02	.00	.00	42.6	.235E+02	.75	11.07	.75	.00
60.02	.00	.00	42.9	.233E+02	.74	11.22	.74	.00
61.02	.00	.00	43.2	.231E+02	.74	11.37	.74	.00
62.03	.00	.00	43.6	.230E+02	.73	11.51	.73	.00
63.03	.00	.00	43.9	.228E+02	.73	11.66	.73	.00
64.03	.00	.00	44.2	.226E+02	.73	11.80	.73	.00

Cumulative travel time = 233. sec

Plume is ATTACHED to LEFT bank/shore.
Plume width is now determined from LEFT bank/shore.

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
64.03	11.80	.00	44.2	.226E+02	.73	23.60	.73	.00
64.05	11.80	.00	44.2	.226E+02	.73	23.60	.73	.00
64.07	11.80	.00	44.2	.226E+02	.73	23.60	.73	.00
64.08	11.80	.00	44.3	.226E+02	.73	23.61	.73	.00
64.10	11.80	.00	44.3	.226E+02	.73	23.61	.73	.00
64.11	11.80	.00	44.3	.226E+02	.73	23.61	.73	.00
64.13	11.80	.00	44.3	.226E+02	.73	23.61	.73	.00
64.14	11.80	.00	44.3	.226E+02	.73	23.62	.73	.00

64.16	11.80	.00	44.3	.226E+02	.73	23.62	.73	.00
64.17	11.80	.00	44.3	.226E+02	.73	23.62	.73	.00
64.19	11.80	.00	44.3	.226E+02	.73	23.62	.73	.00
64.20	11.80	.00	44.3	.226E+02	.73	23.62	.73	.00
64.22	11.80	.00	44.3	.226E+02	.73	23.63	.73	.00
64.24	11.80	.00	44.3	.226E+02	.73	23.63	.73	.00
64.25	11.80	.00	44.3	.226E+02	.73	23.63	.73	.00
64.27	11.80	.00	44.3	.226E+02	.73	23.63	.73	.00
64.28	11.80	.00	44.3	.226E+02	.73	23.64	.73	.00
64.30	11.80	.00	44.3	.226E+02	.73	23.64	.73	.00
64.31	11.80	.00	44.3	.226E+02	.73	23.64	.73	.00
64.33	11.80	.00	44.3	.226E+02	.73	23.64	.73	.00
64.34	11.80	.00	44.3	.226E+02	.73	23.64	.73	.00
64.36	11.80	.00	44.3	.226E+02	.73	23.65	.73	.00
64.37	11.80	.00	44.3	.226E+02	.73	23.65	.73	.00
64.39	11.80	.00	44.3	.226E+02	.73	23.65	.73	.00
64.41	11.80	.00	44.3	.226E+02	.73	23.65	.73	.00
64.42	11.80	.00	44.3	.226E+02	.73	23.66	.73	.00
64.44	11.80	.00	44.3	.225E+02	.73	23.66	.73	.00
64.45	11.80	.00	44.4	.225E+02	.73	23.66	.73	.00
64.47	11.80	.00	44.4	.225E+02	.73	23.66	.73	.00
64.48	11.80	.00	44.4	.225E+02	.73	23.66	.73	.00
64.50	11.80	.00	44.4	.225E+02	.73	23.67	.73	.00
64.51	11.80	.00	44.4	.225E+02	.73	23.67	.73	.00
64.53	11.80	.00	44.4	.225E+02	.73	23.67	.73	.00
64.54	11.80	.00	44.4	.225E+02	.73	23.67	.73	.00
64.56	11.80	.00	44.4	.225E+02	.73	23.68	.73	.00
64.58	11.80	.00	44.4	.225E+02	.73	23.68	.73	.00
64.59	11.80	.00	44.4	.225E+02	.73	23.68	.73	.00
64.61	11.80	.00	44.4	.225E+02	.73	23.68	.73	.00
64.62	11.80	.00	44.4	.225E+02	.73	23.68	.73	.00
64.64	11.80	.00	44.4	.225E+02	.73	23.69	.73	.00
64.65	11.80	.00	44.4	.225E+02	.73	23.69	.73	.00
64.67	11.80	.00	44.4	.225E+02	.73	23.69	.73	.00
64.68	11.80	.00	44.4	.225E+02	.73	23.69	.73	.00
64.70	11.80	.00	44.4	.225E+02	.73	23.69	.73	.00
64.71	11.80	.00	44.4	.225E+02	.73	23.70	.73	.00
64.73	11.80	.00	44.4	.225E+02	.73	23.70	.73	.00
64.75	11.80	.00	44.4	.225E+02	.73	23.70	.73	.00
64.76	11.80	.00	44.4	.225E+02	.73	23.70	.73	.00
64.78	11.80	.00	44.4	.225E+02	.73	23.71	.73	.00
64.79	11.80	.00	44.4	.225E+02	.73	23.71	.73	.00
64.81	11.80	.00	44.5	.225E+02	.73	23.71	.73	.00

Cumulative travel time = 236. sec

Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .185E-01 m^2/s
Horizontal diffusivity (initial value) = .463E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
64.81	11.80	.00	44.5	.225E+02	.73	23.71	.73	.00
87.51	11.80	.00	44.6	.224E+02	.73	23.71	.73	.00
110.22	11.80	.00	44.8	.223E+02	.73	23.71	.73	.00
132.92	11.80	.00	45.0	.222E+02	.74	23.71	.74	.00
155.62	11.80	.00	45.2	.221E+02	.74	23.71	.74	.00
178.33	11.80	.00	45.3	.221E+02	.74	23.71	.74	.00
201.03	11.80	.00	45.5	.220E+02	.74	23.71	.74	.00
223.73	11.80	.00	45.7	.219E+02	.75	23.71	.75	.00
246.44	11.80	.00	45.9	.218E+02	.75	23.71	.75	.00
269.14	11.80	.00	46.1	.217E+02	.75	23.71	.75	.00
291.85	11.80	.00	46.3	.216E+02	.76	23.71	.76	.00
314.55	11.80	.00	46.5	.215E+02	.76	23.71	.76	.00
337.25	11.80	.00	46.7	.214E+02	.76	23.71	.76	.00
359.96	11.80	.00	46.8	.213E+02	.77	23.71	.77	.00
382.66	11.80	.00	47.0	.213E+02	.77	23.71	.77	.00
405.37	11.80	.00	47.2	.212E+02	.77	23.71	.77	.00
428.07	11.80	.00	47.4	.211E+02	.78	23.71	.78	.00
450.77	11.80	.00	47.6	.210E+02	.78	23.71	.78	.00
473.48	11.80	.00	47.8	.209E+02	.78	23.71	.78	.00
496.18	11.80	.00	48.0	.208E+02	.79	23.71	.79	.00
518.88	11.80	.00	48.2	.207E+02	.79	23.71	.79	.00
541.59	11.80	.00	48.5	.206E+02	.79	23.71	.79	.00
564.29	11.80	.00	48.7	.205E+02	.80	23.71	.80	.00
587.00	11.80	.00	48.9	.205E+02	.80	23.71	.80	.00
609.70	11.80	.00	49.1	.204E+02	.80	23.71	.80	.00
632.40	11.80	.00	49.3	.203E+02	.81	23.71	.81	.00
655.11	11.80	.00	49.5	.202E+02	.81	23.71	.81	.00
677.81	11.80	.00	49.7	.201E+02	.81	23.71	.81	.00
700.52	11.80	.00	50.0	.200E+02	.82	23.71	.82	.00
723.22	11.80	.00	50.2	.199E+02	.82	23.71	.82	.00
745.92	11.80	.00	50.4	.198E+02	.82	23.71	.82	.00
768.63	11.80	.00	50.6	.198E+02	.83	23.71	.83	.00
791.33	11.80	.00	50.8	.197E+02	.83	23.71	.83	.00
814.03	11.80	.00	51.1	.196E+02	.83	23.71	.83	.00

836.74	11.80	.00	51.3	.195E+02	.84	23.71	.84	.00
859.44	11.80	.00	51.5	.194E+02	.84	23.71	.84	.00
882.15	11.80	.00	51.8	.193E+02	.85	23.71	.85	.00
904.85	11.80	.00	52.0	.192E+02	.85	23.71	.85	.00
927.55	11.80	.00	52.3	.191E+02	.85	23.71	.85	.00
950.26	11.80	.00	52.5	.190E+02	.86	23.71	.86	.00
972.96	11.80	.00	52.7	.190E+02	.86	23.71	.86	.00
995.67	11.80	.00	53.0	.189E+02	.87	23.71	.87	.00
1018.37	11.80	.00	53.2	.188E+02	.87	23.71	.87	.00
1041.07	11.80	.00	53.5	.187E+02	.87	23.71	.87	.00
1063.78	11.80	.00	53.7	.186E+02	.88	23.71	.88	.00
1086.48	11.80	.00	54.0	.185E+02	.88	23.71	.88	.00
1109.19	11.80	.00	54.3	.184E+02	.89	23.71	.89	.00
1131.89	11.80	.00	54.5	.183E+02	.89	23.71	.89	.00
1154.59	11.80	.00	54.8	.183E+02	.90	23.71	.90	.00
1177.30	11.80	.00	55.0	.182E+02	.90	23.71	.90	.00
1200.00	11.80	.00	55.3	.181E+02	.90	23.71	.90	.00

Cumulative travel time = 4963. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:                                          Subsystem version:
 Submerged Single Port Discharges          CORMIX_v.3.20_____September_1996
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         MACH^BIG^MUDDY^RIVER
 Design case:             CASE^5^-^PORT^5^-^MAXIMUM^FLOW
 FILE NAME:               cormix\sim\MAC5-5X1.cx1
 Time of Fortran run:     01/09/20--13:40:21

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     23.71  AS    =    107.64  QA    =     84.50  ICHREG= 2
 HA    =      4.54  HD    =      4.54
 UA    =       .785 F     =       .058 USTAR = .6688E-01
 UW    =      2.000 UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.4901

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =     11.80
 D0    =       .203 A0    =       .032 H0    =       .50
 THETA =     30.00  SIGMA =       .00
 U0    =      5.487 Q0    =       .178       = .1776E+00
 RHO0  = 1013.3900  DRHO0 =-.1490E+02  GP0   =-.1463E+00
 C0    = .1000E+04  CUNITS=  PPM
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .1776E+00  M0    = .9744E+00  J0    =-.2599E-01  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =       .18  LM    =      6.08  Lm    =      1.26  Lb    =       .05
                                        Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     31.83  R     =      6.98

FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    NH4    1
 1  Applicable layer depth HS =     4.54  1
 11111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+04  CUNITS=  PPM
 NTOX  =  0
 NSTD  =  0
```

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 REGMZ =  0
 XINT  =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        11.80 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y       Z        S       C       B
       .00      .00     .50     1.0  .100E+04    .10

END OF MOD101: DISCHARGE MODULE
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.

 Zone of flow establishment:            THETAE=     27.38  SIGMAE=        .00
  LE    =        .78  XE    =        .68  YE    =        .00  ZE    =        .87

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
       .00      .00     .50     1.0  .100E+04    .10
       .68      .00     .87     1.0  .100E+04    .10
      1.36      .00    1.18     1.8  .550E+03    .19
      2.07      .00    1.43     2.9  .350E+03    .27
      2.80      .00    1.62     3.9  .256E+03    .34
      3.54      .00    1.78     4.9  .204E+03    .40
      4.27      .00    1.91     5.9  .171E+03    .44
      5.02      .00    2.02     6.8  .148E+03    .49
      5.77      .00    2.11     7.6  .131E+03    .53
      6.52      .00    2.19     8.4  .119E+03    .56
      7.27      .00    2.26     9.2  .109E+03    .59
      8.01      .00    2.31     9.8  .102E+03    .62
      8.76      .00    2.36    10.5  .953E+02    .64
      9.51      .00    2.40    11.1  .902E+02    .66
     10.27      .00    2.43    11.6  .858E+02    .68
     11.02      .00    2.46    12.2  .822E+02    .70
     11.76      .00    2.48    12.6  .792E+02    .72
     12.52      .00    2.50    13.1  .765E+02    .73
     13.27      .00    2.51    13.5  .743E+02    .75
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    14.03      .00    2.52    13.8  .723E+02    .76
 Maximum jet height has been reached.
    14.77      .00    2.52    14.1  .707E+02    .77
    15.52      .00    2.52    14.5  .691E+02    .78
    16.28      .00    2.51    14.8  .674E+02    .79
    17.03      .00    2.50    15.2  .657E+02    .80
    17.79      .00    2.48    15.6  .639E+02    .81
    18.53      .00    2.47    16.1  .622E+02    .83
    19.28      .00    2.44    16.6  .604E+02    .84
    20.04      .00    2.42    17.1  .586E+02    .86
    20.79      .00    2.39    17.6  .568E+02    .87
    21.54      .00    2.36    18.2  .550E+02    .89
    22.28      .00    2.33    18.7  .533E+02    .90
    23.04      .00    2.29    19.4  .517E+02    .92
    23.79      .00    2.25    20.0  .500E+02    .93
    24.55      .00    2.21    20.6  .484E+02    .95
    25.30      .00    2.17    21.3  .469E+02    .97
    26.04      .00    2.13    22.0  .454E+02    .99
    26.79      .00    2.08    22.7  .440E+02   1.00
    27.55      .00    2.03    23.5  .426E+02   1.02
    28.30      .00    1.98    24.2  .413E+02   1.04
    29.04      .00    1.93    25.0  .400E+02   1.06
    29.79      .00    1.88    25.8  .388E+02   1.08
    30.54      .00    1.83    26.6  .376E+02   1.09
    31.30      .00    1.78    27.4  .364E+02   1.11
    32.05      .00    1.73    28.3  .354E+02   1.13
    32.79      .00    1.67    29.1  .343E+02   1.15
    33.54      .00    1.62    30.0  .333E+02   1.17
    34.29      .00    1.56    30.9  .324E+02   1.19
    35.05      .00    1.51    31.8  .315E+02   1.21
    35.80      .00    1.45    32.7  .306E+02   1.22
    36.54      .00    1.39    33.6  .297E+02   1.24
    37.29      .00    1.34    34.6  .289E+02   1.26
    38.04      .00    1.28    35.5  .282E+02   1.28
 Cumulative travel time =          32. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B
    38.04      .00    1.28    35.5  .282E+02   1.28

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
```

S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
36.76	.00	.00	35.5	.282E+02	.00	.00	.00	.00
37.15	.00	.00	35.5	.282E+02	1.64	.83	1.64	.00
37.53	.00	.00	35.5	.282E+02	1.95	1.17	1.95	.00
37.92	.00	.00	35.5	.282E+02	2.14	1.43	2.14	.00
38.30	.00	.00	36.5	.274E+02	2.29	1.65	2.29	.00
38.68	.00	.00	41.0	.244E+02	2.40	1.85	2.40	.00
39.07	.00	.00	47.2	.212E+02	2.48	2.02	2.48	.00
39.45	.00	.00	52.9	.189E+02	2.54	2.19	2.54	.00
39.83	.00	.00	56.9	.176E+02	2.58	2.34	2.58	.00
40.22	.00	.00	59.0	.170E+02	2.60	2.48	2.60	.00
40.60	.00	.00	60.4	.166E+02	2.61	2.61	2.61	.00

Cumulative travel time = 35. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
40.60	.00	.00	60.4	.166E+02	2.61	2.61	2.61	.00
41.01	.00	.00	60.6	.165E+02	2.60	2.64	2.60	.00
41.42	.00	.00	60.9	.164E+02	2.58	2.67	2.58	.00
41.82	.00	.00	61.2	.163E+02	2.57	2.70	2.57	.00
42.23	.00	.00	61.5	.162E+02	2.55	2.73	2.55	.00
42.63	.00	.00	61.9	.162E+02	2.54	2.76	2.54	.00
43.04	.00	.00	62.2	.161E+02	2.53	2.78	2.53	.00
43.45	.00	.00	62.5	.160E+02	2.51	2.81	2.51	.00
43.85	.00	.00	62.8	.159E+02	2.50	2.84	2.50	.00
44.26	.00	.00	63.1	.159E+02	2.49	2.87	2.49	.00
44.66	.00	.00	63.4	.158E+02	2.48	2.90	2.48	.00
45.07	.00	.00	63.7	.157E+02	2.46	2.92	2.46	.00
45.48	.00	.00	64.0	.156E+02	2.45	2.95	2.45	.00
45.88	.00	.00	64.3	.155E+02	2.44	2.98	2.44	.00
46.29	.00	.00	64.6	.155E+02	2.43	3.01	2.43	.00
46.70	.00	.00	65.0	.154E+02	2.42	3.03	2.42	.00
47.10	.00	.00	65.3	.153E+02	2.41	3.06	2.41	.00

47.51	.00	.00	65.6	.152E+02	2.40	3.09	2.40	.00
47.91	.00	.00	65.9	.152E+02	2.40	3.11	2.40	.00
48.32	.00	.00	66.2	.151E+02	2.39	3.14	2.39	.00
48.73	.00	.00	66.6	.150E+02	2.38	3.17	2.38	.00
49.13	.00	.00	66.9	.149E+02	2.37	3.19	2.37	.00
49.54	.00	.00	67.2	.149E+02	2.36	3.22	2.36	.00
49.95	.00	.00	67.6	.148E+02	2.36	3.24	2.36	.00
50.35	.00	.00	67.9	.147E+02	2.35	3.27	2.35	.00
50.76	.00	.00	68.3	.147E+02	2.34	3.30	2.34	.00
51.16	.00	.00	68.6	.146E+02	2.34	3.32	2.34	.00
51.57	.00	.00	68.9	.145E+02	2.33	3.35	2.33	.00
51.98	.00	.00	69.3	.144E+02	2.32	3.37	2.32	.00
52.38	.00	.00	69.6	.144E+02	2.32	3.40	2.32	.00
52.79	.00	.00	70.0	.143E+02	2.31	3.42	2.31	.00
53.20	.00	.00	70.3	.142E+02	2.31	3.45	2.31	.00
53.60	.00	.00	70.7	.141E+02	2.30	3.47	2.30	.00
54.01	.00	.00	71.1	.141E+02	2.30	3.50	2.30	.00
54.41	.00	.00	71.4	.140E+02	2.29	3.52	2.29	.00
54.82	.00	.00	71.8	.139E+02	2.29	3.55	2.29	.00
55.23	.00	.00	72.1	.139E+02	2.28	3.57	2.28	.00
55.63	.00	.00	72.5	.138E+02	2.28	3.60	2.28	.00
56.04	.00	.00	72.9	.137E+02	2.27	3.62	2.27	.00
56.45	.00	.00	73.3	.137E+02	2.27	3.65	2.27	.00
56.85	.00	.00	73.6	.136E+02	2.27	3.67	2.27	.00
57.26	.00	.00	74.0	.135E+02	2.26	3.70	2.26	.00
57.66	.00	.00	74.4	.134E+02	2.26	3.72	2.26	.00
58.07	.00	.00	74.8	.134E+02	2.26	3.75	2.26	.00
58.48	.00	.00	75.2	.133E+02	2.26	3.77	2.26	.00
58.88	.00	.00	75.6	.132E+02	2.25	3.79	2.25	.00
59.29	.00	.00	76.0	.132E+02	2.25	3.82	2.25	.00
59.69	.00	.00	76.4	.131E+02	2.25	3.84	2.25	.00
60.10	.00	.00	76.8	.130E+02	2.25	3.87	2.25	.00
60.51	.00	.00	77.2	.130E+02	2.24	3.89	2.24	.00
60.91	.00	.00	77.6	.129E+02	2.24	3.91	2.24	.00

Cumulative travel time = 61. sec

END OF MOD141: BUOYANT AMBIENT SPREADING

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = .607E-01 m^2/s
Horizontal diffusivity (initial value) = .152E+00 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)

ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
60.91	.00	.00	77.6	.129E+02	2.24	3.91	2.24	.00
65.00	.00	.00	85.2	.117E+02	2.28	4.22	2.28	.00
69.09	.00	.00	92.8	.108E+02	2.33	4.50	2.33	.00
73.17	.00	.00	100.5	.995E+01	2.38	4.77	2.38	.00
77.26	.00	.00	108.2	.924E+01	2.44	5.02	2.44	.00
81.35	.00	.00	116.1	.861E+01	2.49	5.26	2.49	.00
85.43	.00	.00	124.1	.805E+01	2.56	5.49	2.56	.00
89.52	.00	.00	132.4	.755E+01	2.62	5.72	2.62	.00
93.61	.00	.00	140.8	.710E+01	2.69	5.93	2.69	.00
97.69	.00	.00	149.4	.669E+01	2.75	6.13	2.75	.00
101.78	.00	.00	158.2	.632E+01	2.83	6.33	2.83	.00
105.86	.00	.00	167.3	.598E+01	2.90	6.53	2.90	.00
109.95	.00	.00	176.6	.566E+01	2.98	6.71	2.98	.00
114.04	.00	.00	186.1	.537E+01	3.05	6.90	3.05	.00
118.12	.00	.00	195.8	.511E+01	3.13	7.07	3.13	.00
122.21	.00	.00	205.7	.486E+01	3.21	7.25	3.21	.00
126.30	.00	.00	215.8	.463E+01	3.29	7.41	3.29	.00
130.38	.00	.00	226.1	.442E+01	3.37	7.58	3.37	.00
134.47	.00	.00	236.6	.423E+01	3.46	7.74	3.46	.00
138.56	.00	.00	247.2	.404E+01	3.54	7.90	3.54	.00
142.64	.00	.00	258.1	.388E+01	3.62	8.06	3.62	.00
146.73	.00	.00	269.0	.372E+01	3.71	8.21	3.71	.00
150.82	.00	.00	280.2	.357E+01	3.79	8.36	3.79	.00
154.90	.00	.00	291.5	.343E+01	3.88	8.50	3.88	.00
158.99	.00	.00	302.9	.330E+01	3.96	8.65	3.96	.00
163.07	.00	.00	314.4	.318E+01	4.05	8.79	4.05	.00
167.16	.00	.00	326.1	.307E+01	4.13	8.93	4.13	.00
171.25	.00	.00	337.8	.296E+01	4.21	9.07	4.21	.00
175.33	.00	.00	349.7	.286E+01	4.30	9.20	4.30	.00
179.42	.00	.00	361.7	.276E+01	4.38	9.34	4.38	.00
183.51	.00	.00	373.7	.268E+01	4.46	9.47	4.46	.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

187.59	.00	.00	385.3	.260E+01	4.54	9.60	4.54	.00
191.68	.00	.00	390.4	.256E+01	4.54	9.73	4.54	.00
195.77	.00	.00	395.5	.253E+01	4.54	9.85	4.54	.00
199.85	.00	.00	400.5	.250E+01	4.54	9.98	4.54	.00
203.94	.00	.00	405.5	.247E+01	4.54	10.10	4.54	.00
208.03	.00	.00	410.4	.244E+01	4.54	10.22	4.54	.00
212.11	.00	.00	415.2	.241E+01	4.54	10.35	4.54	.00
216.20	.00	.00	420.0	.238E+01	4.54	10.46	4.54	.00
220.28	.00	.00	424.7	.235E+01	4.54	10.58	4.54	.00
224.37	.00	.00	429.4	.233E+01	4.54	10.70	4.54	.00

228.46	.00	.00	434.0	.230E+01	4.54	10.81	4.54	.00
232.54	.00	.00	438.6	.228E+01	4.54	10.93	4.54	.00
236.63	.00	.00	443.1	.226E+01	4.54	11.04	4.54	.00
240.72	.00	.00	447.6	.223E+01	4.54	11.15	4.54	.00
244.80	.00	.00	452.0	.221E+01	4.54	11.26	4.54	.00
248.89	.00	.00	456.4	.219E+01	4.54	11.37	4.54	.00
252.98	.00	.00	460.8	.217E+01	4.54	11.48	4.54	.00
257.06	.00	.00	465.1	.215E+01	4.54	11.59	4.54	.00
261.15	.00	.00	469.4	.213E+01	4.54	11.69	4.54	.00
265.24	.00	.00	473.6	.211E+01	4.54	11.80	4.54	.00

Cumulative travel time = 321. sec

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
265.24	11.80	.00	473.6	.211E+01	4.54	23.60	4.54	.00

The passive diffusion plume becomes LATERALLY FULLY MIXED over the channel width during the current prediction interval.

The x-coordinate of bank attachment is 273.82 m.

283.93	11.80	.00	478.4	.209E+01	4.54	23.71	4.54	.00

Effluent is FULLY MIXED over the entire channel cross-section.

Except for possible far-field decay or reaction processes, there are NO FURTHER CHANGES with downstream direction.

302.63	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
321.32	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
340.02	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
358.71	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
377.41	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
396.10	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
414.80	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
433.49	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
452.19	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
470.88	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
489.58	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
508.27	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
526.97	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
545.66	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
564.36	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
583.06	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
601.75	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
620.45	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
639.14	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
657.84	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
676.53	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
695.23	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
713.92	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
732.62	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
751.31	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
770.01	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
788.70	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00

807.40	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
826.09	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
844.79	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
863.49	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
882.18	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
900.88	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
919.57	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
938.27	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
956.96	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
975.66	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
994.35	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1013.05	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1031.74	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1050.44	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1069.13	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1087.83	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1106.52	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1125.22	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1143.91	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1162.61	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1181.31	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00
1200.00	11.80	.00	475.8	.210E+01	4.54	23.71	4.54	.00

Cumulative travel time = 1509. sec

Simulation limit based on maximum specified distance = 1200.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

CORMIX1: Submerged Single Port Discharges End of Prediction File

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OPINIONS ON THE ECOLOGICAL EFFECTS OF WILLIAMSON ENERGY'S RENEWAL OF NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM PERMIT IL0077666

Prepared for:

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Project No. 0101-19-0375

January 17, 2020

POTESTA

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OPINIONS OF THE ECOLOGICAL EFFECTS OF WILLIAMSON ENERGY'S RENEWAL OF NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM PERMIT IL0077666

1.0 INTRODUCTION

This report summarizes the opinions of Dr. Mindy Yeager-Armstead on the Williamson Energy Renewal of National Pollutant Discharge Elimination System (NPDES) Permit IL0077666 being issued for the Pond Creek Mine discharging into the Muddy River in Franklin County, Illinois. Formation of the opinions herein relied on documents provided to me (listed below), review of the draft permit and comments on the permit, review of relevant literature, and my experience. My educational background is described in my Curriculum Vita. My experience includes 15 years of consulting experience with the mining industry, specifically mining permitting and compliance, and 8 years of teaching and research experience at Marshall University. Since joining the faculty at Marshall University in August of 2011 as an assistant professor, I have established a productive research group, obtained tenure and full professorship, and now serve as Chair of the Department of Natural Resources and the Environment. My review is divided into 3 sections which include: review of the permitting procedures employed in permit issuance; consideration of the potential for biological effects from the permit in Muddy Branch; and a response to issues raised by commenters on the draft permit.

2.0 ITEMS REVIEWED

- Draft NPDES Permit No. IL0077666, Notice No 7516c Williamson Energy, LLC Pond Creek Mine Draft Renewed Permit and Fact Sheet
- Williamson Energy's Antidegradation Document for NPDES Permit No. IL0077666, Notice No. 7516c Williamson Energy, LLC, Pond Creek Mine.
- Comments provided to Illinois Environmental Protection Agency (IEPA) Bureau of Water, Water Pollution Control Permit Section (August 12, 2019) by Sierra Club, Illinois Chapter.
- IEPA Memorandum to Iwona Ward from Scott Twait, December 13, 2016, pertaining to Water Quality Based Effluent Limitations for Williamson Energy, LLC – Pond Creek Mine NPDES Permit No. Il007766.
- Additional data collected in response to comments on the draft permit.

- Memorandum to James Plumley from John Michael Corn, P.E. and Pam Hoover, P.E., AquAeTer, Inc. on April 26, 2019 regarding 2019 Mach Mine Pond 009 Effluent Results.
- Illinois Department of Natural Resources Endangered Species Act (and others) Consultation Review Letter dated September 26, 2019 EcoCAT Review # 2001813.
- Water Quality Data from sites in the Big Muddy River watershed obtained from IEPA by Freedom of Information Act.
- Freshwater Mussels of the Big Muddy River, INHS Technical Report, 2012.
- Benthic Macroinvertebrate Community Survey in the Big Muddy River, conducted by Alliance Consulting, December 2019.
- Big Muddy River Total Maximum Daily Load (TMDL) Report, IEPA 2004.
- Stage 3 TMDL Report, Upper Big Muddy River Watershed, LimnoTech 2018.
- Figures prepared for the public meeting on December 18, 2019 and general information on the mixing/dilution studies prepared by consultants.
- Historic documents and other information on the watershed obtained by internet searching.

3.0 PERMITTING PROCEDURES

A review of the draft permit and associated information indicates the permit was developed using appropriate methods consistent with the industry standards and protective of in-stream water quality criteria. The permit development included an exceptional and thorough anti-degradation review containing alternatives analysis, endangered species consultation, appropriate presentation of mixing zone and diffuser design considerations, and a real-time water quality management strategy. The real-time water quality management strategy has been sparsely used in permitting historically, but advances in remote sensing technology make this strategy feasible. The location of an United States Geological Survey (USGS) gaging station in the permit area and the ability to hold discharges when necessary optimize conditions to employ this permitting strategy.

Use of a mixing zone is acceptable to achieve permit compliance, which is widely used and consistent with federal and state regulations. Mixing zones are particularly desirable when pollutants are not persistent or bio-accumulative, such as with salts that are decidedly not toxic in lower levels. Additionally, salt discharges are well suited for mixing or dilution because treatment or removal has inherent environmental costs such as the high-energy demands of reverse osmosis, evaporation, and crystallization. Additionally, the consistent relationship between individual salts and specific conductivity, once established, will allow for real-time monitoring of stream and

discharge constituent concentrations. Generally, the relative mineral concentrations of water from the same source are consistent allowing specific conductivity, a surrogate measurement, to represent chloride in permit evaluations. This consistency is demonstrated with 7 samples collected from the holding basin location (417) on sampling dates from October 25, 2019 to January 13, 2020. Major ion concentrations (alkalinity, sulfate, chloride, and hardness) were summed to estimate total dissolved solids that was not determined. The relative contribution of chloride to the total ions ranged from 34.1% to 37.9% in these 7 samples with this minimal variability suggesting high confidence in the ability to develop a predictive relationship between chloride and specific conductivity, which can be measured in real-time. Utilization of this advanced sensor technology is required in the permit; it will support monitoring of real-time stream conditions, demonstrate consistent compliance with permit conditions, and notify operators of deviations from compliance continuously. The state-of-the-art monitoring discussed in detail below will reliably protect the stream from chloride excursions. It should be noted that my review of the mixing zone and diffuser design does not constitute an engineering review, only that the information is presented and was apparently found to be consistent with regulatory expectations by the agency for permit development.

The extensive and thorough anti-degradation analysis and supporting documents provided by the permittee were reviewed by IEPA for permit development. IEPA conducted a review based on Illinois Pollution Control Board (IPCB) Antidegradation regulations (35 Ill. Adm. Code 302.105) and concluded that the discharge would attain water quality standards and maintain existing uses of the stream based on the information provided and pursuant to additional information provided in comments. I concur with their findings and have seen nothing presented in the public comments reviewed that undermines the agency conclusions.

Consultation with the Illinois Department of Natural Resources (IDNR) was undertaken to ensure protection of threatened and endangered (T&E) species in the permit area. The consultation indicated no T&E aquatic species present in the discharge location (letter dated September 26, 2019), but indicates adherence to the permit conditions is requested to protect fish and mussel populations in the area. No concern was expressed by IDNR regarding aquatic community impairment under the permit conditions. The IEPA permit writer also indicates the web-based database was consulted and confirms no T&E species. This information appears to have been appropriately considered in permit development.

4.0 BIOLOGICAL EFFECTS

A benthic macroinvertebrate survey was conducted in the vicinity of the diffuser on November 20, 2019 by Alliance Consulting. Sampling was conducted by dredge due to river depth and accessibility. Sample results are qualitative due to deviation from optimal sampling timeframes, sample collection methods and habitat necessitated by study objectives, and river condition. However, consideration of the type and diversity of macroinvertebrates collected, with knowledge of their life histories and tolerance values, still provides information on the stream conditions. Land use in the diffuser and mixing zone location is dominated by agriculture.

Riparian zones are forested, wide to narrow, and contribute to fair woody debris that appears to be the only stable substrate in the stream. Steep undercut banks in the area downstream of the diffuser indicate historic instability and heavy erosion. Sediment bar formation is substantial, as is deposition. Substrate in the area is dominated by silty, sandy bottoms with hard packed clay also found. Stream morphology is pool with no riffle/run or gravel/cobble substrate noted in the 0.77 mile surveyed. Stream macroinvertebrate community is considered in the context of the sampling limitations. The benthic macroinvertebrate community is dominated by tolerant taxa generally of the gatherer/collector or filter/collector trophic groups. This community is indicative of the slow moving pool conditions. The community does not appear robust or healthy with limitations potentially resulting from habitat degradation as evidenced by the presence of several less tolerant taxa.

A mussel survey reported in 2012 by the Illinois Natural History survey offers an excellent description of the current (2009/2010) and historical condition of the Big Muddy River. It confirms the aforementioned dominance of silt/clay or "mud" stream bottoms, dominance of woody debris as the primary stable substrate, and the dominance of agriculture with lesser-forested land use in the watershed.

The potential for biological effects resulting from discharge mixing in the Big Muddy River is low due to poor habitat conditions, heavy sedimentation, and historic and ongoing anthropogenic impacts in the watershed. While no unique or highly valued mussel populations were found on the main stem of Big Muddy River, the sampling location most representative of the stream in the discharge area was ranked as moderate. Thirteen taxa were found at this specific site in the main stem of the Big Muddy, with 19 of 25 historically collected taxa also collected in the survey. Restricted or limited mussel communities were found at 75% of the locations sampled. Gravel/cobble/boulder substrate were found to be non-existent in the basin, as reported recently in the aforementioned benthic macroinvertebrate survey. Sediment/siltation may influence the lack of mussel species (INH 2012). These factors were also listed as impairing aquatic life at many locations in the Big Muddy River in the 2010 IEPA Water Quality Report and 303(d) list indicated in the mussel survey and specifically in the reach where the diffuser will be located in the 2018 TMDL Report prepared by LimnoTech for the Big Muddy River. Given these geologic and biologic factors, it is not likely that mussel communities will be adversely impacted by this discharge.

Generally, fish are less sensitive to increases in salinity than other taxa evaluated and are well protected by the 500 mg/l single threshold standard. Fish communities in the Big Muddy River demonstrate moderate abundance and richness indicative of anthropogenically influenced watersheds. Historical record indicates the Big Muddy River has traditionally displayed lowland characteristics with muddy banks, predominantly silt substrate, and sluggish flow. The naturally limited habitat and environmental damage already prevalent in the watershed likely contribute to the limited fish community and to selection for tolerant taxa.

The potential for biological effects resulting from discharge mixing in the Big Muddy River is low due to current/historical poor habitat conditions from heavy sedimentation/siltation which have already limited biological communities in the vicinity of the discharge. The moderately healthy fish and mussel communities are comprised of taxa tolerant of the current conditions and are likely to continue to persist if water with the proposed discharge in compliance with the permitting conditions. The historic and ongoing anthropogenic impacts in the watershed, mainly agricultural, are not likely to abate any time in the future. Although better management practices may improve loading, the substrate in the Big Muddy River is likely to remain unfavorable for establishing optimal habitat conditions necessary to support exceptional aquatic populations.

5.0 RESPONSE TO COMMENTS

Comment: The facility has current and recent violations of their NPDES permit that have yet to be resolved.

Response: The mixing zone and updated real-time discharge limits contained in the draft permit represent a long-term solution to previous permit exceedances. Pond Creek Mine has worked with IEPA to develop acceptable regulatory methods to achieve compliance in the river.

Comment: In view of the frequent violations and the danger of discharges of chemicals that are toxic to aquatic life, the monitoring is inadequate.

Response: The permit limits calculate real-time discharge limits to ensure the constituents of the discharge are not in concentrations toxic to aquatic life and is computer controlled such that the system will shut down to prevent permit exceedances. As indicated above, preliminary evaluations show a substantial relationship between chloride concentration and estimated total dissolved solids; the chloride concentration is relatively stable with respect to the other major ions and should be predictable from the specific conductivity measurements. This relationship will be confirmed with additional measurements and a predictive equation developed. When the discharge is initiated, the continuous, real-time monitoring of Outfall 011 in-stream will further ensure compliance with permit conditions and protect aquatic life from toxicity.

Comment: The chloride acute limit is too weak and the permit lacks a chronic chloride limit and thus fails to protect aquatic life and violates 35 Ill. Adm. Code 302.105(a), 302.210, 304.105. and 309.143.

Response: The hardness values in the mixing zone will be influenced by the discharge which has an average hardness of 610 mg/l $CaCO_3$. The permit derivations are in compliance with the mixing zone regulations, water quality standards, and effluent limitations referenced in the comments. The single-standard approach for

chlorides is consistent with low acute to chronic ratios in salt toxicity and the "pass-through" exposure scenario of organisms moving through the mixing zone. The in-place chloride standard is deemed acceptable by the IEPA and the United States Environmental Protection Agency (USEPA). Changes to the in-place water quality criteria are beyond the purview of this permit which puts in place mechanisms to ensure compliance with the currently approved water quality standards which are developed to be protective of daily and long term biological exposures. Chlorides are not "accumulative".
If the standard was to be changed, the permit conditions would be reevaluated; however, the 500 mg/l chloride standard is not substantially different than that calculated using Soucek's equations. The current single-value standard has been acceptable to USEPA in recent considerations of the IEPA for chloride standard revisions in parts of Illinois where road salt application has resulted in exceedances of the standard (PCB 18-32).

Mixing zone concentrations are calculated as "worst case" with highest discharge concentrations and flow volumes mixed under low stream flow conditions to ensure compliance with the water quality criteria. Water quality standards are also determined as worst case; designed to protect for the most sensitive taxa and with a built in margin of safety. Permit conditions limit discharge volumes and concentrations to be protective under both low-flow and high-flow conditions again utilizing "worst case" conditions for each. For these reasons, the biota in Big Muddy River will be protected from adverse conditions continuously when the diffuser is discharging.

Comment: The Reasonable Potential Analysis is improper because the IEPA did not use the multipliers recommended by USEPA to assure measured reasonable potential or require an adequate amount of testing. See Des Plaines Watershed Alliance v. Illinois EPA, 2007 Ill. Env. Lexis 149 *138 (IPCB 2007).

Response: *Reasonable potential analysis is used to predict upper contaminant concentrations in discharges using the variability in the discharge for ensuring stream protection in the previously mentioned "worst case" discharge scenario. The upper contaminant concentration in Outfall 011 is determined in the permit to be 12,000 mg/l chloride and will be measured in real-time using the relationship between chloride and conductivity, an easily monitored indicator. Estimating this upper limit using reasonable potential calculations is not necessary.*

Comment: The potential effect of the increased discharges has not been determined as to flooding, groundwater use and other factors.

Response: *The permit discusses the increased flow to the stream which may occur under high-flow scenarios and states the maximum pumped volume would raise the water level by less than an inch. I did not conduct an engineering review, but relied on*

the permittee and the IEPA's review to ensure these calculations are correct. The comments present no evidence to the contrary. This has clearly been included in the permit development and approval. There is no evidence that increased chloride concentrations increase the toxicity of algal blooms. The reference suggesting this relationship provided by the comments refers to the condition of freshwater algae flowing into the ocean where they die and release toxins. This specific situation, which occurs in the drainage from Lake Okeechobee in Florida, is not relevant to the discharges in the Big Muddy River.

The permit describes that the volumes of discharge will not exacerbate flooding, as indicated above, under worst case conditions and thus would exist within the range of natural-flow conditions under lower flows. The channel can thus "handle" the discharge without increasing the risk of flooding, the condition of the channel banks, vegetative cover, and in-stream substrates is known to be suboptimal throughout the watershed, but unrelated to this permit.

Comment: Increased chloride levels may increase toxicity of algal blooms in Big Muddy and other waters.

Response: *There is no evidence to indicate that the chloride levels in Big Muddy River will increase the toxicity of algal blooms in the river. On the contrary, references provided in the comments demonstrate the safety of chloride concentrations in the range of those which will be found in the Big Muddy River outside of the mixing zone with effects levels higher than in-stream concentrations.*

Suggestions that the discharges in Big Muddy River will contribute to the toxicity of algal blooms are unfounded as the chloride concentrations included in the study provided were not consistent with the concentrations which will be present in Big Muddy River but were more consistent with ocean water. The USGS reference specifically pertained to the introduction of freshwater blooms to marine conditions where salinity is well above the levels occurring in this case. Additionally, the ecological risks suggested from lake studies are not representative of conditions in the Big Muddy River as comparison of ecological effects from lentic to lotic systems is not feasible. In lakes, particularly those with no outflow, evaporation concentrates salts and continued elevated inputs will concentrate. In flowing systems, the dissolved salts disperse downstream, generally becoming more diluted until reaching the ocean. However, it is noteworthy that the Lind, et al study provided in the comments actually demonstrates, as other peer-reviewed literature demonstrates, the safety of chlorides discharges in concentrations that will be present in the river outside of the mixing zone.

6.0 CLOSING

The scope of this report is limited to the specific project and location described herein and represents my understanding of the factors as presented in this report. If these factors change as additional data concerning this report is obtained, I should be informed so that I may examine the data and, if necessary, modify or revise the opinions presented in this report.

Sincerely,

POTESTA & ASSOCIATES, INC.

Mindy Yeager Armstead

Mindy Yeager-Armstead, Ph.D.
Senior Scientist

MYA/rlh

CURRICULAM VITAE

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EDUCATION

Ph.D. Program in Aquatic Ecology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061. September 1994.
Dissertation: Abiotic and Biotic Factors Influencing the Decline of Native Unionid Mussels in the Clinch River, Virginia.

M.S. in Aquatic Ecology, Marshall University, Huntington, West Virginia, July 1991.
Thesis: An Analysis of Variation in a Disjunct Population of the Central Mudminnow, Umbra limi (Kirtland) in the Greenbottom Wildlife Management Area, Cabell County, West Virginia.

University of North Carolina-Charlotte, Charlotte, North Carolina
21 hours graduate course work, Fall 1988 - Spring 1989.

B.S. Biology, University of Charleston, Charleston, West Virginia.
May 1987 (Cum Laude).

EMPLOYMENT

2011 – 2016
Associate Professor, Marshall University, Interim Chair of the Department of Natural Resources and the Environment since July 2016. Original hiring was into Department of Integrated Science and Technology in August 2011. My original position was an Eminent Scholar appointment to develop research opportunities in the area of Aquatic Ecology.

2007 – 2011
Adjunct faculty, Wheeling Jesuit University, Bold Program – The position involved project oversight of undergraduate research projects and teaching research methods and statistics.

2002 – 2011
Adjunct faculty, Marshall University, College of Information Technology and Engineering – The position involves teaching environmental science classes in the

graduate program at both the Huntington and South Charleston campuses. Classes taught included Water Resources and Ecosystem Dynamics.

1998-1999

Adjunct faculty, Marshall University, College of Integrated Science and Technology – The position involved teaching environmental sciences in the undergraduate program at the Huntington campus. Classes taught included Environmental Problems and Environmental Solutions.

1997 - Present

Senior Scientist, Potesta & Associates, Inc., Charleston, West Virginia – As a senior scientist I have the opportunity to be involved in all aspects of issues relating to aquatic resources in the state of West Virginia. The position involves supervising staff of various backgrounds and levels and solving complex environmental problems. Projects involve determining appropriate water quality standards, assessing aquatic community health and developing strategies to improve or protect stream ecosystems. Current areas of research include the golden algae, *Prymnesium parvum*; selenium; total dissolved solids; and the development of site specific water quality criteria.

1996 - 1997

Senior Scientist, TERRADON Corporation, Poca, West Virginia – The position involved assisting industrial clients with National Pollutant Discharge Elimination System permitting and compliance issues.

1994 - 1996

Research Associate, Department of Biology, Virginia Polytechnic Institute and State University – The position involved the development of a watershed scale restoration plan for Leading Creek in Ohio. The stream was damaged by an acid mine drainage discharge following the accidental flooding of an active coal mine.

1992 - 1994

Graduate Research Assistant, Department of Biology, Virginia Polytechnic Institute and State University

1991 - 1992

Graduate Teaching Assistant, Department of Biology, Virginia Polytechnic Institute and State University

1989 - 1991

Graduate Teaching Assistant, Department of Biology, Marshall University, Huntington, West Virginia

1988 - 1989

Graduate Teaching Assistant, Department of Biology, University of North Carolina - Charlotte, Charlotte, North Carolina

CERTIFICATIONS

Licensed Remediation Specialist, West Virginia

PROFESSIONAL ORGANIZATIONS AND AFFILIATIONS

Society of Environmental Toxicology and Chemistry
Society for Freshwater Science
Air & Waste Management Association
American Fisheries Society

PUBLICATIONS

Armstead, M.M., M. Wilson, A. Parsons-White. 2017. Demonstration of a novel control strategy for *Prymnesium paruvm* management in fish hatcheries. Submitted to North American Journal of Aquaculture 79(3): 238-244.

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FUNDED GRANTS

Armstead, M.M. (Principal), "Development of toxicity evaluations using non-traditional bioassay organisms to sense low levels of contaminants." Marshall University Watershed Complexity, West Virginia EPSCor RII. $52,000. (August 2015 – June 2017).

Armstead, M.M. Co-Principal Investigator with S.E. Sweeten and S.D. Klopfer, Laboratory Investigation of the Effects of Conductivity on a Suite of Stream Organisms found in the coal mining regions of the United States: amphibians, Benthic Macroinvertebrates, and

Fish. Sponsored by the Office of Surface Mining and Reclamation, S16AC20026. $44,996. (July 1, 2016 -6-30-2018)

Armstead, M.M. (Principal), West Virginia American Water's 2016 Environmental Grant Program, $1,400, (April 2016 – December 2016)

Armstead, Mary M (Principal), "Marshall University's Statement of Work for Evaluation of Aquatic Community Health – Research includes mayfly culturing and testing and stream effects of watershed disturbance," Sponsored by ARIES, Private, $90,000.00. (June 30, 2015 - June 30, 2016).

Armstead, M.M. (Principal), "The influence of culture conditions and toxicity induction methods on toxin production in *Prymnesium parvum.*" Marshall University Emerging Areas, West Virginia EPSCor RII. $25,000. (August 2014 – June 2015).

Armstead, Mary M (Principal), "Marshall University's Statement of Work for Evaluation of Aquatic Community Health – Research includes mayfly culturing and testing and stream effects of watershed disturbance," Sponsored by ARIES, Private, $150,000.00. (June 30, 2014 - June 30, 2015).

Armstead, Mary M (Principal), "Marshall University's Statement of Work for Evaluation of Aquatic Community Health – Research includes mesocosm toxicity testing of benthic macroinvertebrates and mayfly culturing and testing," Sponsored by ARIES, Private, $125,000.00. (June 30, 2013 - June 30, 2014).

Armstead, M. M. (Principal), "Marshall University's Statement of Work for Completion of Tasks 1.5, 1.6, and 2.2.5," Sponsored by ARIES, Private, $102,634.00. (June 30, 2012 - June 30, 2013).

Armstead, M. M. (Principal), "Marshall University's Statement of Work for Completion of Tasks 1.5, 1.6, and 2.2.5," Sponsored by ARIES, Private, $49,984.00. (June 30, 2012 - June 30, 2013).

Armstead, M. M. (Principal), "Marshall University's Statement of Work for Completion of Tasks 1.5, 1.6, and 2.2.5," Sponsored by ARIES, Private, $72,359.00. (January 1, 2012 - June 30, 2012).

Armstead, M. M. (Supporting), "Assessing Geomorphic Reclamation in Valley Fill Design for West Virginia," Sponsored by Office of Surface Mining, Federal, $19,834.00. (May 1, 2012 – December 2014).

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White, D.S., S. Hendricks, M. Armstead, J. Fox, and B. Ford. May 2017. RII Track-2 FEC

Sensing and Educating the Nexus to Sustain Ecosystems (SENSE). A Kentucky-West Virginia Partnership. Award number: OIA-1632888. Reporting period dates: 1 August 2016 – 30 April 2017.

Armstead, M., Sweeten, S. (Multiple dates). Laboratory Investigation of the Effect of Conductivity on a Suite of Stream Organisms Found in the Coal Mining Regions of the United States: Amphibians, Benthic Macroinvertebrates and Fish. OSMRE-MU ADTI Cooperative Agreement, S16AC20026. Quarterly Reports for periods ending 9/30/2016, 12/31/2016, 3/31/2017.

Hopkins, L. Quaranta, J., Armstead, M. Hause, J., DePriest, N. 2014. Assessing Geomorphic Reclamation in Valley Fill Designs for WV. OSM Cooperative Agreement Number S12AC20020.

R01865

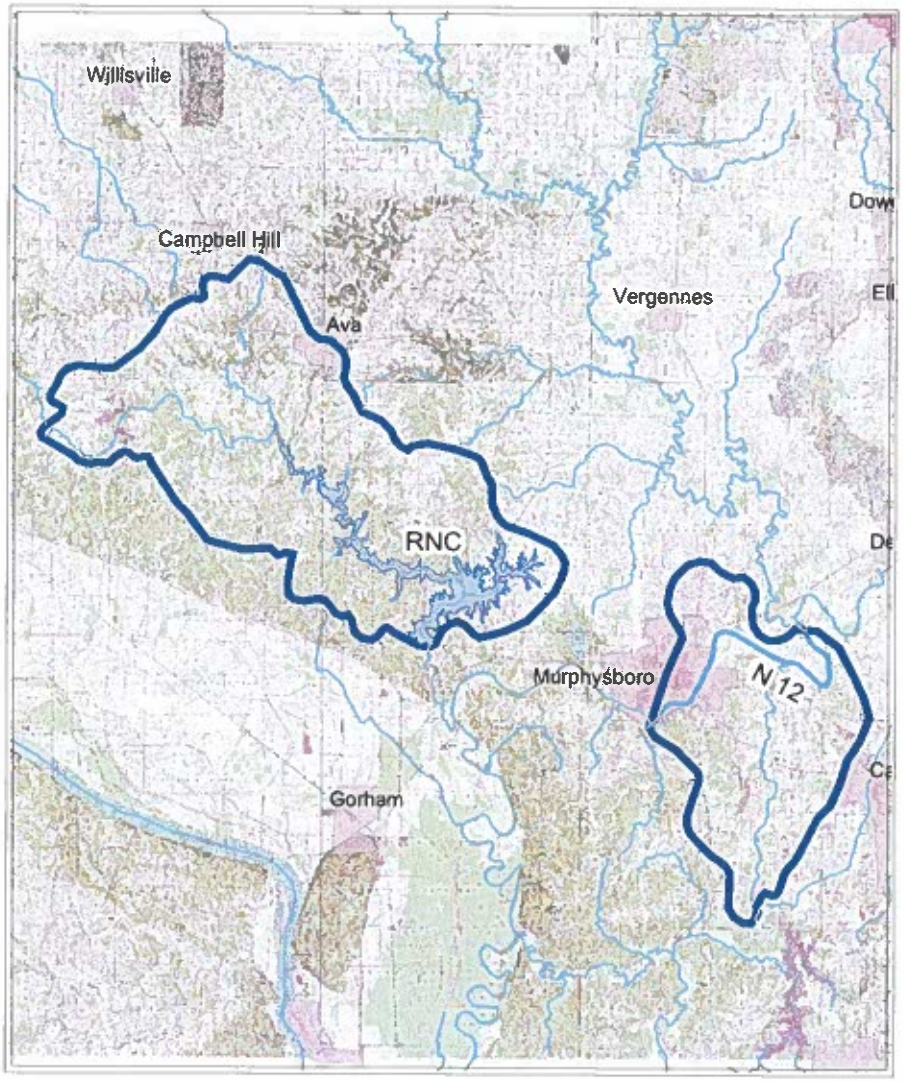
Illinois
Environmental
Protection Agency

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P.O. Box 19276
Springfield, IL 62794-9276

October 2004

IEPA/BOW/04-015

BIG MUDDY RIVER TMDL REPORT





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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

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REPLY TO THE ATTENTION OF
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Marcia Willhite, Chief
Bureau of Water
IEPA
P.O. Box 19276
1021 North Grand Avenue East
Springfield, Illinois 62794-9276

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has conducted a complete review of the final Total Maximum Daily Loads (TMDLs) for phosphorus, manganese, and sulfate, including supporting documentation, for the Big Muddy River watershed, located in Jackson County, Illinois. Based on this review, U.S. EPA has determined that Illinois's TMDLs for these waterbodies meets the requirements of Section 303(d) of the Clean Water Act (CWA) and U.S. EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, by this letter, U.S. EPA hereby approves three TMDLs for the Big Muddy River watershed as listed below:

Waterbody	Pollutant
Kinkaid Lake (RNC)	phosphorus
Big Muddy River (N12)	manganese, sulfate

The statutory and regulatory requirements, and U.S. EPA's review of Illinois's compliance with each requirement, are described in the enclosed decision document.

We wish to acknowledge Illinois's effort in these submitted TMDLs, and look forward to future quality TMDL submissions by the State of Illinois. If you have any questions, please contact Mr. Kevin Pierard, Chief of the Wetlands and Watersheds Branch at 312-886-4448.

Sincerely yours,

S/

Jo Lynn Traub
Director, Water Division

Enclosure

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Parameter changes for developing TMDLs

In May 2001, Illinois EPA entered into a contract with Camp Dresser & McKee to develop Total Maximum Daily Loads (TMDL) for Big Muddy River (N12) and Kinkaid Lake. In the 1998 Section 303(d) List, Big Muddy River (N12) was listed as impaired for the following parameters: Manganese, cyanide, sulfates, nitrogen, pH, siltation, low dissolved oxygen (DO), total dissolved solids (TDS), and total suspended solids (TSS). Kinkaid Lake was initially listed as impaired for: Manganese, mercury, phosphorus, nitrogen, siltation, low DO, TSS, excessive algal growth, and chlorophyll-a.

Since then, new data assessed in 2002 showed that Big Muddy River (N12) is now impaired for manganese, sulfates, pH, low DO, and TSS. The listing of cyanide as a cause of impairment for Big Muddy River (N12) was done so in error and should not have been listed as such. New data assessed in 2002 for Kinkaid Lake showed it is now impaired only for pH, mercury, and siltation.

Illinois EPA has since determined that at this time TMDLs will only be developed for those parameters with numeric water quality standards. These numeric water quality standards will serve as the target endpoints for TMDL development and provide a greater degree of clarity and certainty about the TMDL and implementation plans. As a result, the TMDL for Big Muddy River (N12) will only focus on the parameters of manganese, sulfates, pH, and low DO, for which numeric water quality standards exist. Likewise, the TMDL for Kinkaid Lake will only focus on the parameter of pH. While the impairment caused by mercury is acknowledged, a TMDL will not be developed for it at this time, as mercury contamination is considered to be an interstate and international issue caused primarily by air deposition.

Causes of impairment not based on numeric water quality standards will be assigned a lower priority for TMDL development. Pending the development of numeric water quality standards for these parameters, as may be proposed by the Agency and adopted by the Illinois Pollution Control Board, Illinois EPA will continue to work toward improving water quality throughout the state by promoting and administering existing programs and working toward creating new methods for treating these potential causes of impairment.

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Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	micrograms per liter
ALMP	Ambient Lake Monitoring Program
AMLRD	Abandoned Mined Lands Reclamation Division
AS	acute standard
AWQMN	Ambient Water Quality Monitoring Network
BMP	best management practice
BOD	biochemical oxygen demand
BOD_5	5-day biochemical oxygen demand
$CBOD_{20}$	20-day carbonaceous biochemical oxygen demand
$CBOD_5$	5-day carbonaceous biochemical oxygen demand
CCC	Commodity Credit Corporation
cfs	cubic feet per second
CO_2	carbon dioxide
CRP	Conservation Reserve Program
CS	chronic standard
CWA	Clean Water Act
DEM	Digital Elevation Model
DO	dissolved oxygen
EQIP	Environmental Quality Incentive Program
ET	evapotranspiration
FSA	Farm Service Agency
GIS	geographic information system
GWLF	Generalized Watershed Loading Function
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
ICLP	Illinois Clean Lakes Program
IDA	Illinois Department of Agriculture
IDNR	Illinois Department of Natural Resources
Illinois EPA	Illinois Environmental Protection Agency
IPCB	Illinois Pollution Control Board
ISWS	Illinois State Water Survey
KAWP	Kinkaid Area Watershed Project, Inc.
KDEP	Kentucky Department of Environmental Protection
kg/km^2-yr	kilograms per kilometer squared per year

LA	Load Allocation
LC	Loading Capacity
LTA	long-term average
MBI	Macroinvertebrate Biotic Index
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MOS	Margin of Safety
NASS	National Agricultural Statistics Service
NCSU	North Carolina State University
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service
NWIS	National Water Inventory System
PBT	persistent, bioaccumulative toxic (chemical)
PDEP	Pennsylvania Department of Environmental Protection
ppm	parts per million
SOD	sediment oxygen demand
SSRP	Streambank Stabilization and restoration Practice
STATSGO	State Soil Geographic (database)
STORET	Storage and Retrieval (USEPA database)
TDS	total dissolved solids
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geographical Survey
WERF	Water Environment Research Foundation
WHIP	Wildlife Habitat Incentives Program
WLA	Waste Load Allocation
WRP	Wetlands Reserve Program
WWTP	wastewater treatment plants

Executive Summary
Big Muddy River Watershed

TMDL Fact Sheet

Watershed Name:	Kinkaid Lake	Big Muddy River
Impaired Segments:	RNC	N12
Location:	Jackson County, Illinois	Jackson County, Illinois
Size:	2,350 acres at normal storage	8.0 miles
Primary Watershed Land Uses:	Forest, grassland, and agriculture	Forest, grassland, and agriculture
Criteria of Concern:	pH and Mercury	Manganese, sulfates, pH, and DO
Designated Uses Affected:	General use	General use
Environmental Indicators: ***General use and public and food processing water supply***	pH monitoring	Manganese, sulfates, pH and DO monitoring
Major Sources:	Nonpoint from agriculture	Potentially contaminated groundwater, stagnant stream conditions, elevated instream temperatures, and nonpoint source loading from agriculture
Loading Capacity:	13,983 pounds/year total phosphorus	Mn = 2,244 lbs/day Sulfate = 1,163,422 lbs/day pH = No Allocation DO = No allocation
Waste Load Allocation:	Zero; No point sources	No Allocation
Margin of Safety:	Implicit through conservative modeling; additional explicit of 10 percent	Implicit through data selected for development of TMDL; additional explicit of 10 percent

This Total Maximum Daily Load (TMDL) assessment for impaired water bodies in the Big Muddy River Watershed addresses the sources of water body impairments, reductions in source loading necessary to comply with water quality standards, and the implementation of procedures to mitigate the impairment.

A correlation between pH and total phosphorus was established for Kinkaid Lake, and modeling demonstrates a reduction of 43 percent total phosphorus necessary so that pH water quality standards can be achieved. Primary sources of phosphorus loading to Kinkaid Lake include runoff from agricultural lands. Procedures outlined in the implementation plan to decrease phosphorus loading to the lake include measures applied to the watershed to control nutrients in surface runoff and eroded sediment. Watershed controls include filter strips and wetlands to prevent phosphorus in surface runoff from reaching the lake, conservation tillage to decrease nutrient-rich soil erosion from agricultural fields, and development of nutrient management plans to ensure that excess phosphorus is not applied to agricultural fields.

The TMDLs for manganese and sulfates in Big Muddy River segment N12 was based on analyses performed in a Monte Carlo simulation. The simulation for manganese showed a manganese reduction of 70 percent necessary to achieve water quality standards. Results of the Monte Carlo simulation for sulfates showed a 62 percent reduction for segment N12 necessary to achieve the water quality standard. The

potential source of manganese and sulfates in the Big Muddy River Watershed is contaminated groundwater. The groundwater is potentially contaminated by abandoned coal mines; however, further source identification is recommended. Confirmation that abandoned mines are a source of manganese and sulfates in the watershed would require reclamation of the mines. Passive treatment for mine reclamation is recommended.

The TMDL analysis for DO in Big Muddy River segment N12 was made through investigation of the relationship between DO, total organic carbon (TOC), 5-day biochemical oxygen demand (BOD5), and reaeration in the creek. The likely source of DO impairments in the segment is primarily a lack of aeration caused by stagnant stream conditions and elevated instream temperatures. BOD loadings in runoff from nonpoint source loads may also contribute to DO impairments. However, examination of BOD in the stream segment showed that the concentrations of BOD are low and likely represent ambient conditions in the stream; therefore, reductions in BOD concentrations are not recommended at this time. Due to data limitations and technical considerations of implementation difficulties, a load allocation cannot be developed for reaeration or temperature, so allocations were not developed for segment N12. Procedures to alleviate low DO caused by slow-moving waters can be addressed with in-stream mitigation methods such as reaeration. Additionally, riparian buffer strips aid in decreasing instream temperatures, which could help to alleviate the DO impairment. Excess nutrients can cause excessive algal growth that can also deplete DO in streams; however, analytical tools were not used to assess nutrients, algae, and DO as no algal data was available for Big Muddy River segment N12. Methods to control nutrients were still included in the implementation plan, such as buffer strips along the stream banks, which are similar to filter strips in their ability to remove nutrients from surface runoff. The potential contributions to BOD from nonpoint source loads are attributed to agricultural land uses requiring mitigation methods to control nutrients in sediment erosion and surface runoff from the land contributing to segment N12. These methods include filter strips, wetlands, conservation tillage, and nutrient management plans as discussed above.

The analysis for pH was based on hydrogen ion concentrations and the three-year flow observed in Big Muddy River segment N12. Analysis showed that the existing average hydrogen ion concentration was below the allowable loading, so allocations were not developed for pH in segment N12 at this time. Although an allocation was not developed, mitigation measures for manganese, sulfates, and DO will help control pH in Big Muddy River segment N12.

Section 1
Goals and Objectives for Big Muddy River Watershed (ILN12)

1.1 Total Maximum Daily Load (TMDL) Overview

A Total Maximum Daily Load, or TMDL, is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. TMDLs are a requirement of Section 303(d) of the Clean Water Act (CWA). To meet this requirement, the Illinois Environmental Protection Agency (Illinois EPA) must identify water bodies not meeting water quality standards and then establish TMDLs for restoration of water quality. Illinois EPA lists water bodies not meeting water quality standards every two years. This list is called the 303(d) list, and water bodies on the list are then targeted for TMDL development.

In general, a TMDL is a quantitative assessment of water quality problems, contributing sources, and pollution reductions needed to attain water quality standards. The TMDL specifies the amount of pollution or other stressor that needs to be reduced to meet water quality standards, allocates pollution control or management responsibilities among sources in a watershed, and provides a scientific and policy basis for taking actions needed to restore a water body (U.S. Environmental Protection Agency [USEPA] 1998a).

Water quality standards are laws or regulations that states authorize to enhance water quality and protect public health and welfare. Water quality standards provide the foundation for accomplishing two of the principal goals of the CWA. These goals are:

- restore and maintain the chemical, physical, and biological integrity of the nation's waters,
- where attainable, to achieve water quality that promotes protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water.

Water quality standards consist of three elements:

- the designated beneficial use or uses of a water body or segment of a water body,
- the water quality criteria necessary to protect the use or uses of that particular water body,
- an antidegradation policy.

Examples of designated uses are swimming, recreation, and protection of aquatic life. Water quality criteria describe the quality of water that will support a designated use. Water quality criteria can be expressed as numeric limits or as a narrative statement.

Antidegradation policies are adopted so that water quality improvements are conserved, maintained, and protected.

1.2 TMDL Goals and Objectives for Big Muddy River Watershed

The TMDL goals and objectives for the Big Muddy River Watershed include developing TMDLs for all impaired water bodies within the watershed, describing all of the necessary elements of the TMDL, developing an implementation plan for each TMDL, and gaining public acceptance of the process. Following are the impaired water body segments in the Big Muddy River Watershed, which are also shown in Figure 1-1:

- Big Muddy River (N12)
- Kinkaid Lake (RNC)

The TMDL for each of the segments listed above will specify the following elements:

- Loading Capacity (LC) or the maximum amount of pollutant loading a water body can receive without violating water quality standards
- Waste Load Allocation (WLA) or the portion of the TMDL allocated to existing or future point sources
- Load Allocation (LA) or the portion of the TMDL allocated to existing or future nonpoint sources and natural background
- Margin of Safety (MOS) or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality

These elements are combined into the following equation:

$$\mathbf{TMDL = LC = \Sigma WLA + \Sigma LA + MOS}$$

Each TMDL developed must also take into account the seasonal variability of pollutant loads so that water quality standards are met during all seasons of the year. Also, reasonable assurance that the TMDLs will be achieved is described in the implementation plan. The implementation plan for the Big Muddy River Watershed describes how water quality standards will be attained. This implementation plan includes recommendations for implementing best management practices (BMP), cost estimates, institutional needs to implement BMPs and controls throughout the watershed, and timeframe for completion of implementation activities.

1.3 Report Overview

The remaining sections of this report contain:

- **Section 2 Big Muddy River Watershed Description** provides a description of the impaired water bodies and general watershed characteristics.
- **Section 3 Public Participation and Involvement** discusses public participation activities that occurred throughout the TMDL development.
- **Section 4 Big Muddy River Watershed Water Quality Standards** defines the water quality standards for the impaired water bodies. Pollution sources will also be discussed in this section.
- **Section 5 Big Muddy River Watershed Data Review** provides an overview of available data for the Big Muddy River Watershed.
- **Section 6 Methodologies to Complete TMDLs for the Big Muddy River Watershed** discusses the models and analyses needed for TMDL development.
- **Section 7 Model Development for Kinkaid Lake** provides an explanation of model development for Kinkaid Lake.
- **Section 8 Total Maximum Daily Load for the Kinkaid Lake Watershed** discusses the allowable loadings to water bodies to meet water quality standards and the reduction in existing loadings needed to meet allowable loads.
- **Section 9 Implementation Plan for Kinkaid Lake** provides methods to reduce loadings to impaired water bodies.
- **Section 10 Methodology Development for Big Muddy River** describes the analytical procedures used to examine Big Muddy River.
- **Section 11 Total Maximum Daily Load for Big Muddy River** discusses the allowable loadings to water bodies to meet water quality standards and the reduction in existing loadings needed to meet allowable loads.
- **Section 12 Implementation Plan for Big Muddy River** provides methods to reduce loadings to impaired water bodies.
- **Section 13 References** lists references used in this report.

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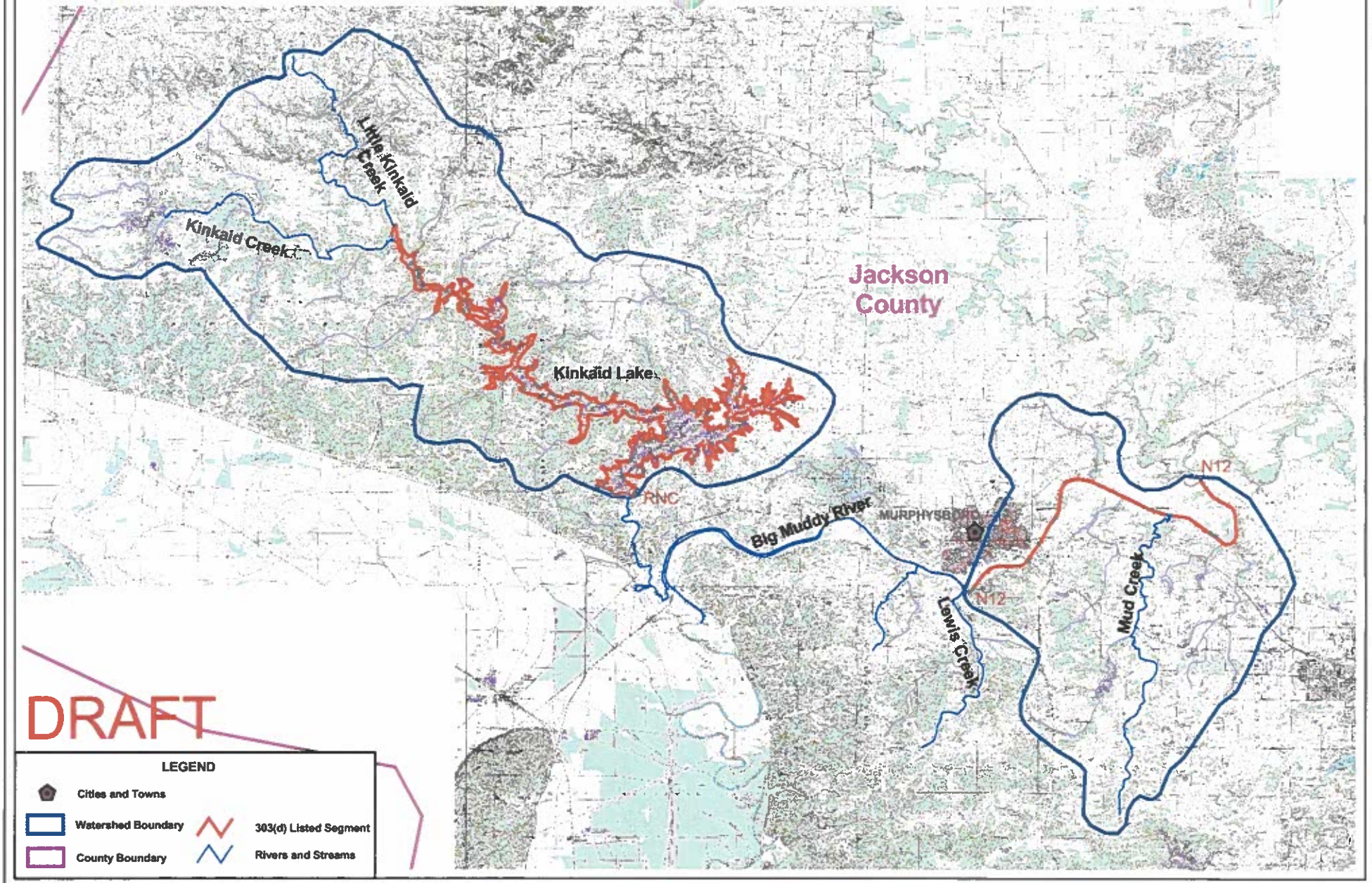


Figure 1-1
Big Muddy River #1 Watershed (ILN12)
Impaired Water Bodies
CDM

iepa/gis_data/apr/bigmuddy1.apr 032903

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Section 2
Big Muddy River Watershed Description

2.1 Big Muddy River Watershed Overview

The Big Muddy River originates in Jefferson County and flows southward. It then flows west towards Kinkaid Lake in Jackson County. Kinkaid Lake is located in Jackson County where the flow moves east towards the Big Muddy River. Big Muddy River segment N12 is located entirely in Jackson County. The entire Big Muddy River watershed, including Kinkaid Lake and all tributaries to Big Muddy River, encompasses an area of approximately 200 square miles and is located in the U.S. Geological Survey (USGS) Big Muddy Basin (Hydrologic Unit Code [HUC] 07140106). Figure 1-1 shows the impaired river and lake segments within the watershed. Impaired segments are shown in red. Table 2-1 lists the water body segments, water body size, and potential causes of impairment for each water body.

Table 2-1 Impaired Water Bodies in Big Muddy River Watershed

Water Body Segment ID	Water Body Name	Size	Potential Causes of Impairment
N12	Big Muddy River	8 miles	Manganese, sulfates, pH, dissolved oxygen (DO)
RNC	Kinkaid Lake	3,475 acres	pH, mercury

Land use data was obtained from the Critical Trends Assessment Land Cover Database of Illinois (Illinois Department of Natural Resources [IDNR] 1996). Land use in the watershed is predominantly forested followed by rural grassland and agricultural land uses. Farmers in the area primarily raise cash crops, such as corn and soybeans.

Soils within the Big Muddy River Watershed are primarily silty soils over clayey sediment. The surface layer is typically seven inches of dark grayish brown silt loam. The subsurface layer is about five inches of light brownish silt loam. The subsoil is a grayish silty clay loam that extends to a depth of more than 60 inches. Permeability is slow, and the available water capacity is moderate to high (U.S. Department of Agriculture [USDA] 1979).

The climate in Big Muddy River Watershed is cold in the winter and warm in the summer. In the winter, October through March, the average temperature is 43 degrees Fahrenheit (°F) and the average daily minimum temperature is 32°F, according to data collected at DuQuoin, Illinois. Summer temperatures are typically 70°F with an average daily maximum of 82°F. Annual precipitation is 46 inches, of which 25 inches, approximately 54 percent, usually falls in April through September (NCDC 2002).

2.2 Stream Segment Site Reconnaissance of Big Muddy River Watershed

The project team conducted a site reconnaissance of the Big Muddy River Watershed on June 19, 2001. This section briefly describes the stream segment and the site reconnaissance.

Table 2-1 lists the impaired stream segments in the Big Muddy River Watershed. Based on the 1998 303(d) list, Illinois EPA determined that one segment of Big Muddy River was impaired, Segment N12. This segment is shown in Figure 1-1. Segment N12 flows from roughly east to west, and includes a large bend to the south. The segment is located entirely in Jackson County, Illinois.

2.3 Lake Segment Site Reconnaissance of Big Muddy River Watershed

The project team visited one site on Kinkaid Lake during the site reconnaissance of the Big Muddy River Watershed on June 19, 2001. This section briefly describes a lake segment and the site reconnaissance.



Kinkaid Lake at Illinois Rt. 151 crossing.

Illinois EPA has listed one lake segment as impaired based on 1998 303(d) list data in the Big Muddy River Watershed. Kinkaid Lake, Segment RNC, is located on Kinkaid Creek in eastern Jackson County as shown in Figure 1-1. Crissenberry Dam was constructed on Kinkaid Creek in 1972. The dam is owned by the IDNR. The dam structure is 980 feet in length and 96 feet tall enabling it to store a maximum of 153,000 acre-feet, although the normal storage volume is 78,500 acre-feet. The lake is used for both recreation and a water supply (U.S. Army Corps of Engineers [USACE] 1999). The drainage area of Kinkaid Lake is approximately 62 square miles and is fed by Kinkaid, Little Kinkaid, Spring and Johnson Creeks.

Kinkaid Lake was observed from the Boat Access at Marina Road. The spillway was also observed, although the lake was not visible from the bottom of the spillway. Kinkaid Lake is a recreational area with both boating and swimming. A marina houses several boats at the lake. The spillway from Kinkaid Lake is a natural rock formation with a few enhancements, and was busy with swimmers and anglers at the time of observation.



Kinkaid Lake spillway.

Section 3
Public Participation and Involvement

3.1 Big Muddy River Watershed Public Participation and Involvement

Public knowledge, acceptance, and follow through are necessary to implement a plan to meet recommended TMDLs. It was important to involve the public as early in the process as possible to achieve maximum cooperation and counter concerns as to the purpose of the process and the regulatory authority to implement the recommendations. Public meetings were held to discuss the Big Muddy River Watershed at 3:00 p.m. and 6:20 p.m. on December 12, 2001 at the Davis McCann Center in Murphysboro, Illinois. A total of 44 interested citizens including public officials and organizations other than Illinois EPA attended the public meeting.

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Section 4
Big Muddy River Watershed Water Quality Standards

4.1 Illinois Water Quality Standards

Water quality standards are developed and enforced by the state to protect the "designated uses" of the state's waterways. In the state of Illinois, setting the water quality standards is the responsibility of the Illinois Pollution Control Board (IPCB). Illinois is required to update water quality standards every three years in accordance with the CWA. The standards requiring modifications are identified and prioritized by Illinois EPA, in conjunction with USEPA. New standards are then developed or revised during the three-year period.

Illinois EPA is also responsible for developing scientifically based water quality criteria and proposing them to the IPCB for adoption into state rules and regulations. The Illinois water quality standards are established in the Illinois Administrative Rules Title 35, Environmental Protection; Subtitle C, Water Pollution; Chapter I, Pollution Control Board; Part 302, Water Quality Standards.

4.2 Designated Uses

The waters of Illinois are classified by designated uses, which include: General Use, Public and Food Processing Water Supplies, Lake Michigan, and Secondary Contact and Indigenous Aquatic Life Use (Illinois EPA 2000). The only designated uses applicable to the Big Muddy River are General Use.

The General Use classification provides for the protection of indigenous aquatic life, primary and secondary contact recreation (e.g., swimming or boating), and agricultural and industrial uses. The General Use is applicable to the majority of Illinois streams and lakes (Illinois EPA 2000).

4.3 Illinois Water Quality Standards

To make 303(d) listing determinations, Illinois EPA compares collected data for the water body to the available water quality standards developed by Illinois EPA for assessing water body impairment. Table 4-1 presents the water quality standards of the potential causes of impairment for TMDLs that will be developed in the Big Muddy River Watershed. These water quality standards are further discussed in the remainder of the section.

Table 4-1 Summary of General Use Water Quality Standards for Big Muddy River Watershed

Parameter	General Use Water Quality Standard
pH	6.5 to 9.0
DO	Greater than 5.0 milligrams per liter (mg/L) Greater than 6.0 mg/L (16 hours of any 24-hour period)
Phosphorus	0.05 mg/L Lakes/reservoirs >20 acres and streams entering lakes or reservoirs
Mercury	AS = 2.6 micrograms per liter (µg/L) CS = 1.3 µg/L
Manganese	1.0 mg/L
Sulfates	500 mg/L

4.3.1 pH

The parameter pH is listed as a cause of impairment for the Big Muddy River segment N12. The General Use water quality standard for pH is a range with a minimum of 6.5 and maximum of 9.0. This is with the exception of pH levels outside this range due to natural causes.

The pH parameter is listed as a cause of less than full support use attainment in streams if there is at least one General Use water quality violation based on the last three years of Ambient Water Quality Monitoring Network (AWQMN) data, or at least one violation determined from the most recent basin survey or facility survey data. The AWQMN is a series of fixed stations throughout Illinois streams that are sampled every six weeks for a minimum of 55 parameters. Segments without AWQMN stations are sampled as part of the intensive basin survey, which occurs every five years.

4.3.2 Dissolved Oxygen

DO is listed as a cause of impairment for Big Muddy River and Kinkaid Lake. The General Use water quality standard for DO is based on a minimum value of 5.0 mg/L. Therefore, DO levels shall not be less than 5.0 mg/L at any time. In addition, DO levels should not be less than 6.0 mg/L for more than 16 hours of any 24-hour period.

DO is listed as a cause of less than full support use attainment in streams if there is at least one General Use water quality violation based on the last three years of AWQMN data or at least one violation determined from the most recent basin survey or facility survey data. DO is a source of impairment in lakes and reservoirs if there is at least one General Use water quality violation based on Ambient Lake Monitoring Program (ALMP), or Illinois Clean Lakes Program (ICLP) data, or if there was a known fish kill due to DO depletion.

4.3.3 Mercury

Mercury is listed as a cause of impairment for Kinkaid Lake. The General Use water quality standard for mercury is based on an acute standard (AS) and chronic standard (CS). The AS for mercury is 2.6 µg/L and the CS is 1.3 µg/L.

Mercury is listed as a cause of less than full support use attainment in lakes and reservoirs if there is at least one General Use water quality violation based on ALMP or ICLP data. Mercury is also listed as a cause of less than full support if the sediment concentration is 0.701 milligrams per kilogram (mg/kg) or higher based on dry weight, or if there have been fish advisory reports due to mercury.

4.3.4 Manganese

Manganese is listed as a cause of impairment for Big Muddy River segment N12. The General Use water quality standard for manganese is 1.0 mg/L and is based on total manganese. Manganese is listed as a cause of less than full support use attainment in streams if there is at least one General Use water quality violation based on the last three years of AWQMN data, or at least one violation determined from the most recent basin survey or facility survey data. Manganese is also listed as a cause of less than full support if there have been fish advisory reports due to manganese or the manganese concentration in the sediment is 2,800 mg/kg or higher (Illinois EPA 2000).

Manganese is listed as a cause of less than full support use attainment in lakes or reservoirs if there is at least one General Use water quality violation based on ICLP, or if the sediment concentration exceeds 2,800 mg/kg (M.B. Short 1997).

4.3.5 Sulfates

Sulfates are listed as a cause of impairment for the Big Muddy River. The General Use water quality standard for sulfates is 500 mg/L and the public and food processing water supplies standard is 250 mg/L. Sulfate is listed as a cause of a less than full support use attainment in streams if there is at least one General Use water quality violation based on the last three years of AWQMN data, or at least one violation from the most recent basin survey or facility survey data.

4.3.6 Parameters without Water Quality Standards

It should be noted that although formal TMDLs will not be developed for parameters without water quality standards in the Little Muddy River Watershed, many of the management measures discussed in Section 9 of this report will result in reductions of the parameters listed in the 1998 and 2002 303(d) lists that do not currently have adopted water quality standards. For example, many of the management measures that will be discussed in Section 9 address the other parameters of concern for the watershed. For total suspended sediments (TSS) and siltation management measures that control erosion, such as filter strips and wetlands, will reduce sediment from entering the waterways thereby reducing TSS caused by eroding stream banks.

4.4 Pollution Sources

As part of the Illinois EPA use assessment presented in the annual Illinois Water Quality Report, the causes of the pollutants resulting in a less than full support use attainment are associated with a potential source, based on data, observations, and other existing information. The following is a summary of the sources associated with the listed causes for the TMDL listed segments in this watershed. They are summarized in Table 4-2.

Table 4-2 Summary of Potential Sources of Pollutants

Potential Source	Cause of Impairment
Municipal Point Source	DO
Agriculture Nonirrigated crop production Pasture Land Animal Holding/Management Areas	DO
Resource Extraction Mining Mine Tailings	Sulfates pH Mercury Manganese
Contaminated Sediments	Mercury Manganese DO
Urban Runoff/Storm Sewers	DO

4.4.1 Municipal Point Sources

Municipal point sources include wastewater treatment plants (WWTP) operated by municipalities to treat municipal wastewater generated by the community. A National Pollutant Discharge Elimination System (NPDES) permit issued by Illinois EPA regulates the discharge. The NPDES permit sets limits that must be met at the discharge to the receiving stream.

Historically, these point sources have impacted water quality of the receiving streams, particularly during low flow conditions. Many municipal WWTPs have upgraded the facilities through grant and low-interest loan programs, thereby improving effluent quality and reducing impacts to the receiving stream.

Municipal point source effluents are typically regulated for ammonia nitrogen and biochemical oxygen demand (BOD). BOD is associated with oxygen demand. The higher the BOD, the more likely the effluent is to reduce the DO levels in the stream.

Phosphorous can be attributed to municipal point sources and can originate from domestic sources. Control of phosphorous entering the stream may reduce the amount of algal growth/chlorophyll "a" in the stream.

There are a total of 186 NPDES permits issued to dischargers in the Big Muddy River basin. A total of nine WWTPs discharge to the Big Muddy River mainstem, all downstream of Rend Lake. Four of these dischargers are considered major municipal dischargers (design average flow greater than one million gallons per day) (Muir et al. 1997). The point sources specific to the Big Muddy River N12 and Kinkaid Lake watersheds are discussed in Section 5.

4.4.2 Agriculture

The southern Illinois area is largely agriculture land use. Row crop agriculture is the largest single category land use in the basin. Agricultural land uses potentially contribute sediment, TSS, nutrients, and BOD loads to the water resource loading. The amount that is contributed is a function of the soil type, slope, crop management,

precipitation, total amount of cropland, and the distance to the water resource (D.B. Muir, R.L. Hite, M.M. King, and M.R. Matson 1995).

Erosion of the land and streambanks carries sediment to the streams and lakes, resulting in higher levels of BOD, which impacts DO concentrations, TSS, and siltation. This can also be caused by livestock on pastures and feedlots. Wastes from livestock can enter streams, adding to the ammonia nitrogen loading and impact DO.

4.4.3 Resource Extraction

Resource extraction consists of both active mining and abandoned mine lands. Runoff and discharges from mines can contain sulfates, salinity/total dissolved solids (TDS)/ chlorides, metals, TSS, and can affect the pH of the stream or lake. There are currently 47 permitted coal mines with 169 authorized discharges in the Big Muddy River basin. In addition, 1,177 inactive or abandoned mines have been identified. There are 4 pre-law inactive coal mines located in the Big Muddy River segment N12 Watershed and no permitted mines within the Kinkaid Lake Watershed. Mining is most concentrated in Beaucoup Creek, Galum Creek, Little Muddy River, Pond Creek, Hurricane Creek, and Rend Lake watersheds (Muir et al. 1997).

Drainage from the mines can be impacted by contact with exposed soil, spoil piles, or pumped water from pits. Acid mine drainage occurs when water and oxygen come in contact with iron pyrite material. This combination makes ferrous iron and sulfuric acid, creating acidic runoff and impacting the stream pH. Although acid mine drainage may come from active mines, most acid mine drainage entering streams is from abandoned mine lands.

4.4.4 Contaminated Sediments

Sediments are carried to streams, lakes, and reservoirs during runoff conditions and are generally deposited in streambeds or lake bottoms. Constituents contained in sediment may include nutrients, which can impact BOD loads, and metals. Both agricultural lands and urban areas contribute to the nutrient loading in the sediment.

Suspended sediments settle out to stream bottoms during periods of low flow. During periods of high flow, sediments are resuspended and carried downstream to be deposited in another location. Once the sediment reaches a lake or reservoir, the sediments are deposited and typically accumulate in these areas. The source of the contaminated sediment can therefore be located much farther upstream than the location detected.

Contaminated sediments can slowly leach contaminants to the water column, thereby being a continual source of impact to the water body. Phosphorous is commonly released from sediment into the water column especially when anoxic conditions persist.

4.4.5 Urban Runoff/Storm Sewers

Urban areas in the Big Muddy River Watershed constitute a small percentage of land use in the watershed; however, polluted runoff from urban sections can be significant. Runoff from urban areas reaches streams or lakes either by sheet flow runoff or through storm sewer discharges. The runoff can originate from any number of areas including highways; roadways; parking lots; industrial, commercial, or residential areas; or undeveloped lands. Phosphorous, which can influence BOD loads, can originate from fertilizer use, natural phosphorous levels in sediment, and from sanitary waste where combined sewer overflows are present.

Section 5
Big Muddy River Watershed Data Review

5.1 Existing Data Review

The following data sources were reviewed for model selection and analysis:

- mapping data
- topography data
- flow data
- precipitation data
- temperature data
- evaporation data
- existing water quality data
- land use
- soil data
- cropping practices
- reservoir characteristics
- point sources
- dairy and animal confinement locations
- septic systems

5.1.1 Mapping Data

USGS quadrangle maps (scale 1:24,000) were collected for the watershed in paper and electronic form. These were utilized for base mapping.

5.1.2 Topography Data

A Digital Elevation Model (DEM) was used to delineate watersheds in a geographic information system (GIS) for Kinkaid Lake and Big Muddy River impaired segment N12. A DEM is a digital representation of the landscape as a GIS-compatible grid in which each grid cell is assigned an elevation. DEMs of 90-meter resolution were downloaded from the *BASINS* database (USEPA 2002a) for watershed delineation. GIS watershed delineation defines the boundaries of a watershed by computing flow directions from elevations and locating elevation peaks on the DEM. The GIS-delineated watershed was checked against USGS 7.5-minute topographic maps to ensure agreement between the watershed boundaries and natural topographic boundaries. Figure 5-1 at the end of this section shows the location of historic flow and water quality gages for the Kinkaid Lake segment RNC and Big Muddy River segment N12 Watersheds and the boundaries for each watershed. The watershed boundaries define the area investigated for causes of impairments in each segment. Purple areas in Figure 5-1 represent features of the topographic maps that have been updated through aerial photography but have not been field verified.

The watershed for segment N12 only represents the area that drains directly to segment N12. Beaucoup Creek converges with the main stem of the Big Muddy River directly

upstream of segment N12. The Big Muddy River segment directly downstream of segment N12 is also listed as full support. Sources of impaired constituents in Beaucoup Creek segment NC07 (upstream of segment N12) will be addressed separately. Therefore, the sources of impairments in segment N12 will focus on areas draining directly to the segment.

5.1.3 Flow Data

Analyses of the Kinkaid Lake and Big Muddy River Watersheds require an understanding of flow into Kinkaid Lake and through the Big Muddy River segment N12. A gage is located in segment N12; however, no gage for the tributaries to Kinkaid Lake exists. Therefore, the drainage area ratio method, represented by the following equation, was used to estimate flows into the lake.

$$Q_{gaged}\left(\frac{Area_{ungaged}}{Area_{gaged}}\right) = Q_{ungaged}$$

where Q_{gaged} = streamflow of the gaged basin
$Q_{ungaged}$ = streamflow of the ungaged basin
$Area_{gaged}$ = area of the gaged basin
$Area_{ungaged}$ = area of the ungaged basin

The assumption behind the equation is that the flow per unit area is equivalent in watersheds with similar characteristics. Therefore, the flow per unit area in the gaged watershed times the area of the ungaged watershed will result in a flow for the ungaged watershed.

USGS gage 05595820 (Casey Fork at Mt. Vernon, Illinois) was chosen as an appropriate gage from which to compute flow into Kinkaid Lake. Gage 05595820 captures flow from a drainage area of 77 square miles in an upstream section of the Casey Fork Watershed, which is about 50 miles northeast of the Kinkaid Lake Watershed. Daily streamflow data for the gage were downloaded from the USGS National Water Inventory System (NWIS) for the entire period of record from October 1, 1985 to September 30, 2000 (USGS 2002a). Figure 5-2 at the end of this section shows the average monthly flows over the period of record into Kinkaid Lake calculated from the drainage area ratio method using gage 05595820.

USGS gage 05599500 (Big Muddy River at Murphysboro, Illinois) is located at the downstream end of segment N12 as shown in Figure 5-1. Gage 05599500 captures flow from a drainage area of approximately 2,169 square miles. Daily streamflow data for the gage were downloaded from the USGS NWIS for the entire period of record from January 1, 1972 to September 30, 2000 (USGS 2002a). Figure 5-3 at the end of this section shows the seasonal patterns of streamflow through segment N12 over the period of record. Flows are higher in the spring months of March through May. For Big Muddy River segment N12, average monthly flows range from 403 to 4,180 cubic feet per second (cfs) with a mean annual flow of 2,080 cfs. The 7Q10 flow

(lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years) is typically utilized as the critical low flow for NPDES permitting and is estimated to 55 cfs for segment N12 (ISWS 2000).

5.1.4 Precipitation, Temperature, and Evaporation Data

Two sites with historical temperature and precipitation data were identified in Jackson County through the NCDC database. The data from gage 1265 were used for analysis because the recent dataset was more complete than the data set from gage 5983. Fifteen months of data were missing from gage 1265 over the period from 1985 to 2001. Missing data were supplemented with data from the gage in neighboring Williamson County. Table 5-1 lists the station details for the Jackson County and Williamson County gages (NCDC 2002).

Table 5-1 Historical Precipitation Data for the Big Muddy River Watershed (NCDC 2002)

NCDC Gage Number	Station Location (Name)	Period of Record
5983	Jackson County (Murphysboro 2SW)	1948 to present
1265	Jackson County (Carbondale Sewage Plant)	1970 to present
5342	Williamson County (Marion 4NNE)	1948 to present

Table 5-2 Average Monthly Precipitation in Jackson County from 1985 to 2001

Month	Average Precipitation (inches)
January	3.2
February	3.2
March	3.6
April	4.5
May	4.9
June	5.3
July	3.0
August	3.5
September	3.5
October	3.1
November	4.8
December	3.5
Total	**46**

Table 5-2 shows the average monthly precipitation of the dataset developed for Jackson County for the years 1985 to 2001. The average annual precipitation over the same period is approximately 46 inches.

Pan evaporation data is available through the Illinois State Water Survey (ISWS) website at nine locations across Illinois (ISWS 2002). The Carlyle station was chosen for its proximity to the 303(d)-listed water bodies and stream segments in southern Illinois and the completeness of the dataset as compared to other stations. The Carlyle station is approximately 60 miles northeast of the Kinkaid Lake and Big Muddy River Watersheds. The average monthly pan evaporation for the years 1980 to 2001 at the Carlyle station was downloaded from the ISWS website and summed to produce an average annual pan evaporation of 44.2 inches. Actual evaporation is typically less than pan evaporation, so the average annual pan evaporation was multiplied by 0.75 to calculate an average annual evaporation of 33.2 inches (ISWS 2002).

5.1.5 Water Quality Data

Twelve historic water quality stations exist within the Kinkaid Lake and Big Muddy River segment N12 watersheds and are presented in Table 5-3. This table provides the

location, station identification number, and the agency that collected the water quality data. Location and station identification number are also shown in Figure 5-1.

Table 5-3 Historic Water Quality Stations in the Big Muddy River Watershed

Location	Station Identification Number	Data Collection Agency
Big Muddy River	N12	Illinois EPA Division of Water Pollution Control
Big Muddy River	05599500	USGS
Kinkaid Lake	05599540 RNC-1	USGS Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-2	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-3	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-4	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-5	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-6	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-7	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-8	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-9	USEPA Region 5 Data

The impaired water body segments in the Big Muddy River Watershed were presented in Section 2. For Kinkaid Lake, segment RNC, there are 10 historic water quality stations. For Big Muddy River segment N12 there are two historic water quality stations listed in Table 5-3 and shown in Figure 5-1. The Kinkaid Lake stations beginning with "RN" have a concurrent period of record. Stations RN-A08-C-1 and 05590540 are positioned in the same place in Kinkaid Lake and have overlapping periods of record. The two stations in segment N12 are also located in the same place, but have different sampling periods. Table 5-4 summarizes available historic water quality data since 1990 from the USEPA *Storage and Retrieval (STORET)* database associated with impairments discussed in Section 2 for segments RNC and N12. Stations RNC-5 through RNC-9 are not included in Table 5-4 because their periods of record ended prior to 1990. Illinois volunteer lake monitoring data was not utilized in modeling efforts.

Table 5-4 Summary of Constituents Associated with Potential Impairments for Big Muddy River Segments N12 and RNC (USEPA 2002b and Illinois EPA 2002)

Sample Location and Parameter	Period of Record Examined for Samples	Number of Samples
Big Muddy River Segment N12; Sample Location 05599500		
Manganese	1/9/90-4/24/97	51
Sulfates	1/9/90-4/24/97	65
pH	1/9/90-4/24/97	102
DO	1/9/90-4/24/97	102
Big Muddy River Segment N12; Sample Location N12		
Manganese	10/27/97-9/6/00	27
Sulfates	11/20/97-9/6/00	25
pH	10/27/97-9/6/00	27
DO	10/27/97-9/6/00	27
Kinkaid Lake Segment RNC; Sample Location 05599540, RNC-1, RNC-2, RNC-3, RNC-4		
05599540		
pH	1/08/90-8/28/97	70
RNC-1		
pH	4/30/90-10/11/01	52
RNC-2		
pH	4/30/90-10/11/01	25
RNC-3		
pH	4/30/90-10/11/01	25
RNC-4		
PH	4/30/90-10/11/01	25

5.1.5.1 Kinkaid Lake Water Quality Data

There are four active water quality stations in Kinkaid Lake as shown in Figure 5-1 and listed in Table 5-4. The water quality station data for Kinkaid Lake were downloaded from the *STORET* online database for the years of 1977 to 1998 (USEPA 2002b). Data collected after 1998 were available from the Illinois EPA and were incorporated into the electronic database. The data summarized in this section include water quality data for impaired constituents in Kinkaid Lake as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

The constituents of concern in Kinkaid Lake are pH and mercury. The mercury TMDL will be addressed in a regional TMDL by USEPA and will not be addressed at the state level. The regional TMDL will focus on air deposition of mercury. USEPA's strategy for addressing persistent, bioaccumulative toxic chemicals (PBT) is a two-track approach. The "fast track" involves actions that can be implemented immediately, including pollution prevention and the "virtual elimination" project. The "science track" includes the study and assessment of the problems and solutions through modeling, monitoring, and emission inventories. The "virtual elimination" project, a cooperative Canadian – U.S. strategy to virtually eliminate persistent toxic substances in the Great Lakes Basin (the Bi-national Strategy), seeks to achieve quantifiable reduction goals between now and 2005 for specific toxic substances, including mercury (USEPA 2003). Mercury is addressed by USEPA with these strategies; therefore, Illinois EPA does not address it as part of this TMDL.

Constituents are sampled at various depths throughout Kinkaid Lake, and compliance with water quality standards is determined by the sample at a one-foot depth from the lake surface. This section discusses the one-foot depth samples of water quality constituents used in modeling efforts for Kinkaid Lake. The exception is chlorophyll "a," which was sampled at various depths at each water quality station and will be presented as an average over all sample depths. Modeling of the reservoir required use of phosphorus samples at all depths, which is discussed and presented in Section 7.3.3.2.

5.1.5.1.1 pH

The average pH measurements at one-foot depth for each year of available data after 1990 at each monitoring site in Kinkaid Lake are presented in Table 5-5. At station RNC-1, samples were taken at one-foot depth from the lake surface and at the lake bottom. Samples at stations RNC-2, RNC-3, and RNC-4 were only taken at a one-foot depth from the lake surface. The TMDL endpoints for pH are a minimum of 6.5 and a maximum of 9.0. The annual averages at all three stations and the annual lake averages are all within the endpoint limits, but individual measurements in 1991, 1994, and 2000 exceeded the upper limit. Specifically, the pH value at station RNC-3 on July 9, 1991 was 9.1, and on July 12, 1994, the pH value was 9.1 at RNC-1. On June 5, 2000 and August 2, 2000, the pH value measured was 9.2 at RNC-1 and RNC-3, respectively. At gage 05599540, three values were below the lower limit for pH. On September 25, 1991 and January 11, 1996, the pH was recorded as 6.3, and on December 14, 1995, the pH was recorded as 6.2.

Table 5-5 Average pH (s.u.) Values in Kinkaid Lake

Year	RNC-1 and 05599540	RNC-2	RNC-3	RNC-4	Lake Average
1990	7.7	8.2	8.1	7.5	7.9
1991	7.7	8.1	8.2	7.6	7.9
1992	7.4				7.4
1993	8.0				8.0
1994	8.2	8.3	8.4	8.1	8.2
1995	7.2				7.2
1996	7.1				7.1
1997	7.7	7.9	7.9	7.4	7.7
2000	8.3	8.3	8.5	8.2	8.3

Fluctuations in pH can be correlated to photosynthesis from algae. Plants and algae use carbon dioxide (CO_2) during photosynthesis, which causes pH levels to rise. The photosynthetic rate progressively decreases as the residual CO_2 concentration declines and ceases completely with the extinction of light. During the night, reaeration and respiration replenish CO_2 causing the pH levels to decrease overnight (Welch 1980). Chlorophyll "a" indicates presence of excessive algal or aquatic plant growth. Reducing total phosphorus is likely to reduce algal growth thus resulting in attainment of the pH standard. Therefore, the relationship between pH, chlorophyll "a," and total phosphorus in Kinkaid Lake was investigated. The correlation between pH and chlorophyll "a" is expected to indicate a direct relationship between the two constituents. Likewise, the correlation between chlorophyll "a" and total phosphorus is

expected to indicate a direct relationship. These relationships would suggest that controlling phosphorus will decrease chlorophyll "a" concentrations, which will in turn control the pH. This hypothesis is supported by Wetzel who asserts that photosynthesis and respiration are major influences on pH (1983).

5.1.5.1.2 Total Phosphorus

The average total phosphorus concentrations at one-foot depth for each year of available data from 1990 to 2000 at each monitoring site in Kinkaid Lake are presented in Table 5-6. At station RNC-1, samples were taken at a one-foot depth from the lake surface and at the lake bottom. Samples at stations RNC-2 and RNC-3 were only taken at a one-foot depth from the lake surface. The water quality standard for total phosphorus is less than or equal to 0.05 mg/L at one-foot depth. Additionally, multiple samples taken at one-foot depth since 1990 do violate the TMDL endpoint for phosphorus. It is apparent from Table 5-6 that concentrations at Station RNC-4 repeatedly violate the phosphorus standard. The raw data for all sample depths are contained in Appendix A.

Table 5-6 Average Total Phosphorus Concentrations (mg/L) in Kinkaid Lake at One-foot Depth (USEPA 2002b and Illinois EPA 2002)

Year	RNC-1 and 05599540	RNC-2	RNC-3	RNC-4	Lake Average
1990	0.06	0.01	0.02	0.09	0.05
1991	0.02	0.02	0.03	0.10	0.04
1992	0.02				0.02
1993	0.02		0.03		0.02
1994	0.03	0.02	0.04	0.14	0.06
1995	0.02				0.02
1996	0.03				0.03
1997	0.02	0.03	0.04	0.13	0.06
1998	0.03				0.03
2000	0.01	0.01	0.02	0.05	0.03

Phosphorus exists in water in either a particulate phase or a dissolved phase. Particulate matter includes living and dead plankton, precipitates of phosphorus, phosphorus adsorbed to particulates, and amorphous phosphorus. The dissolved phase includes inorganic phosphorus and organic phosphorus. Phosphorus in natural waters is usually found in the form of phosphates (PO_4 and PO_3). Phosphates can be in inorganic or organic form. Inorganic phosphate is phosphate that is not associated with organic material. Types of inorganic phosphate include orthophosphate and polyphosphates. Orthophosphate is sometimes referred to as "reactive phosphorus." Orthophosphate is the most stable kind of phosphate and is the form used by plants or algae. There are several forms of phosphorus that can be measured. Total phosphorus is a measure of all the forms of phosphorus, dissolved or particulate, that are found in a sample. Soluble reactive phosphorus is a measure of orthophosphate, the filterable (soluble, inorganic) fraction of phosphorus, the form directly taken up by plant cells.

5.1.5.1.3 Chlorophyll "a"

The average chlorophyll "a" concentrations for each year of available data from 1990 to 2001 at each active monitoring site in Kinkaid Lake are presented in Table 5-7. There was no chlorophyll "a" data available at station 05599540. The raw data for all sample depths are contained in Appendix A.

Table 5-7 Average Chlorophyll "a" Concentrations (µg/L) in Kinkaid Lake (USEPA 2002b and Illinois EPA 2002)

Year	RNC-1	RNC-2	RNC-3	RNC-4	Lake Average
1990	9.8	13.6	14.5	32.7	17.6
1991	9.0	10.5	17.1	43.1	19.9
1994	19.1	23.4	24.3	52.1	29.7
1997	13.2	19.4	27.5	48.9	27.3
1998	21.9				21.9
2000	18.4	12.7	16.4	38.0	21.4

5.1.5.1.4 Tributary Data

There is no water quality data available for the tributaries to Kinkaid Lake. The primary tributaries to Kinkaid Lake are Kinkaid Creek and Little Kinkaid Creek. Tributary water quality data along with flow information would be useful in assessing contributing loads from the watersheds to help differentiate between external loading and internal loading. External loads are those loadings from the watershed, such as nonpoint source runoff and point sources. Internal loads are caused by low DO conditions near lake sediments, which promote re-suspension of phosphorus from the sediments into the water column. External versus internal loads will be discussed further in Section 7.4.

5.1.5.2 Big Muddy River Water Quality Data

There is one active and one historic water quality station in Big Muddy River segment N12 as shown in Figure 5-1. The water quality station data for segment N12 were downloaded from the *STORET* online database for the years of 1990 to 1998 (USEPA 2002b). Data collected after 1998 were available from the Illinois EPA and were incorporated into the electronic database. The data summarized in this section include water quality data for impaired constituents in the Big Muddy River segment N12 as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

5.1.5.2.1 Manganese and Sulfates

Table 5-8 summarizes historical manganese and sulfates data since 1990 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for impaired segments in the Big Muddy River Watershed. The raw historical water quality data are contained in Appendix A. For impairments on segment N12, the average of the data sets do not exceed the water quality standard for either manganese and sulfates. The historical water quality samples were also taken during months with historically varying flow conditions.

Table 5-8 Summary of Constituents Associated with Potential Impairments for the Big Muddy River Segment N12

Sample Location and Parameter	Endpoint (mg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum
Big Muddy River Segment N12; Sample Location 05599500					
Manganese	1.0	1/9/90-4/24/97; 51	0.6	2.5	0.1
Sulfates	500	1/9/90-4/24/97; 65	237	660	59
Big Muddy River Segment N12; Sample Location N12					
Manganese	1.0	10/27/97-9/6/00; 27	0.6	1.9	0.2
Sulfates	500	11/20/97-9/6/00; 24	285	653	68

Figures 5-4 and 5-5 (at the end of this section) show concentrations of manganese and sulfates, respectively, with corresponding flows in segment N12. Figures 5-4 and 5-5 exclude samples taken between October 1993 and September 1995 because flow data was unavailable for those months. The flow for each sample date was compared to the monthly average flow shown in Figure 5-3 for the month the sample was taken. Based on this analysis, about 75 percent of manganese samples and 88 percent of sulfates samples were taken at below average flow conditions. This suggests that most historical samples were taken under low flow conditions in segment N12 of the Big Muddy River Watershed. Analysis of impaired sample dates showed that more than half of the impaired samples were taken at below average flows.

5.1.5.2.2 DO and TOC

Table 5-9 summarizes the available historic DO and total organic carbon (TOC) data since 1990 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for Big Muddy River segment N12 (raw data contained in Appendix A). TOC data are presented here because they are used in the DO analysis. The average DO concentration for segment N12 is above the water quality standard of 6.0 mg/L (16 hours of any 24-hour period), but the minimum values observed are less than the water quality standard of 6.0 mg/L.

Table 5-9 Existing DO and TOC Water Quality Data and TMDL Endpoints

Sample Location and Parameter	Endpoint (mg/L)	Period of Record Examined and Number of Data Points	Mean (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Big Muddy River Segment N12; Sample Location 05599500					
DO	6.0 (16 hours of any 24-hour period)	1/9/90-4/24/97; 102	8.7	20.8	3.7
Big Muddy River Segment N12; Sample Location N12					
DO	6.0 (16 hours of any 24-hour period)	10/27/97-9/6/00; 25	7.7	12.4	4.7
TOC	–	10/27/97-9/6/00; 2	5.6	5.6	5.5

Historical flow data were presented in Section 5.1.3. The flow values during the historical sampling events for DO that had corresponding TOC measurements are presented in Table 5-10. The flow for each sample date was compared to the monthly average flow shown in Figure 5-3 for the month the sample was taken. Based on this comparison, the September 6, 2000 sample was taken at below average flows, and the

July 24, 2000 sample was taken at above average flows. Low flow values within the stream segment result in slow-moving waters, which could decrease the amount of aeration occurring in the stream. In addition, the day with DO impairment (September 6, 2000) occurred in a typically warm weather month. Elevated stream temperatures affect the aquatic environment by limiting the concentration of DO in the water column. For example, the DO concentration for 100 percent air saturated water at sea level is 14.6 mg O_2/L at 0 degrees Celsius (°C) (32°F) and decreases to 8.6 mg O_2/L at 25°C (77°F) (Brown and Brazier 1972).

Table 5-10 DO Sampling Events and Associated Flow Values

Sample Location	Date	Flow (cfs)	DO (mg/L)
Big Muddy River (N12)	7/24/00	2,060	7.9
Big Muddy River (N12)	9/6/00	400	4.7

5.1.5.2.3 pH and TDS

Table 5-11 summarizes the available historic pH data from 1990 to 2001 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for Big Muddy River segment N12 (raw data contained in Appendix A). Although the segment is not impaired for TDS, the data are used in the pH calculations. The average pH concentration for the segment is within the water quality boundaries of 6.5 and 9.0, but the minimum value observed is less than the water quality standard of 6.5.

Table 5-11 Existing pH and TDS Water Quality Data and TMDL Endpoints

Sample Location and Parameter	Endpoint (mg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum
Big Muddy River Segment N12; Sample Location 05599500					
pH	6.5 - 9	1/9/90-4/24/97; 102	7.4	8.8	6.4
TDS	1,000	1/9/90-2/29/96; 16	620	2,010	197
Big Muddy River Segment N12; Sample Location N12					
pH	6.5 - 9	10/27/97-9/6/00; 25	7.1	8.1	6.4
TDS	1,000	7/24/00-9/6/00; 2	356	487	225

Figure 5-6 shows a histogram of pH values in Segment N12 of the Big Muddy River. This histogram illustrates that, based on historic data, three percent of the measured pH values in segment N12 violated the pH standard. The last violation occurred in August of 1998.

5.1.6 Land Use

The Illinois Natural Resources Geospatial Clearinghouse distributes the Critical Trends Assessment Land Cover Database of Illinois. This database represents 23 land use classes created by satellite imagery captured between 1991 and 1995. The data were published in 1996 and are distributed by county in grid format for use in GIS. The GIS-delineated watershed for Kinkaid Lake and Big Muddy River segment N12 were used to obtain the land use from the Critical Trends Assessment Land Cover grid. Tables 5-12 and 5-13 list the land uses contributing to the Kinkaid Lake Watershed and the segment N12 watershed, as well as each land use area and percent of total area.

Table 5-12 Critical Trends Assessment Land Uses in Kinkaid Lake (IDNR 1996)

Land Use	Acres	Percent of Area
Deciduous Forest	21,597	56%
Rural Grassland (pastureland, grassland, waterways, buffer strips, CRP land, etc.)		
Pasture	2,977	8%
Grassland	5,953	16%
Row Crop (corn, soybeans, and other tilled crops)	3,576	9%
Open Water	2,703	7%
Small Grains (wheat, oats, etc.)	751	2%
Coniferous Forest	461	1%
Forested Wetlands	368	1%
Urban (high and medium density)	101	0%
Shallow Water Wetlands	61	0%
Shallow Marsh/Wetlands	27	0%
Urban Grassland	17	0%
Deep Marsh	7	0%
Barren Land	5	0%
Cattle Feedlot	6	0%
Total	38,610	100%

*Subclasses of rural grassland were estimated by the Jackson County NRCS (2002a)

Table 5-13 Land Use for Segment N12 Watershed

Land Use	Area (Acres)	Percent of Total
Deciduous	7,164	39%
Rural Grassland	5,175	28%
Row Crop	1,989	11%
Urban Grassland	1,241	7%
Forested Wetland	813	4%
Medium Density	529	2.5%
Small Grains	491	2.5%
Orchard/Nurseries	297	2%
Open Water	292	2%
High Density	200	1%
Shallow Water/Wetlands	159	1%
Coniferous	27	0%
Shallow Marsh/Wetlands	16	0%
Low Density	11	0%
Swamp	3	0%
Deep Marsh	1	0%
Total	18,408	100%

Additional land use data were obtained from the Spatial Analysis Research Center's Cropland Data Layer to supplement the Critical Trends Assessment dataset. The data were requested from the National Agricultural Statistics Service (NASS) website for the years of 1999 and 2000 (NASS 2002). The Cropland Data Layer is also derived from satellite imagery, but the land use classes for crops are more detailed than those presented in the Critical Trends Assessment dataset. The detailing of crops in the Cropland Data Layer land use classes makes it a more accurate dataset for calculation of crop-related parameters. The dataset was also used to verify the land use obtained from the Critical Trends Assessment. Table 5-14 shows the cropland use classes of the

Cropland Data Layer and the Critical Trends Assessment classes to which they were applied.

Table 5-14 Comparison of Land Use Classes in the Kinkaid Lake Watershed

Cropland Data Layer Land Use Class	Critical Trends Assessment Land Use Class
Corn	Row Crop
Sorghum	Small Grains
Soybeans	Row Crop
Winter Wheat	Small Grains
Other Small Grains & Hay	Small Grains
Double-Cropped Winter Wheat/Soybeans	Half to Small Grains Half to Row Crops

5.1.7 Point Sources and Animal Confinement Operations

5.1.7.1 Coal Mines and Oil and Gas Fields

Acid mine drainage from coal mines could contribute to manganese and sulfates concentrations in a watershed. Data from the Illinois Natural Resources Geospatial Data Clearinghouse was reviewed for coal mines, oil fields, and non-coal mines within the Big Muddy River Watershed from the following references (full citation provided in Section 13):

- Chenoweth, Cheri, 1998, Areas Mined for the Springfield (No. 5) Coal in Illinois
- Stiff, Barbara J., 1997, Areas Mined for Coal in Illinois - Part 1
- Stiff, Barbara J., 1997, Areas Mined for Coal in Illinois - Part 2
- Coal Section, Illinois State Geological Survey, 1991, Point Locations of Active and Abandoned Coal Mines in Illinois
- Illinois Office of Mines and Minerals, 1998, Coal Mine Permits Boundaries in Illinois
- Staff, ISGS, 1996, Non-coal Underground Mines of Illinois
- Staff, ISGS, 1996, Non-coal Underground Mines of Illinois - Points
- Illinois State Geological Survey, not published, Oil and Gas Fields in Illinois

Figure 5-7 presents the findings from these databases for extraction operations in the Big Muddy River Watershed. Multiple coal mines were identified within the watershed and labeled on Figure 5-7. The mine names and dates of operation are listed in Appendix B. There are no permitted mines in this watershed, and a comparison of the existing and permitted mine databases suggests that non-permitted mines are likely abandoned or closed. No oil or gas fields or non-coal mines were located in the segment N12 Watershed; however, the non-coal mine database contains only 20 percent of the non-coal mines in Illinois due to the lack of a legal filing requirement.

Both Illinois EPA and IDNR Office of Mines and Minerals have responsibilities relating to the permitting of active coal mines and the regulation of mine drainage. Mine drainage is any groundwater, surface water, or rainwater that flows through, or in any way contacts an area affected by mining. Mine drainage from sites in Illinois are either non-acid drainage or acid drainage and can be classified as pre-law and post-law. Pre-law mines are those mines operated prior to 1977, which are abandoned and not permitted and are typically acid drainage mines (Muir et al. 1997).

Acid mine drainage is formed when three essential components combine: iron pyrite material, oxygen, and water. Pyritic material may come in several different forms, some of which are very stable and difficult to break down while others are very reactive and break down readily. Iron pyrite is commonly found associated with coal and coal refuse materials. As water contacts iron pyrite in the presence of oxygen, a chemical reaction occurs that forms ferrous iron and sulfuric acid. The ferrous iron then undergoes oxidation to form ferric iron. With the presence of ferrous iron, ferric iron, pyrite, oxygen, and water, several chemical reactions occur that produce additional acidity, further lowering the pH of the water. The formation of new acid is practically continuous when erosion of the refuse material exposes unreacted pyrite in the presence of oxygen and water. The negative impacts of acid mine drainage are high levels of dissolved solids, especially iron, sulfates, chlorides, and manganese associated with the mine drainage (Muir et al. 1997).

As mentioned previously, the sampling data for manganese and sulfates, shown in Figures 5-4 and 5-5, were taken primarily under low-flow conditions. The figures show a decrease in concentrations with increases in flow indicating that groundwater is the potential source of these constituents. If the source of manganese and sulfates were due to surface runoff, an increase in concentrations would be expected with increased flows. The absence of exceedences of the water quality standards for manganese or sulfates at higher flows in the figures supports the conclusion that manganese and sulfates could have leached into the groundwater from pools within the mine sites and be the source of manganese and sulfates concentrations in segment N12. In addition, no data are available to assess the natural background of manganese and sulfates in the watershed. Natural background concentrations typically are attributed to what occurs naturally in groundwater due to mineral conditions of the soils (Water Environment Research Foundation [WERF] 1997).

5.1.7.2 Animal Confinement Operations

The Illinois EPA provided a GIS shapefile illustrating the location of livestock facilities in the Big Muddy River Basin, which contains Kinkaid Lake and Big Muddy River segment N12. The Illinois EPA assessed the potential impact of each facility on water quality with regard to the size of the facility, the site condition and management, pollutant transport efficiency, and water resources vulnerability. Two livestock facilities (cattle feedlots) were identified in the Kinkaid Lake watershed as shown in Figure 5-8. One of the feedlots was determined to have no impact on the receiving waters, and the other was determined to have a slight impact on receiving waters. Three animal management operations were located in the segment N12 watershed; two are

designated as having no impact on receiving waters, and the third was not assessed. Figure 5-9 shows the animal management operations within the segment N12 Watershed.

5.1.7.3 Wastewater Treatment Plants

Table 5-15 lists the wastewater treatment facilities within the N12 watershed. No point sources were located within the Kinkaid Lake Watershed. Table 5-15 also provides information on whether there is potential for the facility to impact DO concentrations in Segment N12. With exception of the Carbondale Northwest Wastewater Treatment Plan, none of the facilities has the potential to impact DO concentrations in Segment N12. The facilities are either no discharge or discharge such little effluent that it is unlikely that they impact the Big Muddy River. The Carbondale Northwest Plant will be further discussed in Section 10.

Table 5-15 Wastewater Treatment Plants within N12 Watershed

Facility Name	NPDES Number	Potential to Impact DO Concentrations in N12
Lake Chautauqua Home	IL0045705	No
Fairway Motor Home Park	IL0045306	No
New Thompson Lake Fishing Club	IL0048569	No
Jackson Country Club	IL0038521	No
Fairway Vista Group	IL0061786	No
Paul Parrish Apartments	IL0048089	No
Green Tree Mobile Home Park	IL0036935	No
Happy Ours Mobile Home Park	IL0046299	No
Carbondale Northwest Wastewater Treatment Plant	IL0027871	Yes

5.1.8 Soil Data

State Soil Geographic (STATSGO) database data, created by the USDA – National Resource Conservation Service (NRCS) Soil Survey Division, are aggregated soil surveys for GIS use published for Illinois in 1994. The *STATSGO* shapefiles were downloaded by HUC from the USEPA *BASINS* website (USEPA 2002a). *STATSGO* data are presented as map units of soils in which each map unit has a unique code linking it to attribute tables listing percentages of soil types within a map unit, soil layer depths, hydrologic soil groups, and soil texture among other soil properties.

5.1.9 Cropping Practices

Tillage practices can be categorized as conventional till, reduced till, mulch-till, and no-till. The percentage of each tillage practice for corn, soybeans, and small grains by county are generated by the Illinois Department of Agriculture from County Transect Surveys. Data specific to the Kinkaid Lake Watershed were not available; however, the Jackson County NRCS office recommended percentages of each tillage practice for application to the Kinkaid Lake Watershed as shown in Table 5-16 (NRCS 2002a).

Table 5-16 Tillage Practices in the Kinkaid Lake Watershed (NRCS 2002a)

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	20%	0%	20%
Reduced Till	15%	10%	50%
Mulch-Till	15%	5%	10%
No-Till	50%	85%	20%

5.1.10 Reservoir Characteristics

Reservoir characteristics were obtained from GIS analysis, the Illinois EPA, the Kinkaid Lake watershed plan, and USEPA water quality data. The watershed plan for Kinkaid Lake lists a normal pool of 2,350 acres (Kinkaid Area Watershed Project, Inc. [KAWP] 2000). Illinois EPA originally estimated the surface area of Kinkaid Lake as 3,475 acres, resulting in a large discrepancy between this value and those obtained from the watershed plan and GIS. Based on recent studies in the watershed, the surface area of 2,350 acres from the watershed plan was used to validate the surface area of 2,402 acres obtained from GIS analysis. For modeling analyses, the area obtained through GIS analysis was scaled to equal the area from the resource plan.

The water quality dataset described in Section 5.1.5.1 was used to determine the average depth of Kinkaid Lake. On each date sampled for water quality constituents, the total depth at the site was measured. Table 5-17 lists the average depth calculated for each water quality site in Kinkaid Lake for each year of available data after 1990.

Table 5-17 Average Depths in Feet for Kinkaid Lake

Year	RNC-1	RNC-2	RNC-3	RNC-4	Lake Average
1990	55.9	42.3	6.5	6.5	27.8
1991	63.0	40.3	22.0	3.4	32.2
1992	80.4	15.2	13.8	4.3	28.4
1993	73.0	22.4	15.6	6.5	29.4
1994	60.0	35.7	24.7	4.0	31.1
1996	60.0	41.1	9.2	9.2	29.9
1997	57.9	40.2	27.4	9.4	33.7
1998	57.9	39.5	29.0	10.5	34.2
2000	51.3	39.4	26.8	10.2	31.9

Reservoir characteristics that were unavailable were flows into and out of the reservoir.

5.1.11 Septic Systems

Typically, septic systems near lake waters have greater potential for impacting water quality than systems near streams due to their proximity to the water body of concern. The number of septic systems within the watersheds could not be confirmed from available data sources. There were no residences observed near the lake during the site visit described in Sections 2.2 and 2.3. It is anticipated that failing septic systems are a negligible source of pollutant loads in this watershed.

5.1.12 Aerial Photography

Aerial photographs of the Big Muddy River Watershed were obtained from the Illinois Natural Resources Geospatial Data Clearinghouse. The photographs were used to supplement the USGS quadrangle maps when locating facilities.

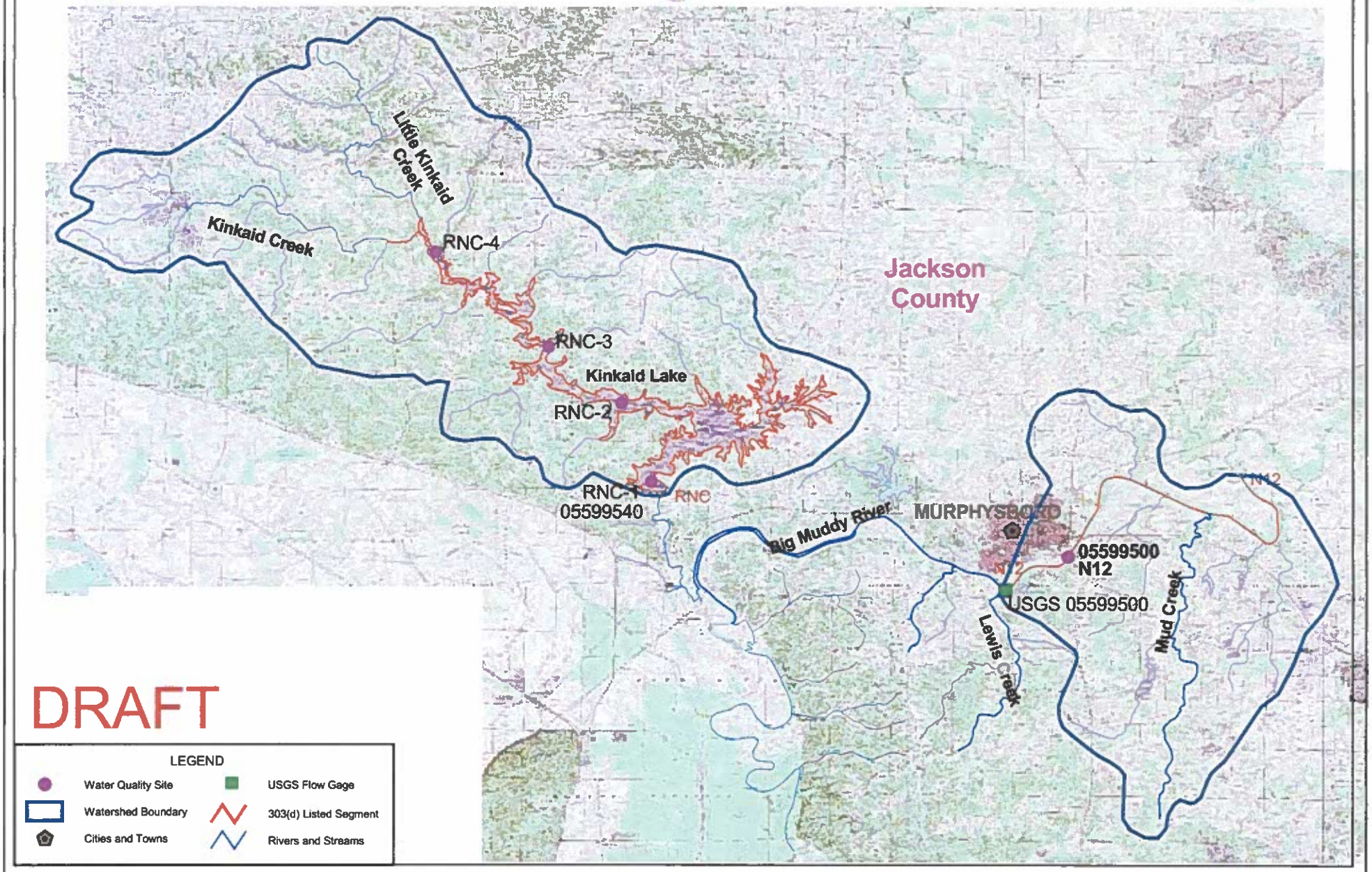


Figure 5-1
Big Muddy River #1 Watershed
Historic Flow and Water Quality Gages

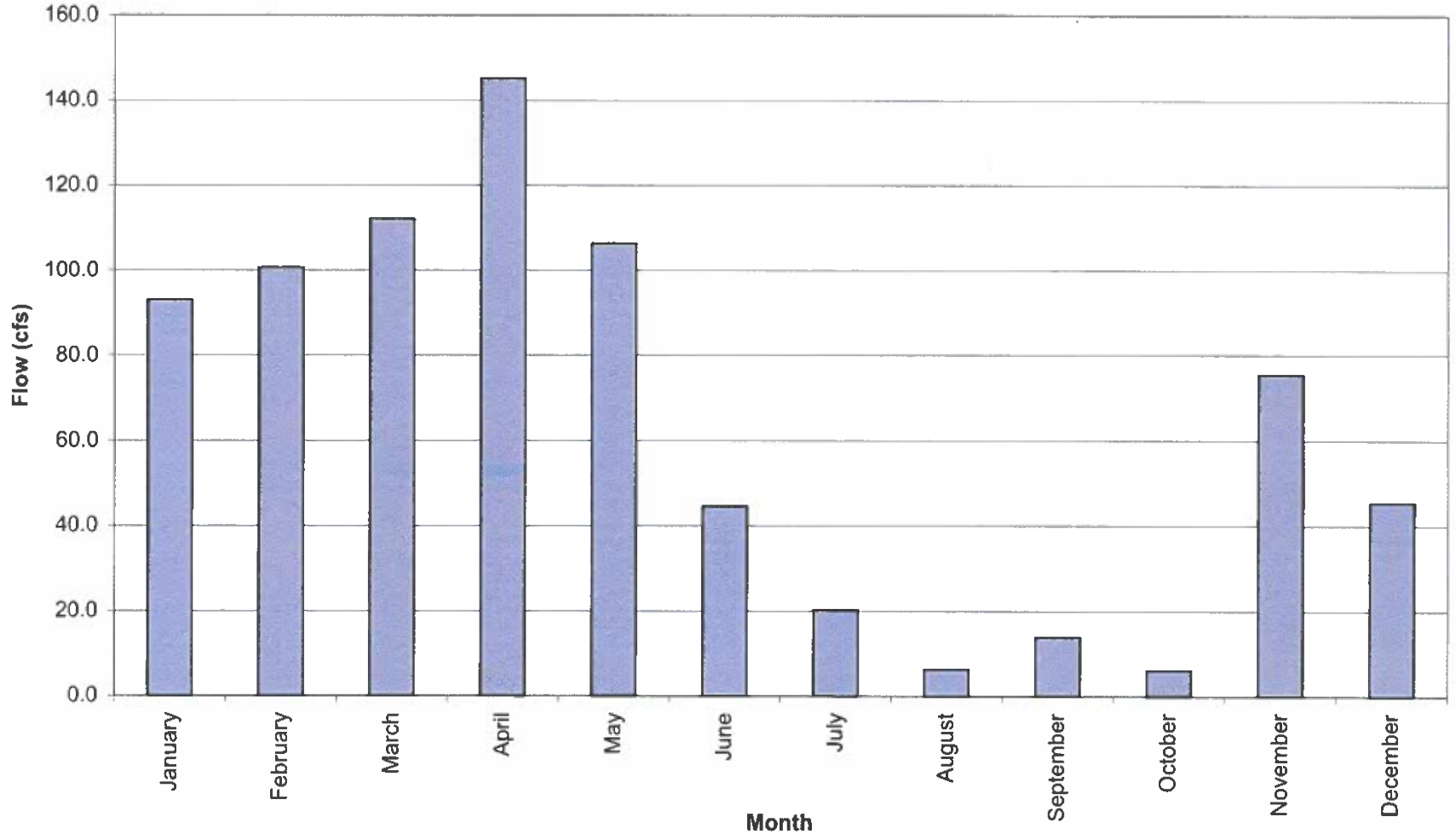
CDM

iepa/gis_data/apr/bigmuddy1.apr 032803 mjf

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Figure 5-2: Estimated Streamflow Upstream of Kinkaid Lake Calculated from Gage 05595820



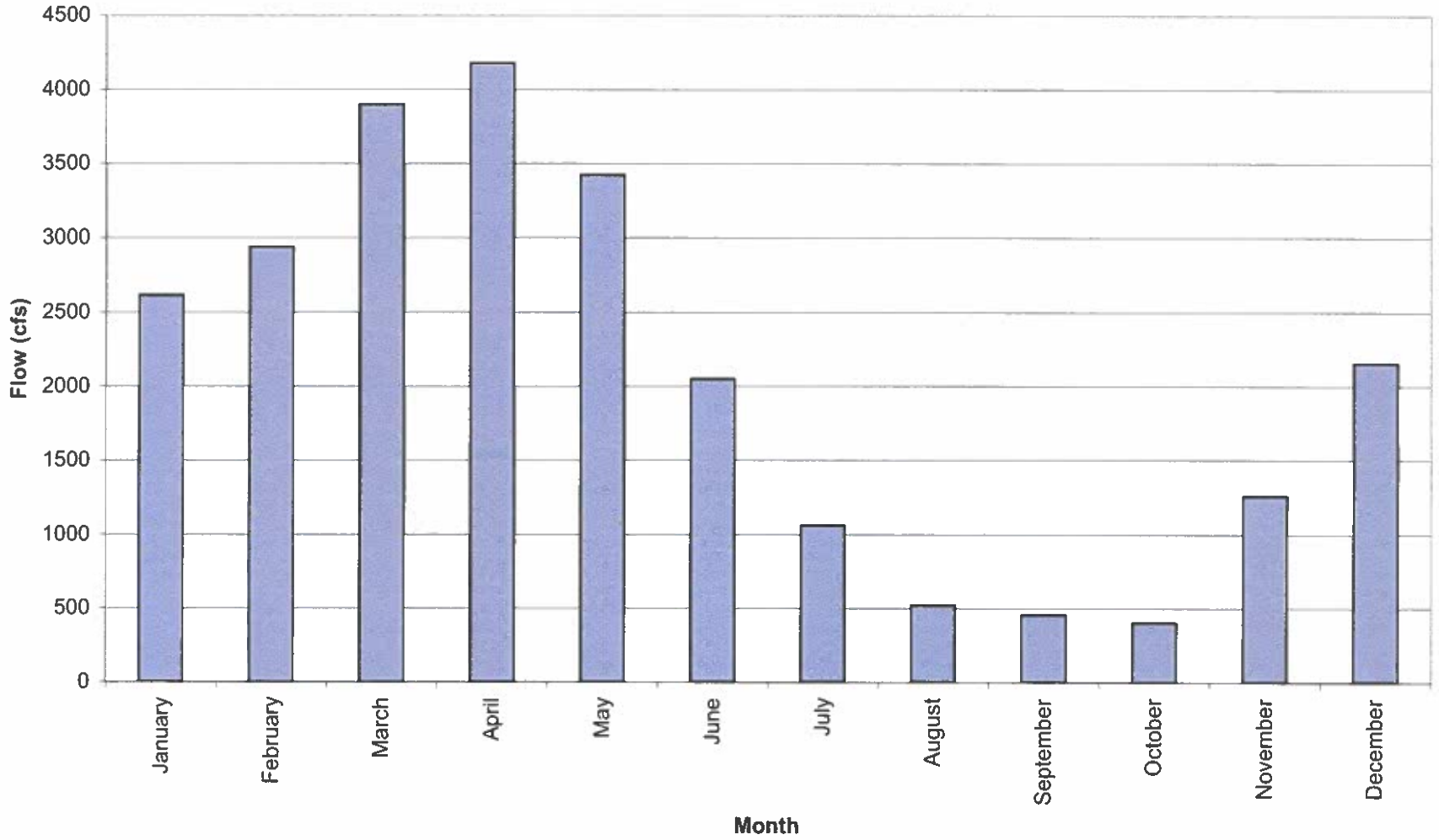
Period of Record
October 1, 1985 to September 30, 2000

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Figure 5-3: Flows in the Big Muddy River Segment N12
Gage 05599500



Period of Record
January 1, 1972 to September 30, 2000

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Figure 5-4 Manganese Concentrations and Flows in Big Muddy River Segment N12

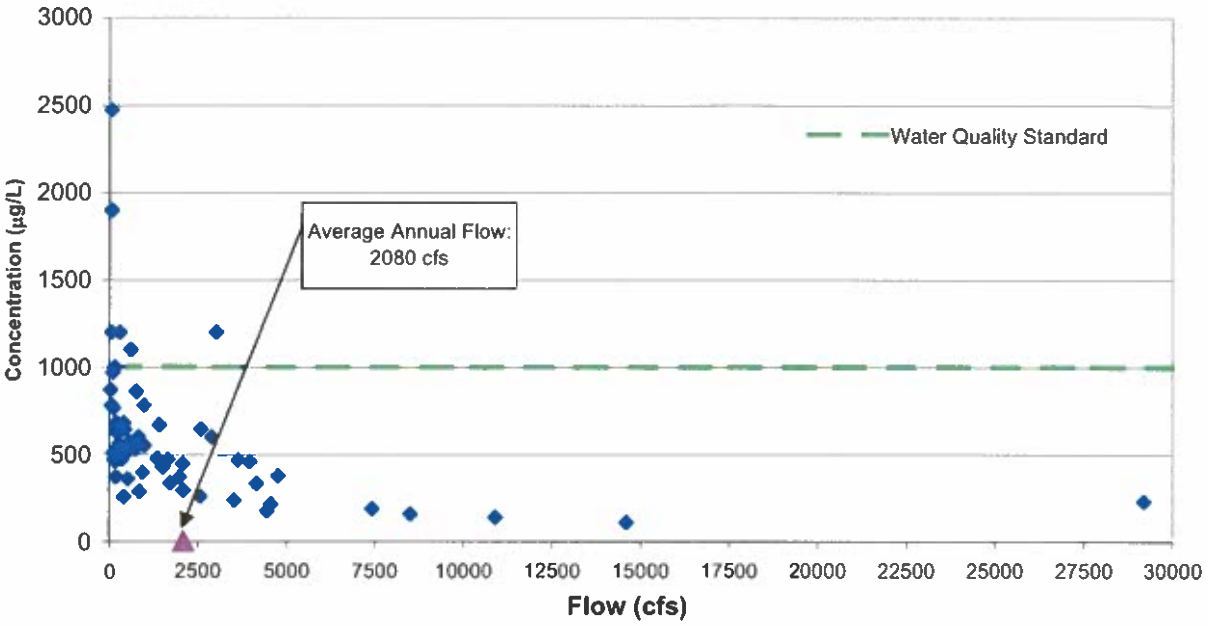
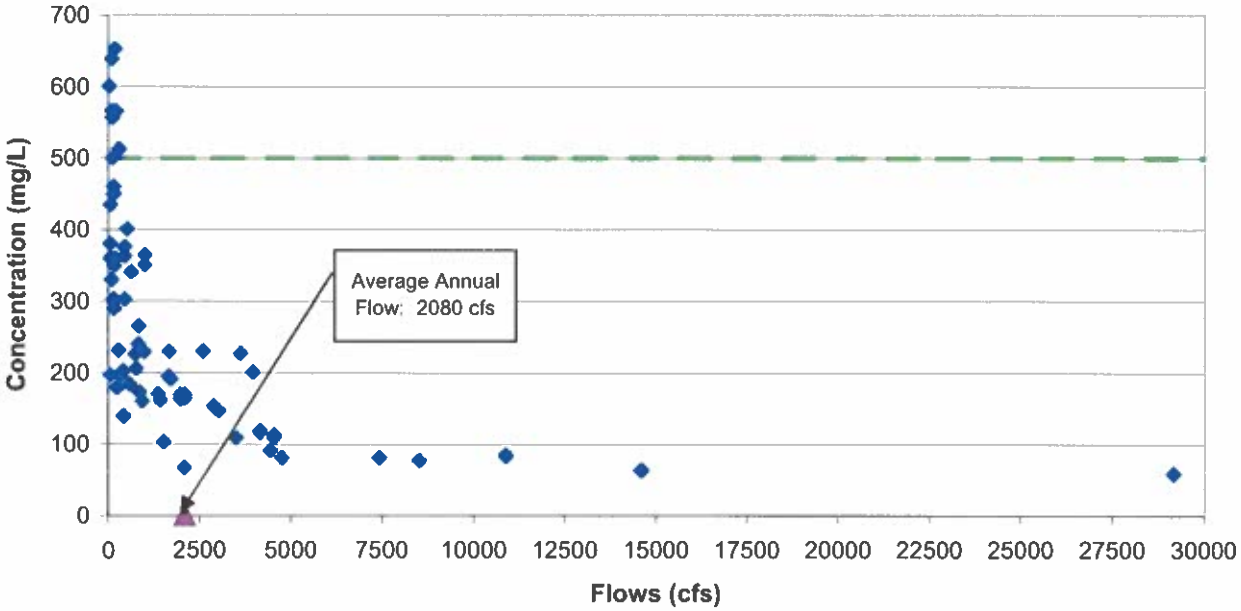
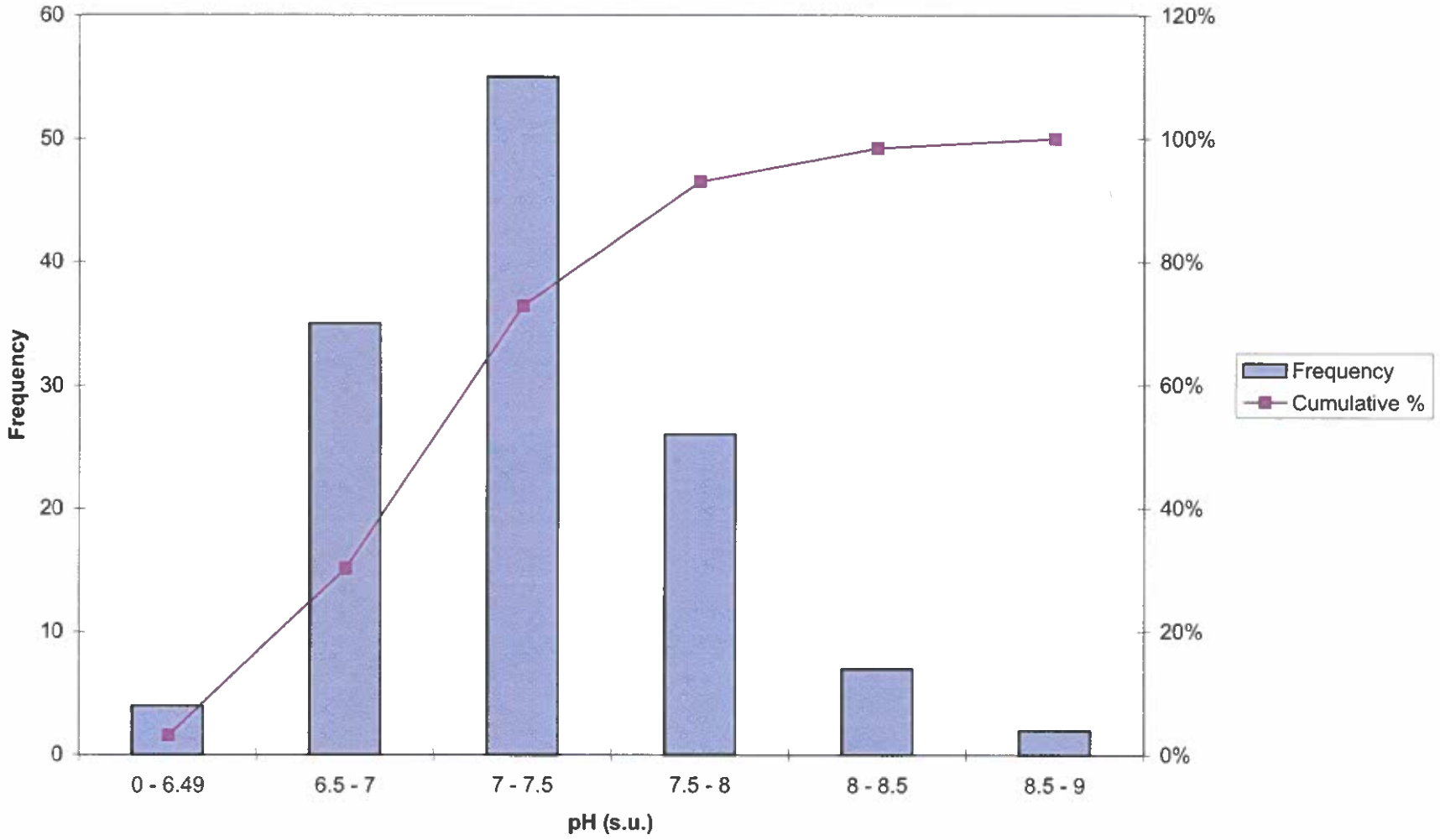


Figure 5-5: Sulfate Concentrations and Flows in Big Muddy River Segment N12



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Figure 5-6: pH Histogram for Segment N12 in the Big Muddy River



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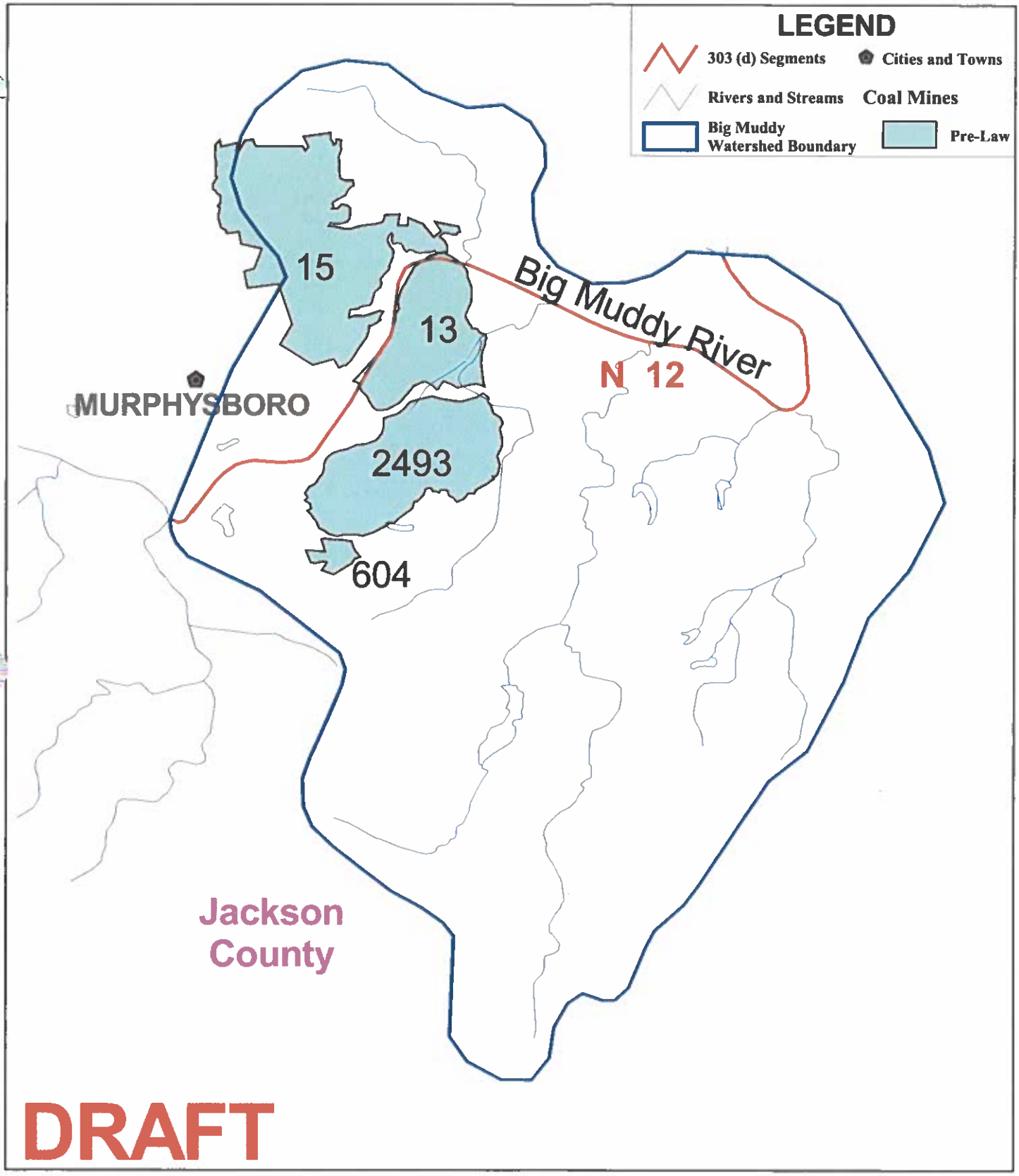


Figure 5-7
Coal Mines in the Big Muddy River #1 Watershed
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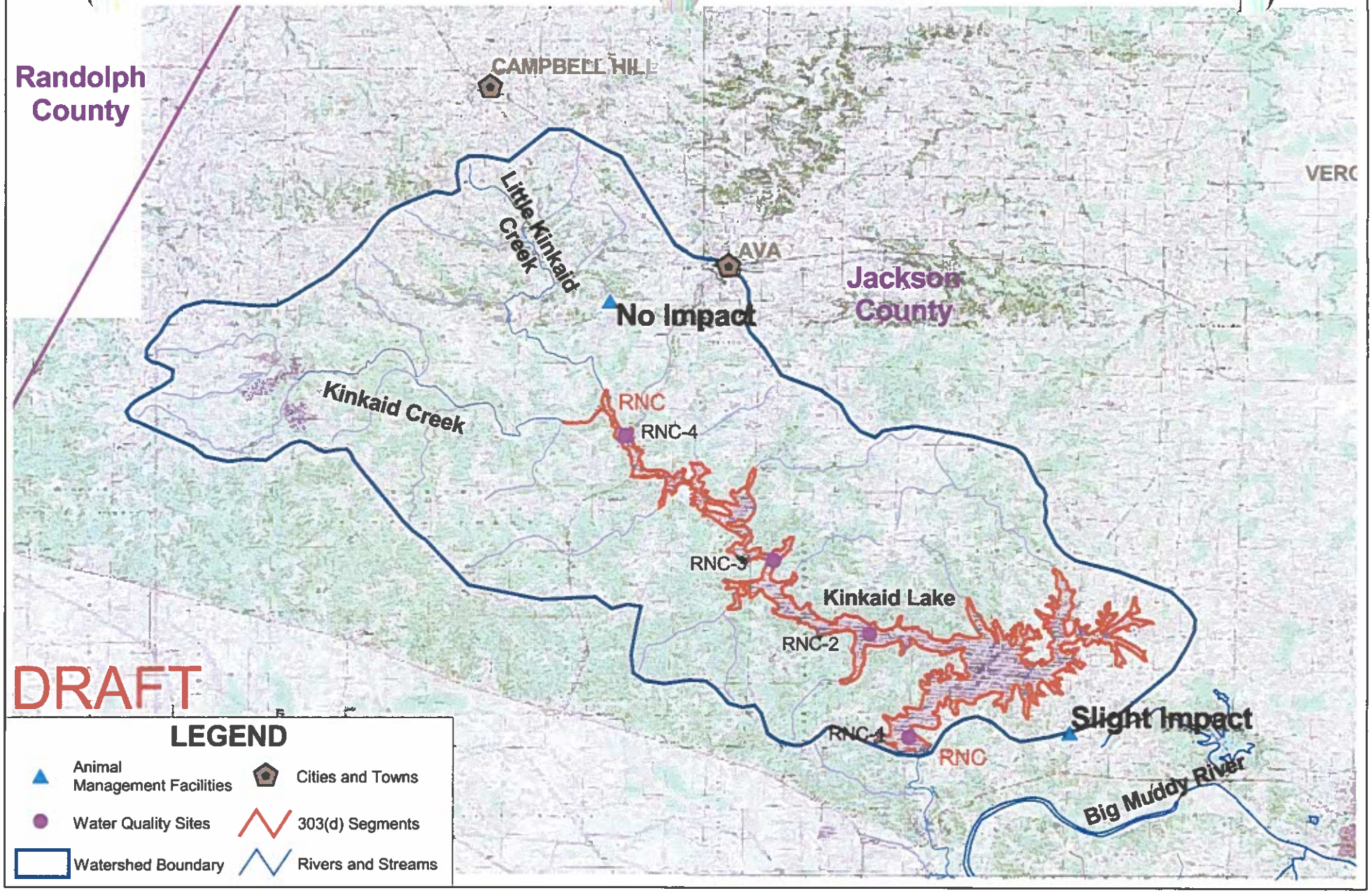


Figure 5-8
Animal Management Facilities in the
Kinkaid Lake Watershed

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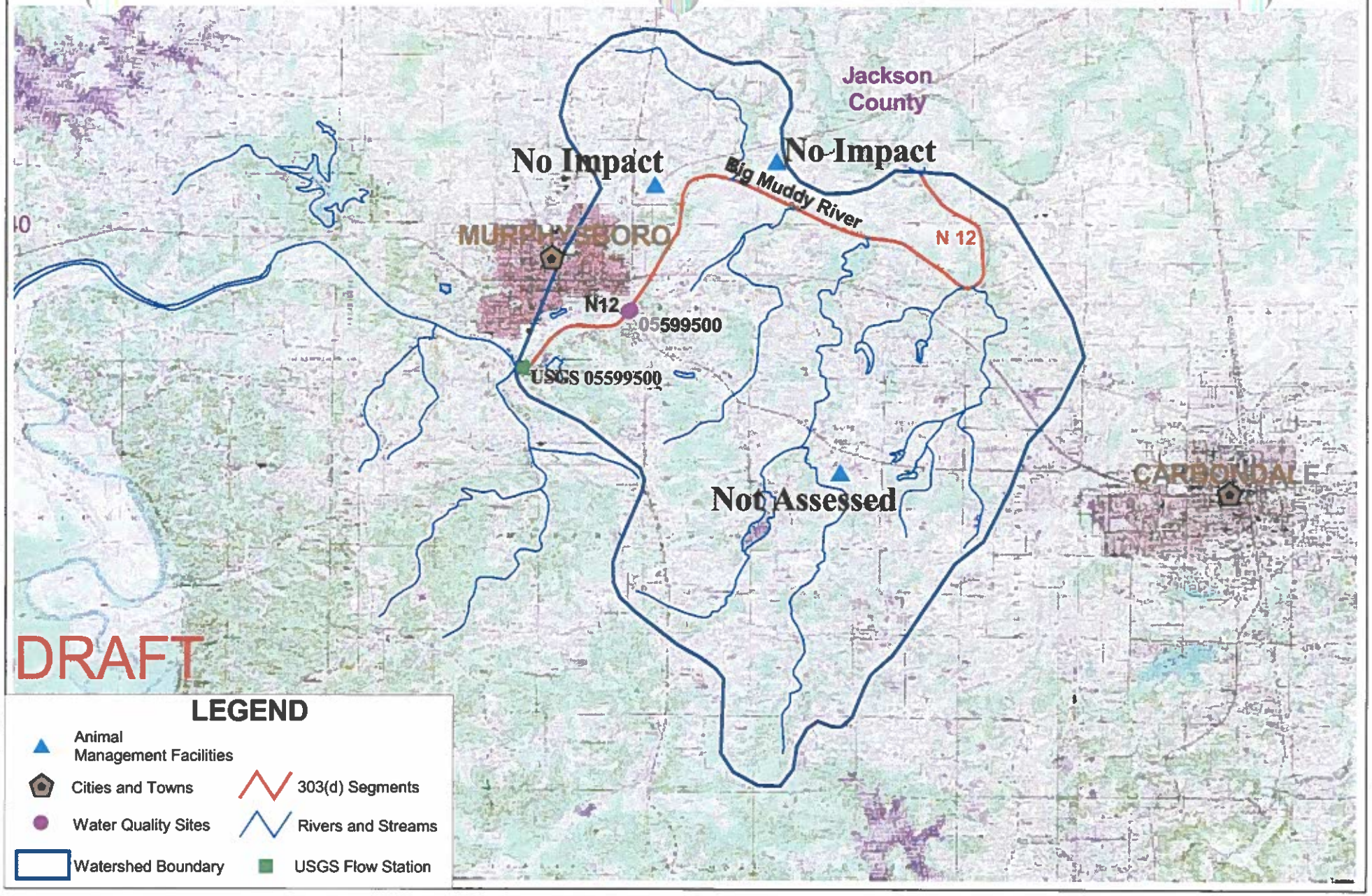


Figure 5-9
Animal Management Facilities in the
Big Muddy River #1 Watershed

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Section 6
Methodologies and Models to Complete TMDLs for the Big Muddy River

6.1 Set Endpoints for TMDLs

TMDLs are used to define the total amount of pollutants that may be discharged into a particular water body within any given day based on a particular use of that water body. Developing TMDLs must, therefore, account for both present and future stream users, habitat, flow variability, and current and future point and nonpoint pollutant loadings that may impact the water body. Defining a TMDL for any particular stream segment must take into account not only the science related to physical, chemical, and biological processes that may impact water body water quality, but must also be responsive to temporal changes in the watershed and likely influences of potential solutions to water quality impairments on entities that reside in the watershed.

Stream and lake water quality standards were presented in Section 4, specifically in Table 4-1. Biological data, such as the Index of Biotic Integrity (IBI) and the Macroinvertebrate Biotic Index (MBI), are used to support 305(b) and 303(d) listing decisions; however, TMDLs were not developed specifically to meet biological endpoints for the Big Muddy River Watershed. The endpoints presented in Section 4, which are chemical and physical endpoints of the following constituents, were targeted:

- stream segments: sulfates, pH, DO, manganese;
- lake segment: pH.

6.2 Methodologies and Models to Assess TMDL Endpoints

Methodologies and models were utilized to assess TMDL endpoints for the Big Muddy River Watershed. Model development is more data intensive than using simpler methodologies or mathematical relationships for the basis of TMDL development. In situations where only limited or qualitative data exist to characterize impairments, methodologies were used to develop TMDLs and implementation plans as appropriate.

In addition to methodologies, watershed and receiving water computer models are available for TMDL development. Most models have similar overall capabilities but operate at different time and spatial scales and were developed for varying conditions. The available models range between empirical and physically based. However, all existing watershed and receiving water computer models simplify processes and often include obviously empirical components that omit the general physical laws. They are, in reality, a representation of data.

Each model has its own set of limitations on its use, applicability, and predictive capabilities. For example, watershed models may be designed to project loads within annual, seasonal, monthly, or storm event time scales with spatial scales ranging from

large watersheds to small subbasins to individual parcels such as construction sites. With regard to time, receiving water models can be steady state, quasi dynamic, or fully dynamic. As the level of temporal and spatial detail increases, the data requirements and level of modeling effort increase.

6.2.1 Watershed Models

Watershed or loading models can be divided into categories based on complexity, operation, time step, and simulation technique. USEPA has grouped existing watershed-scale models for TMDL development into three categories based on the number of processes they incorporate and the level of detail they provide (USEPA 1997):

- simple models,
- mid-range models,
- detailed models.

Simple models primarily implement empirical relationships between physiographic characteristics of the watershed and pollutant runoff. A list of simple category models with an indication of the capabilities of each model is shown in Table 6-1. Simple models may be used to support an assessment of the relative significance of different nonpoint sources, guide decisions for management plans, and focus continuing monitoring efforts. Generally, simple models aggregate watershed physiographic data spatially at a large-scale and provide pollutant loading estimates on large time-scales. Although they can easily be adopted to estimate storm event loading, their accuracy decreases since they cannot capture the large fluctuations of pollutant concentrations observed over smaller time-scales.

Table 6-1 Evaluation of Watershed Model Capabilities - Simple Models (USEPA 1997)

Criteria		USEPA Screening[1]	Simple Method[1]	Regression Method[1]	SLOSS-PHOSPH[2]	Watershed	FHWA	WMM
Land Uses	Urban	○	◒	◒	–	◒	○[3]	●
	Rural	◒	–	○	◒	◒	○	●
	Point Sources	–	–	–	–	○	–	○
Time Scale	Annual	●	●	●	●	●	●	●
	Single Event	○	○	○	–	–	○	–
	Continuous	–	–	–	–	–	–	–
Hydrology	Runoff	–[4]	◒	–	–	–	○	○
	Baseflow	–	–	–	–	–	–	○
Pollutant Loading	Sediment	◒	◒	◒	◒	◒	–	–
	Nutrients	◒	◒	◒	◒	◒	◒	◒
	Others	○	◒	◒	–	◒	◒	◒
Pollutant Routing	Transport	–	–	–	–	–	–	–
	Transformation	–	–	–	–	–	–	○
Model Output	Statistics	–	–	–	–	◒	○	○
	Graphics	–	–	–	–	◒	–	○
	Format Options	–	–	–	–	◒	–	○
Input Data	Requirements	○	○	○	○	○	○	○
	Calibration	–	–	–	○	◒	–	◒
	Default Data	●	●	◒	◒	○	◒	◒
	User Interface	–	–	–	–	◒	○	◒
BMPs	Evaluation	○	○	–	○	◒	◒	◒
	Design Criteria	–	–	–	–	–	–	–
Documentation		●	●	●	●	●	●	◒

[1] Not a computer program
[2] Coupled with GIS
[3] Highway drainage basins
[4] Extended Versions recommended use of SCS-curve number method for runoff estimation

● High ◒ Medium ○ Low – Not Incorporated

Mid-range models attempt a compromise between the empiricism of the simple models and complexity of detailed mechanistic models. Mid-range models are designed to estimate the importance of pollutant contributions from multiple land uses and many individual source areas in a watershed. Therefore, they require less aggregation of the watershed physiographic characteristics than the simple models. Mid-range models may be used to define large areas for pollution migration programs on a watershed basis and make qualitative evaluations of BMP alternatives. A list of models within the mid-range category and their capabilities is shown in Table 6-2.

Table 6-2 Evaluation of Watershed Model Capabilities - Mid-Range Models (USEPA 1997)

Criteria		SITEMAP	GWLF	P8-UCM	Auto-QI	AGNPS	SLAMM
Land Uses	Urban	●	●	●	●	–	●
	Rural	●	●	–	–	●	–
	Point Sources	◒	◒	●	–	●	●
Time Scale	Annual	–	–	–	–	–	–
	Single Event	○	–	●	–	●	–
	Continuous	●	●	●	●	–	●
Hydrology	Runoff	●	●	●	●	●	●
	Baseflow	○	●	○	○	–	○
Pollutant Loading	Sediment	–	●	●	●	●	●
	Nutrients	●	●	●	●	●	●
	Others	–	–	●	●	–	●
Pollutant Routing	Transport	○	○	○	◒	●	◒
	Transformation	–	–	–	–	–	–
Model Output	Statistics	◒	○	–	–	–	○
	Graphics	◒	◒	●	–	●	○
	Format Options	●	●	●	○	●	●
Input Data	Requirements	◒	◒	◒	◒	◒	◒
	Calibration	○	○	○	◒	○	◒
	Default Data	●	●	◒	○	◒	◒
	User Interface	●	●	●	◒	◒	●
BMPs	Evaluation	○	○	●	◒	◒	◒
	Design Criteria	–	–	●	◒	◒	○
Documentation		●	●	●	◒	●	◒

● High ◒ Medium ○ Low – Not Incorporated

Detailed models use storm event or continuous simulation to predict flow and pollutant concentrations for a range of flow conditions. These models explicitly simulate the physical processes of infiltration, runoff, pollutant accumulation, instream effects, and groundwater/surface water interaction. These models are complex and were not designed with emphasis on their potential use by the typical state or local planner. Many of these models were developed for research into the fundamental land surface and instream processes that influence runoff and pollutant generation rather than to communicate information to decision-makers faced with planning watershed management (USEPA 1997). Although detailed or complex models provide a comparatively high degree of realism in form and function, complexity does not come without a price of data requirements for model construction, calibration, verification, and operation. If the necessary data are not available, and many inputs must be based upon professional judgment or taken from literature, the resulting uncertainty in predicted values undermine the potential benefits from greater realism. Based on the available data for the Big Muddy River Watershed, a detailed model could not be constructed, calibrated, and verified with certainty and the watershed model selection should focus on the simple or mid-range models.

6.2.1.1 Watershed Model Recommendation

The watershed model recommendation for Kinkaid Lake is the Generalized Watershed Loading Function (GWLF) model. No watershed models will be utilized for stream TMDLs as methodologies will be utilized for stream segments in the Big Muddy River Watershed. The GWLF model was chosen for the Kinkaid Lake TMDL based on the following criteria:

- ease of use and Illinois EPA familiarity
- compatible with pollutants of concern and existing data
- provide adequate level of detail for decision making

The GWLF manual estimates dissolved and total monthly phosphorus loads in streamflow from complex watersheds. Both surface runoff and groundwater sources are included, as well as nutrient loads from point sources and onsite wastewater disposal (septic) systems. In addition, the model provides monthly streamflow, soil erosion, and sediment yield values (Haith et al. 1996).

6.2.2 Receiving Water Quality Models

Receiving water quality models differ in many ways, but some important dimensions of discrimination include conceptual basis, input conditions, process characteristics, and output. Table 6-3 presents extremes of simplicity and complexity for each condition as a point of reference. Most receiving water quality models have some mix of simple and complex characteristics that reflect tradeoffs made in optimizing performance for a particular task.

Table 6-3 General Receiving Water Quality Model Characteristics

Model Characteristic	Simple Models	Complex Models
Conceptual Basis	Empirical	Mechanistic
Input Conditions	Steady State	Dynamic
Process	Conservative	Nonconservative
Output Conditions	Deterministic	Stochastic

The concept behind a receiving water quality model may reflect an effort to represent major processes individually and realistically in a formal mathematical manner (mechanistic), or it may simply be a "black-box" system (empirical) wherein the output is determined by a single equation, perhaps incorporating several input variables, but without attempting to portray constituent processes mechanistically.

In any natural system, important inputs, such as flow in the river, change over time. Most receiving water quality models assume that the change occurs sufficiently slowly so that the parameter (for example, flow) can be treated as a constant (steady state). A dynamic receiving water quality model, which can handle unsteady flow conditions, provides a more realistic representation of hydraulics, especially those conditions associated with short duration storm flows, than a steady-state model. However, the price of greater realism is an increase in model complexity that may be neither justified nor supportable.

The manner in which input data are processed varies greatly according to the purpose of the receiving water quality model. The simplest conditions involve conservative substances where the model need only calculate a new flow-weighted concentration when a new flow is added (conservation of mass). Such an approach is unsatisfactory for constituents such as DO or labile nutrients, such as nitrogen and phosphorus, which will change in concentration due to biological processes occurring in the stream.

Whereas the watershed nonpoint model's focus is the generation of flows and pollutant loads from the watershed, the receiving water models simulate the fate and transport of the pollutant in the water body. Table 6-4 presents the steady-state (constant flow and loads) models applicable for this watershed. The steady-state models are less complex than the dynamic models. Also, as discussed above, the dynamic models require significantly more data to develop and calibrate an accurate simulation of a water body.

Table 6-4 Descriptive List of Model Components - Steady-State Water Quality Models

Model	Water Body Type	Parameters Simulated	Process Simulated	
			Physical	Chemical/Biological
USEPA Screening Methods	River, lake/ reservoir, estuary, coastal	Water body nitrogen, phosphorus, chlorophyll "a," or chemical concentrations	Dilution, advection, dispersion	First order decay - empirical relationships between nutrient loading and eutrophication indices
EUTROMOD	Lake/reservoir	DO, nitrogen, phosphorus, chlorophyll "a"	Dilution	Empirical relationships between nutrient loading and eutrophication indices
BATHTUB	Lake/reservoir	DO, nitrogen, phosphorus, chlorophyll "a"	Dilution	Empirical relationships between nutrient loading and eutrophication indices
QUAL2E	Rivers (well mixed/shallow lakes or estuaries)	DO, CBOD, arbitrary, nonconservative substances, three conservative substances	Dilution, advection, dispersion	First order decay, DO-BOD cycle, nutrient-algal cycle
EXAMSII	Rivers	Conservative and nonconservative substances	Dilution, advection, dispersion	First order decay, process kinetics, daughter products, exposure assessment
SYMPTOX3	River/reservoir	Conservative and nonconservative substances	Dilution, advection, dispersion	First order decay, sediment exchange
STREAMDO	Rivers	DO, CBOD, and ammonium	Dilution	First order decay, BOD-DO cycle, limited algal component

6.2.2.1 Receiving Water Model Recommendation

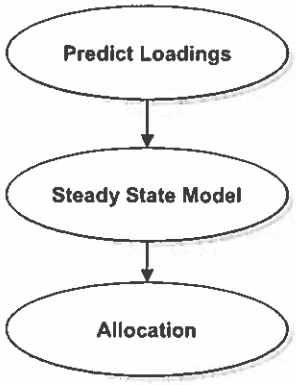
The receiving water model recommended for Kinkaid Lake is BATHTUB, which applies a series of empirical eutrophication models to reservoirs and lakes. The program performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network that accounts for advective and diffusive transport, and

nutrient sedimentation. Eutrophication-related water quality conditions are predicted using empirical relationships (USEPA 1997).

Because of the lack of spatial data sets for the stream segments within the Big Muddy River Watershed, methodologies based on the USEPA Screening Methods and Monte Carlo simulations will be utilized for stream TMDL development as discussed in the following section.

6.2.3 Kinkaid Lake TMDL

For Kinkaid Lake, a TMDL for pH will be completed using a watershed/receiving water model combination. The strategy for completing the watershed/receiving water model TMDL for Kinkaid Lake is shown in the schematic to the right. This strategy applies to constituents whose loads can be predicted using GWLF. This approach allows a linkage between source and endpoint resulting in an allocation to meet water quality standards. After loads are predicted, the BATHTUB model will be used to determine the resulting phosphorus concentrations within Kinkaid Lake. Model development is discussed further in Section 7.



Schematic 1
Strategy for Lake TMDL Modeling

6.2.4 Stream TMDLs for the Big Muddy River Watershed

Because of limited data available for watershed and receiving water model development for the Big Muddy River Watershed, TMDLs for the following constituents will be completed using methodologies: sulfates, pH, DO, and manganese. For DO, a Streeter-Phelps analysis based on the USEPA Screening Procedures was developed. This analysis is described in Section 8. For sulfates and manganese, a Monte Carlo simulation was conducted, and the description of this analysis is also contained in Section 8. For pH, an analysis based on recurrence interval and pH was created, and this discussion is also included in Section 8.

6.2.5 Calibration and Validation of Models

The results of loading and receiving water simulations are more meaningful when they are accompanied by some sort of confirmatory analysis. The capability of any model to accurately depict water quality conditions is directly related to the accuracy of input data and the level of expertise required to operate the model. It is also largely dependent on the amount of data available. Calibration involves minimization of deviation between measured field conditions and model output by adjusting parameters of the model. Data required for this step are a set of known input values along with corresponding field observation results. Validation involves the use of a second set of independent information to check the model calibration. The data used for validation should consist of field measurements of the same type as the data output from the model. Specific features such as mean values, variability, extreme values, or all predicted values may be of interest to the modeler and require testing. Models are

tested based on the levels of their predictions, whether descriptive or predictive. More accuracy is required of a model designed for absolute versus relative predictions. If the model is calibrated properly, the model predictions will be acceptably close to the field predictions.

The GWLF and BATHTUB models were calibrated based on existing data. As will be outlined in Section 7, the GWLF model was calibrated based on historical flow records. The calibration factors taken into account for the GWLF model were the recession constant and seepage constant. Water quality data on the tributaries to Kinkaid Lake were not available so the GWLF model could not be calibrated to tributary nutrient loads. Nutrient loads were based on literature values for Southern Illinois. GWLF model validation was not conducted, as the hydrology was calibrated based on 16 years of observed flow. Data collection activities needed to calibrate nutrient loads are outlined in Section 9 Implementation Plan. The calibration process for the BATHTUB model is also outlined in Section 7. For Kinkaid Lake, loads from a below normal, above normal, and dry precipitation year were taken from GWLF and entered into the BATHTUB model, which predicted average in-lake concentrations that were in turn compared to observed lake concentrations as the basis for calibration.

6.2.6 Seasonal Variation

Consideration of seasonal variation, such that water quality standards for the allocated pollutant will be met during all seasons of the year, is a requirement of a TMDL submittal. TMDLs must maintain or attain water quality standards throughout the year and consider variations in the water body's assimilative capacity caused by seasonal changes in temperature and flow (USEPA 1999). Seasonal variation for the Kinkaid Lake Watershed is discussed in Section 8 and for the Big Muddy River Watershed discussed in Section 11.

6.2.7 Allocation

Establishing a TMDL requires the determination of the LC of each stream segment. The models or methodologies were used to establish what the LC is for each segment for each pollutant. The next step was to determine the appropriate MOS for each segment. After setting the MOS, WLA of point sources and LA from the nonpoint sources were set.

The MOS can be set explicitly as a portion of the LC or implicitly through applying conservative assumptions in data analysis and modeling approaches. Data analyses and modeling limitations were taken into account when recommending a MOS. The allocation scheme (both LA and WLA) demonstrates that water quality standards will be attained and maintained and that the load reductions are technically achievable. The allocation is the foundation for the implementation and monitoring plan. Further discussion on the allocation is presented in Section 9.

6.2.8 Implementation and Monitoring

For the Big Muddy River Watershed, a plan of implementation was produced to support the developed TMDL. The plan of implementation has reasonable assurance of being achieved. The plan provides the framework for the identification of the actions that must be taken on point and nonpoint sources to achieve the desired TMDLs. The accomplishment of the necessary actions to reach these targets may involve substantial efforts and expenditures by a large number of parties within the watershed. Depending upon the specific issues and their complexity in the Big Muddy River Watershed, the time frame for achieving water quality standards has been developed.

The implementation plan delineates a recommended list of the sources of stressors that are contributing to the water quality impairments. The amount of the reduction needed from various sources to achieve the water quality limiting parameter was then delineated. For nonpoint sources, the use of BMPs is one way to proceed to get the desired reduction in loading. The effectiveness of various BMPs was factored into the modeling and methodologies to develop the range of options of BMPs to use. Associated with those BMPs is cost information, as available. Reductions from point services through waste stream management, pretreatment controls, and other structural and nonstructural programs were also identified as applicable. The implementation plan for the Big Muddy River Watershed is presented in Section 12.

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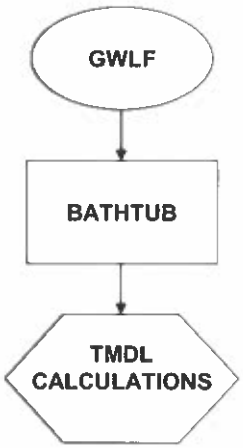
Section 7
Model Development for Kinkaid Lake

7.1 Basis for pH TMDL

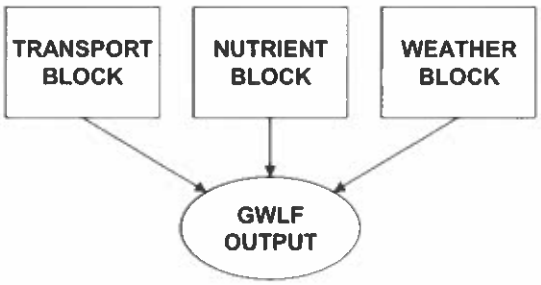
The relationships between pH, chlorophyll "a," and phosphorus were discussed in Section 5.1.5.1.1. Figures 7-1 and 7-2 show the relationship between chlorophyll "a" and pH at Kinkaid Lake stations RNC-1 and RNC-3, respectively. The relationships are only provided at these two locations because samples at stations RNC-2 and RNC-4 did not show exceedences of the pH standard. As explained in Section 5.1.5.1.1, the figures are expected to show an increase with pH as chlorophyll "a" increases. Increased chlorophyll "a" concentrations may also lead to low pH values as the CO_2 decreases during respiration. The relationship between chlorophyll "a" and phosphorus at stations RNC-1 and RNC-3 are shown in Figures 7-3 and 7-4, respectively. Likewise, these figures are expected to show a direct relationship between the constituents. The relationships presented in Figures 7-1 through 7-4 provide general trends between model constituents and represent the data available from sampling. The general relationships shown in Figures 7-1 through 7-4 suggest that controlling total phosphorus will decrease chlorophyll "a" concentrations, which will in turn bring pH into the range required for compliance with water quality standards. The TMDL will be based on the existing relationships with the knowledge that a larger data set would result in a more robust TMDL. It is therefore recommended that a TMDL endpoint of 0.05 mg/L for total phosphorus for Kinkaid Lake be utilized so that the pH standard is achieved.

7.2 Model Overview

The models used for the TMDL analysis of Kinkaid Lake were GWLF and BATHTUB. These models require input from several sources including online databases, GIS-compatible data, and hardcopy data from various agencies. This section describes the existing data reviewed for model development, model inputs, and model calibration and verification.



Schematic 1 Models used for Kinkaid Lake TMDL calculation.

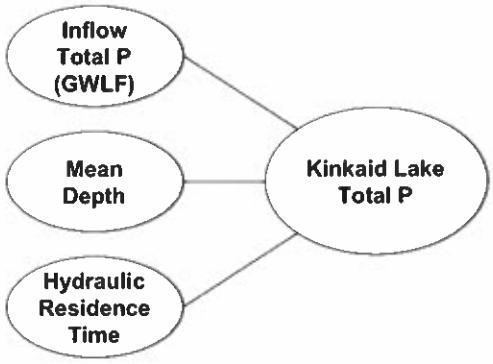


Schematic 2 GWLF Model

Schematic 1 shows how the GWLF model and BATHTUB model are utilized in calculating the TMDL. The GWLF model predicts phosphorus loads from the watershed. These loads are then inputted in the BATHTUB model to assess resulting phosphorus concentrations. The GWLF model outlined in Schematic 2 shows how GWLF predicts phosphorus loads from the watershed. The transport

block of the GWLF model uses the Universal Soil Loss Equation to determine erosion in the watershed. The transport block also calculates runoff based on the SCS Curve Number equation. The nutrient block allows the model user to input concentrations of phosphorus contained in the soil and in the dissolved phase for runoff. These two blocks, in conjunction with the weather block, predict both solid and dissolved phosphorus loads.

Schematic 3 shows how, by using total phosphorus concentrations predicted from GWLF, the resulting in-lake total phosphorus concentrations can be predicted. The BATHTUB model uses empirical relationships between mean reservoir depth, total phosphorus inputted into the lake, and the hydraulic residence time to determine in-reservoir concentrations.



Schematic 3
BATHTUB Model Schematic

7.3 Model Development and Inputs

The ability of the GWLF and BATHTUB models to accurately reflect natural processes depends on the quality of the input data. The following sections describe the selection, organization, and use of existing data as input to the GWLF and BATHTUB models and outline assumptions made in the process.

Due to the size of the Kinkaid Lake Watershed and the multiple tributaries contributing to the lake, the watershed area was divided into four subwatersheds for accurate representation in the GWLF model. Flows within each of the subbasins were calculated from gage 05595820 with the drainage area ratio method presented in Section 5.1.3. To model Kinkaid Lake accurately in BATHTUB, the lake was divided in four sections surrounding each of the three monitoring stations.

7.3.1 Watershed Delineation

Prior to developing input parameters for the GWLF or BATHTUB models, a watershed for Kinkaid Lake was delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation indicates that Kinkaid Lake captures flows from a watershed of approximately 60.3 square miles, which is consistent with the drainage area of 60.5 square miles reported in the watershed plan (KAWP 2000). The flow through the lake is primarily from northeast to southwest. Figure 7-5 at the end of this section shows the location of each water quality station in Kinkaid Lake, the boundary of the GIS-delineated watershed contributing to Kinkaid Lake, the four subbasins used in GWLF modeling, and the division of the lake for BATHTUB modeling purposes.

7.3.2 GWLF Inputs

GWLF requires input in the form of three data files that represent watershed parameters, nutrient contributions, and weather records. Each data file will be discussed in the following sections. The input files and actual values used for each parameter are listed in Appendix C. The GWLF manual is contained in Appendix D.

DEMs of 30-meter resolution were downloaded from the USGS National Elevation Dataset for development of GWLF model parameters discussed in this section (USGS 2002b).

7.3.2.1 Transport Data File

The transport data file provides watershed parameters including land use characteristics, evapotranspiration and erosion coefficients, groundwater and streamflow characteristics, and initial soil conditions. Table 7-1 presents each transport file input parameter and its source. Those requiring further explanation are discussed in the next section.

Table 7-1 Data Needs for GWLF Transport File (Haith et al. 1996)

Input Parameter	Source
Land Use	Critical Trends Assessment Database, GIS
Land Use Area	GIS
Curve Number	*STATSGO*, GIS, Critical Trends Assessment Database, TR-55 Manual, WMM Manual
KLSCP	*STATSGO*, GIS, DEM, GWLF Manual pages 34 and 35, NRCS
Evapotranspiration Cover Coefficient	GWLF Manual page 29
Daylight Hours	GWLF Manual page 30
Growing Season	GWLF Manual Recommendation page 54
Erosivity Coefficient	GWLF Manual pages 32 and 37
Sediment Delivery Ratio	GIS, GWLF Manual page 33
5-day Antecedent Rain and Snow	GWLF Manual Recommendation page 37
Initial Unsaturated Storage	GWLF Manual Recommendation page 30
Initial Saturated Storage	GWLF Manual Recommendation page 37
Recession Constant	Calibrated
Seepage Constant	Calibrated
Initial Snow	GWLF Manual Recommendation page 37
Unsaturated Available Water Capacity	GWLF Manual Recommendation page 37

7.3.2.1.1 Land Use

Land use for the Kinkaid Lake Watershed was extracted from the Critical Trends Assessment Database grid for Jackson County in GIS. Within the transport input file, each land use must be identified as urban or rural. The land uses were presented in Table 5-12.

Individually identifying each field of crops or urban community in GWLF would be time intensive, so each land use class was aggregated into one record for GIS and GWLF representation. For example, the area of each row crop field was summed to provide a single area for row crops. Additionally, the parameters for each row crop field were averaged to provide a single parameter for the row crop land use. Details of the parameter calculation are contained in the remainder of this section.

GWLF computes runoff, erosion, and pollutant loads from each land use, but it does not route flow over the watershed. For example, the model does not recognize that runoff may flow from a field of corn over grassland and then into the river. The model assumes all runoff from the field of corn drains directly to the stream. Therefore, the location of each land use is irrelevant to the model allowing each land use class to be aggregated into a single record.

To provide accurate modeling in GWLF, the rural grassland land use class, presented in Table 5-12, was separated into two subclasses of pasture and grassland based on the recommendation of the Jackson County NRCS (2002a). The GWLF model requires nutrient runoff concentrations for each land use, and the two subclasses of rural grassland have varying concentrations. The area of each subclass was estimated from the GIS-derived rural grassland area and suggested percentages of each subclass by the Jackson County NRCS (2002a).

Due to the detailing of crops, the Cropland Data Layer land use classes, presented in Table 5-14, were used to generate evapotranspiration cover coefficients, cropping management factors, and to verify the land use obtained from the Critical Trends Assessment. Land uses used in GWLF correspond to land uses in the Critical Trends Assessment, so calculations based on the Cropland Data Layer land use classes were typically weighted by area to match the Critical Trends Assessment classes. Details of the calculations are presented in later sections and Appendix E.

7.3.2.1.2 Land Use Area

GIS was used to summarize the area of each aggregated land use in square meters as well as acres and hectares. Area in hectares was input for each land use in the transport data file.

7.3.2.1.3 Curve Number

The curve number, a value between zero and 100, represents the ability of the land surface to infiltrate water, which decreases with increasing curve number. The curve number is assigned with consideration to hydrologic soil group and land use. The hydrologic soil group, represented by the letters A through D, denotes how well a soil drains. A well-drained, sandy soil would be classified as a type A soil, whereas clay would be classified as a type D soil. This property is identified in the *STATSGO* attribute table for each soil type.

Assigning curve numbers to a large area with multiple soil types and land uses was streamlined using the GIS *ArcView* project, CRWR-PrePro (Olivera 1998), developed at the University of Texas at Austin. This process was used to develop a curve number grid. Scripts in the project intersect shapefiles of land use and soil with the *STATSGO* attribute table to create a grid in which each cell contains a curve number based on the combination.

The transport data file requires that a single curve number be associated with each land use. To accomplish this, the curve number in each grid cell was averaged over each aggregated land use area. Details of the GIS process are provided in Appendix E.

7.3.2.1.4 KLSCP

GWLF uses the Universal Soil Loss Equation, represented by the following equation (Novotny and Olem 1994), to calculate soil erosion.

$$A = (R)(K)(LS)(C)(P)$$

where A = calculated soil loss in tons/ha for a given storm or period
R = rainfall energy factor
K = soil erodibility factor
LS = slope-length factor
C = cropping management factor
P = supporting practice factor

The combined coefficient, KLSCP, is required as input to GWLF for each rural land use. The development of each factor will be discussed in the next sections. GWLF calculates the rainfall energy factor (R) with precipitation and a rainfall erosivity coefficient that will be discussed in Section 7.3.2.1.5.

Soil Erodibility Factor (K). The soil erodibility factor, K, represents potential soil erodibility. The *STATSGO* soils representation in GIS is by map unit, which incorporates multiple soil types (and K-values) in each unit, but the *STATSGO* attribute table lists the K factor for each soil type. Using this column, a weighted K factor was developed for each GIS map unit. Details of this process are provided in Appendix E.

Topographic Factor (LS). The topographic, or LS, factor represents the contribution to erosion from varying topography. This factor is independent of soil type, but dependent on land use and land surface elevations, requiring use of the DEM. Multiple equations and methodologies are used to calculate the LS factor and for this application we used methodology outlined in the *TMDL USLE* software package (USEPA 2001). The LS factor was calculated with a series of equations that compute intermediate values of slope steepness, runoff length, and rill to interill erosion before combining them into the LS factor. This process was also performed with GIS analyses to automate computational tasks. Details of the GIS computation are provided in Appendix E.

Cropping Management Factor (C). The cropping management factor, C, represents the influence of ground cover, soil condition, and management practices on erosion. The Jackson County NRCS office provided a table of C factors for various crops and tillage practices (NRCS 2002a). The table is included as Appendix F. The NRCS office also estimated the percentage of each tillage practice for corn, soybeans, and small grains in the Kinkaid Lake Watershed (NRCS 2002a). Although the percentage of each tillage practice is known, the specific locations in the watershed to which these practices are applied were unknown, so a weighted C-factor was created for these

crops. In Table 7-2, the weighted C factor for corn, soybeans, and small grains and the C factor for other land uses are listed by the Cropland Data Layer land uses and areas in the Kinkaid Lake Watershed.

Table 7-2 Cropland Data Layer Land Uses and C Factors

Land Use	Area (acres)	C factor
Corn	1,590	0.21
Sorghum	0	–
Soybeans	1,702	0.08
Winter Wheat	271	0.13
Other Small Grains & Hay	1,315	0.13
Double-Cropped WW/SB	1,038	0.12
Idle Cropland/CRP	20	0.02
Fallow/Idle Cropland	2,310	0.02
Pasture/Grassland/Nonag	7,937	0.02
Woods	19,220	0.003
Clouds	87	–
Urban	322	–
Water	1,962	–
Buildings/Homes/Subdivisions	438	–
Wetlands	388	–

The identification of crops is more detailed in the Cropland Data Layer file than the Critical Trends Land Assessment file, but the latter is used for GWLF input. Therefore, the C factor associated with the Cropland Data Layer land uses was weighted by area to create a C factor for the Critical Trends Land Assessment land uses shown in Table 7-3. A more detailed description of the weighting procedure is provided in Appendix E.

Table 7-3 Critical Trends Land Assessment Land Uses and C Factors

	Subbasin 1		Subbasin 2		Subbasin 3		Subbasin 4	
Land Use	Area (ac)	C-factor	Area (ac)	C-factor	Area (ac)	C-factor	Area (ac)	C-factor
High Density	12	–	0	–	0	–	0	–
Medium Density	89	–	0	–	0	–	0	–
Row Crop	2,618	0.14	217	0.11	35	0.12	705	0.14
Small Grains	573	0.13	21	0.13	1	0.13	156	0.13
Urban Grassland	17	0.02	0	–	0	–	0	–
Rural Grassland	6,080	0.02	984	0.02	142	0.020	1,724	0.02
Deciduous1	11,850	0.003	4,330	0.003	1,916	0.003	3,402	0.003
Deciduous2	54	0.003	7	0.003	3	0.003	34	–
Coniferous	304	0.003	113	0.003	44	0.003	0	–
Open Water	240	–	489	–	405	–	1,569	–
Shallow Marsh/ Wetland	23	–	2.7	–	0	–	1	–
Deep Marsh	5	–	0	–	0	–	2	–
Forested Wetland	308	–	2	–	9	–	49	–
Shallow Water Wetland	34	–	7	–	2	–	18	–
Barren Land	5	–	0	–	0	–	0	–

Supporting Practice Factor (P). The supporting practice factor, P, represents erosion control provided by various land practices such as contouring or terracing. None of these land practices are utilized in the Kinkaid Lake Watershed, so a P factor of one was assigned to each land use.

7.3.2.1.5 Erosivity Coefficient

The erosivity coefficient varies spatially across the United States. Figure B-1 on page 32 of the GWLF manual places Kinkaid Lake in Zone 19, which corresponds to a cool season rainfall erosivity coefficient of 0.14 and a warm season coefficient of 0.27.

7.3.2.1.6 Evapotranspiration (ET) Cover Coefficient

An ET cover coefficient for each month is required as an input parameter to GWLF representing the effects of ground cover on evapotranspiration. Ground cover changes with land use and growing season, so the computation of a single cover coefficient for each month required a series of calculations. ET cover coefficients for corn, winter wheat, sorghum, and soybeans at 10 percent increments of the growing season were obtained from GWLF Manual, page 29. These coefficients were weighted by the area of each crop in the Cropland Data Layer land use file to compute a single crop ET cover coefficient for each 10 percent increment of the growing season. The crop coefficients for each portion of the growing season were averaged to obtain a single crop coefficient for each calendar month. Monthly ET cover coefficients for pasture, woods, and urban areas were also obtained from pages 29 and 30 of the GWLF Manual. A monthly cover coefficient for water and wetlands was assumed to be 0.75. Weighting the coefficient for each land use by the Cropland Data Layer land use area created a single ET cover coefficient for each month. Details of the ET cover coefficient calculation are provided in Appendix E.

7.3.2.1.7 Recession Constant

The recession coefficient controls the falling limb of the hydrograph in GWLF. This coefficient was calibrated to USGS streamflow and is discussed in Section 7.4.1.

7.3.2.1.8 Seepage Constant

The seepage constant controls the amount of water lost from the GWLF system by deep seepage. This value was also determined by calibration and is detailed in Section 7.4.1.

7.3.2.1.9 Sediment Delivery Ratio

The sediment delivery ratio is based on watershed area. The watershed area determined by GIS was used to obtain the corresponding sediment delivery ratio from the chart on page 33 of the GWLF manual. The sediment delivery ratios representing the annual sediment yield per annual erosion for each subbasin contributing to Kinkaid Lake are presented in Table 7-4.

Table 7-4 Sediment Delivery Ratios in Kinkaid Lake Watershed

Subbasin	Area (ac)	Sediment Delivery Ratio
1	22,210	0.13
2	6,175	0.18
3	2,557	0.22
4	7,661	0.17

7.3.2.2 Nutrient Data File

The nutrient input file contains information about dissolved phosphorus and nitrogen from each rural land use, solid-phase phosphorus and nitrogen from urban runoff, solid-phase nutrient concentrations in the soil and groundwater, and any point source inputs of phosphorus or nitrogen.

All solid-phase nutrient concentrations from runoff for Kinkaid Lake were obtained from the GWLF manual. Figure B-4 (page 39 of Appendix D) was utilized for determining solid-phase phosphorus concentrations in the soil. A mid-range value of 0.07 percent phosphate was selected and then converted to 700 parts per million (ppm) using the relationship 0.1 percent = 1,000 ppm. Phosphate is composed of 44 percent phosphorus, so the 700 ppm phosphate was multiplied by 0.44 to obtain a value of 308 ppm phosphorus in the sediment. This solid-phase phosphorus concentration was multiplied by the recommended enrichment ratio of 2.0 and therefore a total solid-phase concentration of 616 ppm was utilized for modeling purposes. The enrichment ratio represents the ratio of phosphorus in the eroded soil to that in the non-eroded soil. Specific soil phosphorus data is not available, so the GWLF manual recommended enrichment ratio of 2.0 was used. Dissolved phosphorus concentrations in the runoff from each agricultural land use were obtained from page 41 of the GWLF manual with the exception of grassland under the rural grassland land use and concentrations from animal management facilities. The grassland dissolved phosphorus concentration was estimated from the dissolved phosphorus concentration for pasture. Grassland is assured to have less animals, and therefore less animal waste, than pasture land, so the concentration was reduced for hayland. The selection of dissolved phosphorus concentrations will be confirmed in Section 7.4.1. The runoff phosphorus concentration from the feedlots and animal management areas were obtained from Novotny and Olem with a range of 4 to 15 mg/L (1994). The concentrations used to model the animal management areas were dependent on the impact each facility had on the receiving waters as recorded in the GIS file discussed in Section 5.1.7. One feedlot was identified in the Kinkaid Lake Watershed as potentially having a slight impact on water quality and one facility was identified as potentially having no impact on water quality in the receiving stream. The animal management facilities in the Kinkaid Lake Watershed were assigned dissolved phosphorus concentrations of 4 and 5.5 mg/L for the no impact and slight impact facilities, respectively, because these are at the lower end of the literature range.

Table 7-5 Dissolved Phosphorus Concentrations in Runoff from the Kinkaid Lake Watershed

Land Use	Dissolved Phosphorus (mg/L)
Row Crop	0.26
Small Grains	0.30
Rural Grasslands	
Pasture	0.25
Grassland	0.15
Deciduous Forest	0.009
Coniferous Forest	0.009
Animal Management Facility	4.5 - 15
Barren Land	0.008
Urban-High Density	0.01

Table 7-5 lists the land uses in the Kinkaid Lake Watershed and associated runoff phosphorus concentrations used in the GWLF model. It should be noted that although the majority of dissolved phosphorus concentrations in Table 7-5 exceed the endpoint of 0.05 mg/L of total phosphorus, once the surface runoff reaches Kinkaid Lake or its tributaries, it mixes with water already in the stream or lake and the

concentration decreases. Therefore, it cannot be concluded without analysis that constituents with dissolved concentrations above the endpoint for total phosphorus are responsible for water quality impairments.

The GWLF manual suggests nutrient concentrations in groundwater based on the percentage of agricultural versus forestlands. These percentages were calculated from the land use areas in the watershed, and the appropriate groundwater concentrations were selected from the GWLF manual, page 41. The percentage of agricultural lands in each subbasin and their corresponding groundwater dissolved phosphorus concentrations are provided in Table 7-6.

Table 7-6 Percentage of Agricultural and Forest Lands and Groundwater Phosphorus Concentrations in the Kinkaid Lake Watershed (Haith et al. 1996)

Subbasin	Agriculture	Forest	Dissolved Phosphorus (mg/L)
1	42%	55%	0.015
2	20%	72%	0.012
3	7%	77%	0.012
4	34%	45%	0.015

7.3.2.3 Weather Data File

The weather data file is a text file of daily precipitation and temperature and was compiled from weather data presented in Section 5.1.4. An excerpt of the weather data file is recorded in Appendix C. The precipitation data are used in GWLF to determine runoff, erosion, and evapotranspiration, and temperature data are used to compute potential evaporation and snowmelt.

7.3.3 BATHTUB Inputs

BATHTUB has three primary input interfaces: global, reservoir segment(s), and watershed inputs. The individual inputs for each of these interfaces are described in the following sections and the data input screens are provided in Appendix C.

Multiple simulations of the BATHTUB model were run to investigate variations in total phosphorus concentrations in a wet, normal, and dry year of precipitation to bracket conditions for calibration. The first step in choosing the wet, normal, and dry years was to calculate average annual precipitation. BATHTUB models lake concentrations based on a water year (October to September), so the precipitation data presented in Section 5.1.4 were averaged to coincide with the water year. Table 7-7 shows these annual and average annual precipitation values in Jackson County. Each water year was then

Table 7-7 Annual Precipitation in Jackson County

Model Year	Precipitation (inches)
1986	52
1987	35
1988	43
1989	47
1990	48
1991	41
1992	43
1993	54
1994	44
1995	46
1996	57
1997	49
1998	45
1999	40
2000	51
Average	**46**

classified as wet, dry, or normal based on a comparison to the average water year precipitation of 46 inches. Another consideration in selecting the years for simulation was determining which years coincided with the collection dates of in-lake total phosphorus concentrations at the water quality stations within recent years. With these criteria, the only years available for modeling Kinkaid Lake are 1994, 1997, and 2000. Based on Table 7-7, 1994 is designated as the normal year and 1997 and 2000 are both designated as wet years.

7.3.3.1 Global Inputs

Global inputs represent atmospheric contributions of precipitation, evaporation, and atmospheric phosphorus. Precipitation was discussed in the previous section and is shown in Table 7-7 for the model years 1994, 1997, and 2000. An average annual evaporation was determined from pan evaporation data as discussed in Section 5.1.4. The default atmospheric phosphorus deposition rate suggested in the BATHTUB model was used in absence of site-specific data, which is a value of 30 kilograms per kilometer squared per year (kg/km^2-yr) (USACE 1999b).

7.3.3.2 Reservoir Segment Inputs

The data included as segment inputs represents reservoir characteristics in BATHTUB. These data were used in BATHTUB simulations and for calibration targets. The calibration targets are observed water quality data summarized in Section 5.1.5.1.

Kinkaid Lake was modeled as four segments in BATHTUB to represent the lake characteristics around each water quality station, so an average annual value of total phosphorus was calculated for each site for input of observed data. The lake segments are shown in Figure 7-5 at the end of this section. The averages of total phosphorus sampled at one-foot depth were presented in Table 5-6; however, the BATHTUB model calculates an average lake concentration. Therefore, total phosphorus samples at all depths were averaged to provide targets for the BATHTUB model. Table 7-8 shows the average annual total phosphorus concentrations for all sample depths at each station in Kinkaid Lake for the years modeled. As mentioned in Section 5.1.5.1.2, station RNC-1 had samples taken at one-foot depth from the surface and at the lake bottom, whereas stations RNC-2, RNC-3, and RNC-4 were only sampled at one-foot depth. The raw data for all sample depths are contained in Appendix A.

Table 7-8 Average Total Phosphorus Concentrations in Kinkaid Lake (mg/L) over All Depths

Year	RNC-1	RNC-2	RNC-3	RNC-4	Lake Average
1994	0.03	0.02	0.04	0.14	0.05
1997	0.04	0.03	0.04	0.13	0.06
2000	0.03	0.01	0.02	0.05	0.03

Other segment inputs include lake depth, lake length, and depth to the metalimnion. The lake depth was represented by the averaged data from the water quality stations shown in Table 5-16. The lake length was determined in GIS, and the depth to the metalimnion was estimated from a chart of temperature versus depth. The charts are presented in Appendix G.

7.3.3.3 Tributary Inputs

Tributary inputs to BATHTUB are drainage area, flow, and total phosphorus (dissolved and solid-phase) loading. The drainage area of each tributary is equivalent to the basin or subbasin it represents, which was determined with GIS analyses. For the Kinkaid Lake Watershed, the four subbasins modeled in GWLF represent tributary inputs. Loadings were calculated with the monthly flow and total phosphorus concentrations obtained from GWLF output. The monthly values were summed over the water year for input to BATHTUB. To obtain flow in units of volume per time, the depth of flow was multiplied by the drainage area and divided by one year. To obtain phosphorus concentrations, the nutrient mass was divided by the volume of flow.

7.4 Model Calibration and Verification

The GWLF model was calibrated prior to BATHTUB calibration. The GWLF model for the Kinkaid Lake Watershed was calibrated to flow data, as tributary phosphorus concentrations were not available. Nutrient concentrations entered into the GWLF model were calibrated based on response occurring in the BATHTUB model. Therefore, the nutrient block of the GWLF model and the BATHTUB model were calibrated together to reach agreement with observed data in Kinkaid Lake.

7.4.1 GWLF Calibration

The GWLF model must run from April to March to coincide with the soil erosion cycle. GWLF does not retain erodible sediment between model years, so the model year must begin after the previous year's sediment has been washed off. The model assumes that the soil erosion cycle begins with spring runoff events in April and that erodible soil for the year has been washed off by the end of winter for the cycle to begin again the following April. GWLF generates monthly outputs including precipitation, flow, runoff and nutrient mass per watershed, and annual outputs including precipitation, flow, runoff, and nutrient mass per land use. These outputs are part of the input for the BATHTUB model.

Instream nutrient data was not available for model calibration, so GWLF was only calibrated to flow. The monthly average flow output from GWLF was compared to the monthly average streamflow calculated from USGS gage 05595820 with the drainage area ratio method presented in Section 5.1.3. The model flow was calibrated visually through the recession constant and seepage constant. Visual calibration is a subjective approach to model calibration in which the modeler varies inputs to determine the parameter combination that looks like the best fit to the observed data (Chapra 1997). According to the GWLF manual, an acceptable range for the recession constant is 0.01 to 0.2. No range suggestions are provided for the seepage constant. Figure 7-6 (at the end of this section) shows the comparison between the two flows for subbasin 1 of Kinkaid Lake. The GWLF model for Kinkaid Lake was visually calibrated with a resulting recession constant of 0.15 and a seepage constant of 0.15 in each subbasin. Once calibrated, the model output data could properly be included as BATHTUB inputs. The GWLF model was not validated as flow was calibrated by visually

comparing 16 years of observed flow. The summary output from GWLF for each subbasin is included in Appendix C.

Although instream nutrient concentrations are not available for the tributaries to Kinkaid Lake, Clean Lakes Studies have been conducted by the Illinois EPA on various Illinois lake watersheds, which do provide instream nutrient data for lake tributaries including dissolved and total phosphorus. A Clean Lake Study was conducted on Kinkaid Lake during the summer of 2003. The dissolved and total phosphorus concentrations predicted by GWLF for tributaries to the Kinkaid Lake subbasins were compared to the measured dissolved and total phosphorus concentrations from tributaries to lakes observed in the Clean Lakes studies as shown in Figure 7-7.

Table 7-9 shows the comparison between dissolved and total phosphorus in watersheds from Clean Lakes Studies and in the Kinkaid Lake Watershed. The dissolved phosphorus concentration in Subbasin 3 in the Kinkaid Lake Watershed was too low to be calculated by GWLF, so it is assumed to be negligible and presented as zero concentration.

Table 7-9 Percentage of Dissolved Phosphorus to Total Phosphorus Concentrations in Clean Lake Study Watersheds and the Kinkaid Lake Watershed

Watershed	Site	Mean Dissolved Phosphorus (mg/L)	Mean Total Phosphorus (mg/L)	Dissolved / Total Phosphorus
Nashville City	ROO 02	0.68	0.89	0.76
Paradise	RCG 02	0.06	0.07	0.87
Raccoon	RA 02	0.30	0.46	0.66
	RA 03	0.21	0.29	0.71
	RA 04	0.46	0.63	0.73
	RA 05	0.07	0.22	0.30
Lake Lou Yeager	A	0.06	0.13	0.46
	B	0.15	0.16	0.92
	C	0.05	0.25	0.20
	D	0.13	0.17	0.78
	E	0.06	0.12	0.46
	F	0.17	0.20	0.87
	G	0.33	0.41	0.79
	H	0.33	0.35	0.93
	I	0.13	0.14	0.96
Kinkaid	1	0.06	0.18	0.31
	2	0.01	0.10	0.12
	3	0.0	0.07	–
	4	0.03	0.10	0.26

The ratio of dissolved to total phosphorus in the Kinkaid Lake subbasins is within the range of ratios represented by the Clean Lakes Studies, except for Subbasin 2, which is below the low end of the range.

7.4.2 BATHTUB Comparison with Observed Data

The BATHTUB model's response to changes in the GWLF nutrient block were compared to known in-lake concentrations of total phosphorus and chlorophyll "a" for each year of simulation. These known concentrations were presented in Tables 5-6 and 5-7. The BATHTUB manual defines the limits of total phosphorus calibration factors as 0.5 and 2.0.The calibration factor accounts for sedimentation rates, and the limits were determined by error analysis calculations performed on test data sets (USACE 1999). The calibration limits for chlorophyll "a" are not defined in the BATHTUB manual.

The GWLF model was set at a total phosphorus soil concentration of 660 ppm based on comparison with observed data in the BATHTUB model. As part of the comparison process, the watershed was also modeled with a total phosphorus soil concentration of 440 ppm to perform a sensitivity analysis on soil phosphorus. Decreasing the total soil phosphorus concentration shows little impact on the estimated in-lake concentrations (Table 7-10). The calibration factor range for total phosphorus modeling in BATHTUB is 0.5 to 2 and use of the 616-ppm total phosphorus in the soil falls within this accepted range. Table 7-10 also shows what calibration factors for chlorophyll "a" would be required so that estimated concentrations would match observed concentrations. The columns labeled *target* in Table 7-10 represent the average observed in-lake concentrations. The results of the modeling sensitivity analyses are contained in Appendix H.

Table 7-10 Kinkaid Lake Calibration Sensitivity Analysis

Year	In-Lake Target Total Phosphorus (mg/L)	In-Lake Estimated Total Phosphorus (mg/L)	% of Total Loads from Internal Loading Required to Meet Target	Phosphorus Calibration Factor	In-Lake Target Chlorophyll "a" (µg/L)	In-Lake Estimated Chlorophyll "a" (µg/L)	Chlorophyll "a" Calibration Factor
Soil Total Phosphorus 440 ppm							
1994	0.04	0.04	0	1.0	23.6	14.6	1.6
1997	0.05	0.04	0	1.4	19.9	9.9	2.0
2000	0.03	0.04	0	0.6	18.9	12.4	1.5
Soil Total Phosphorus 616 ppm							
1994	0.04	0.03	0	1.2	23.6	13.1	1.8
1997	0.05	0.03	0	1.6	19.9	9	2.2
2000	0.03	0.04	0	0.7	18.9	11.2	1.7

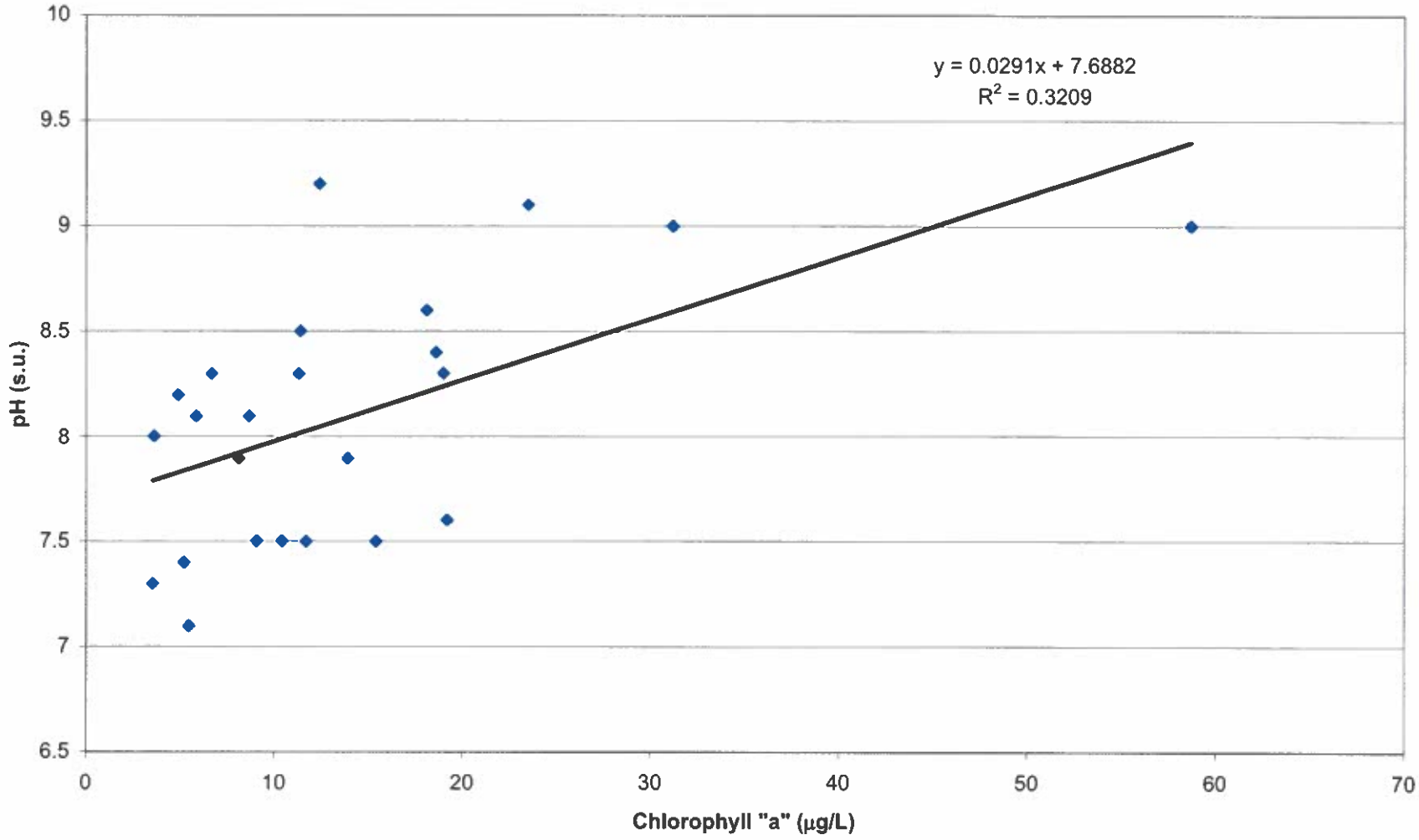
A robust calibration and validation of Kinkaid Lake could not be completed because the following information was not available: observed nutrient concentrations in tributaries to the lake, site-specific data on internal cycling rates, reservoir outflow rates, and nutrient concentrations in reservoir releases. The analysis presented in Table 7-10 is therefore considered a preliminary calibration. However, BATHTUB modeling results indicate a fair estimate between predicted and observed values for the years modeled based on error statistics calculated by the BATHTUB model and should be sufficient for estimating load reductions required in the watershed. BATHTUB calculates three measures of error on each output concentration. If the absolute value

of the error statistic is less than 2.0, the modeled output concentration is within the 95 percent confidence interval for that constituent (USACE 1999b). A robust calibration and validation of Kinkaid Lake will be possible if data collection activities outlined in the future monitoring in Section 9 Implementation are implemented.

Based on modeling results, it appears that internal cycling is not occurring in Kinkaid Lake. The BATHTUB manual notes that internal cycling can be significant in shallow prairie reservoirs and provides Lake Ashtabula (approximately 42 feet deep) as an example (USACE 1999b and 2003). Table 5-17 notes a depth of approximately 62 feet for Kinkaid Lake, which places it outside of the category of shallow reservoir making it appropriate that internal cycling is not occurring in modeled results. Literature sources suggest that internal loading for deeper, more stratified lakes could be in the range of 10 to 30 percent of total loadings and that values for shallower reservoirs could be much higher (Wetzel 1983).

Because the modeling of the Kinkaid Lake changes based on annual loadings and climatic conditions, a validation of the model could not be completed. The model was calibrated for three climatic conditions, which will be the basis for the TMDL analysis presented in Section 8. The preliminary calibrated model was used to estimate the amount of load reductions needed from the watershed to meet water quality standards.

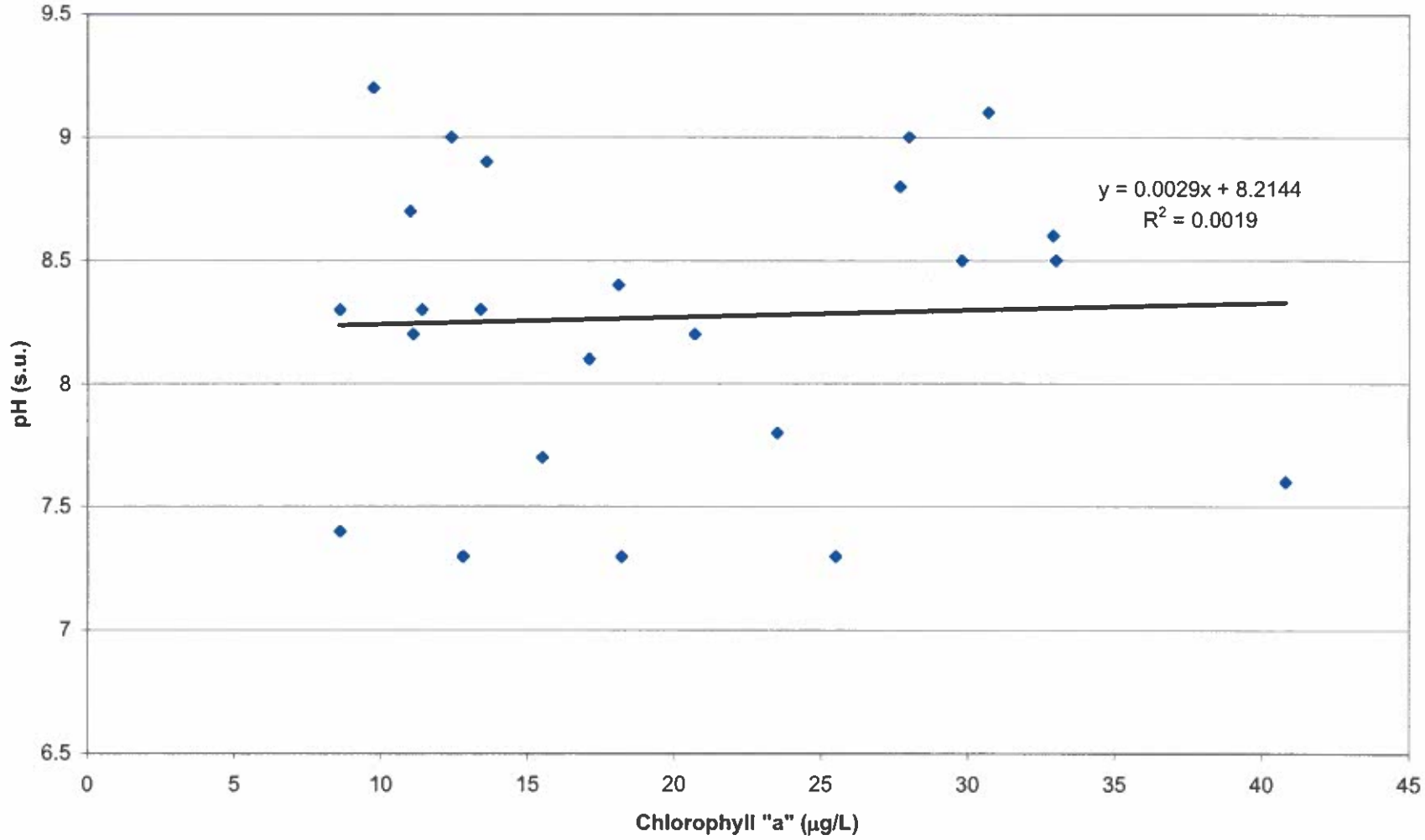
Figure 7-1: Relationship between pH and Chlorophyll "a" at Kinkaid Lake Station RNC-1



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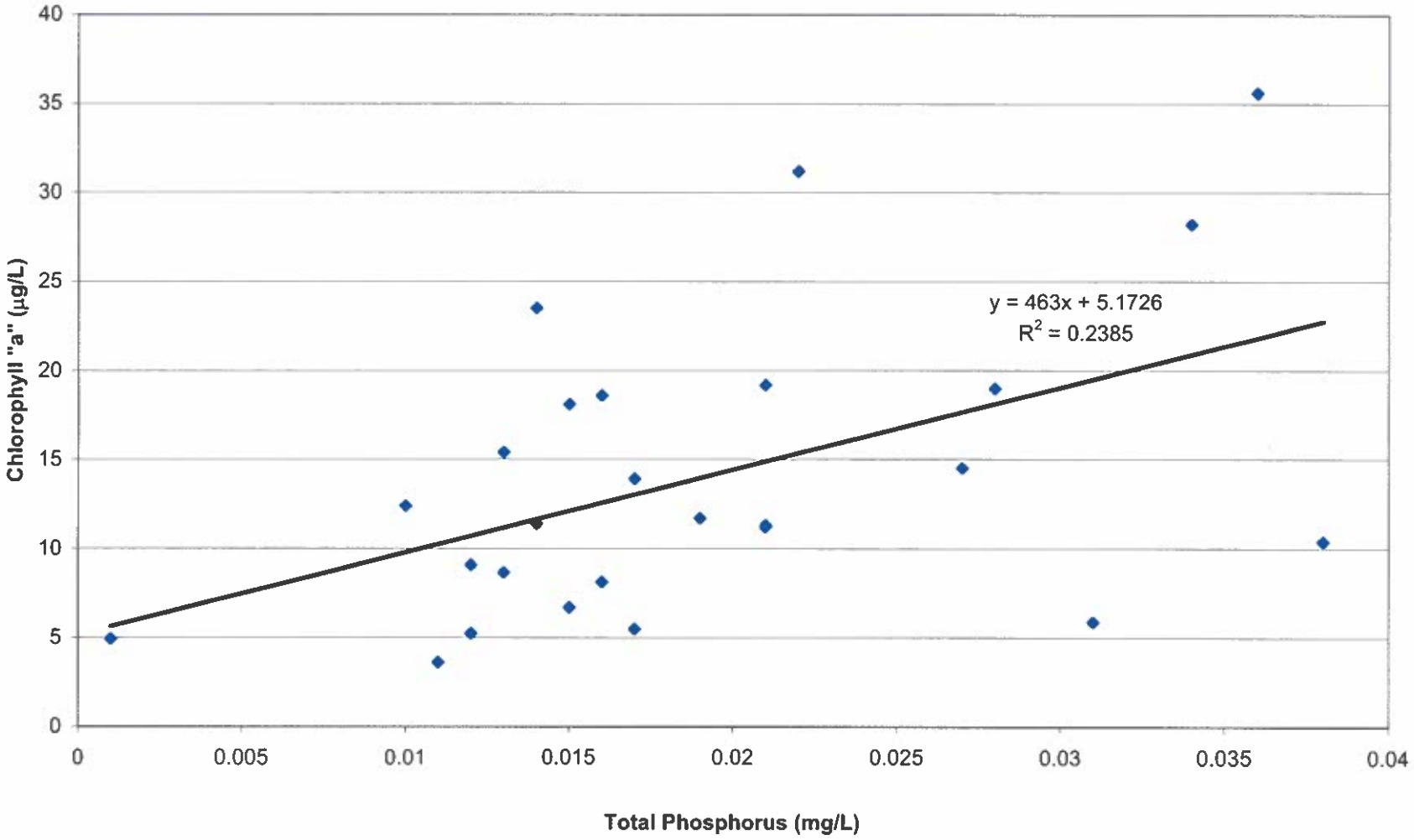
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Figure 7-2: Relationship between pH and Chlorophyll "a" at Kinkaid Lake Station RNC-3



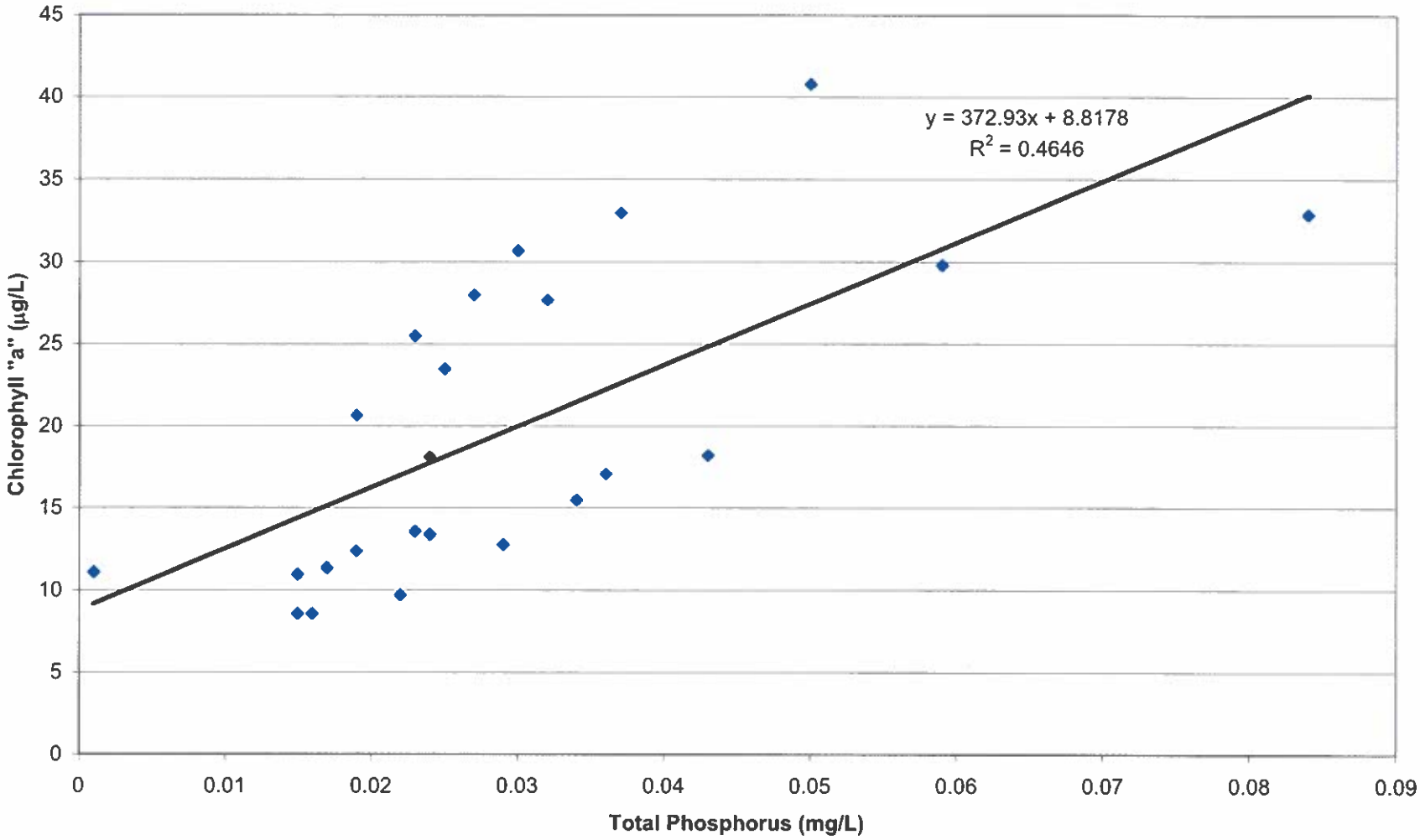
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Figure 7-3: Relationship between Total Phosphorus at One-Foot Depth and Chlorophyll "a" at Kinkaid Lake Station RNC-1



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Figure 7-4: Relationship between Total Phosphorus at One-Foot Depth andChlorophyll "a" at Kinkaid Lake Station RNC-3



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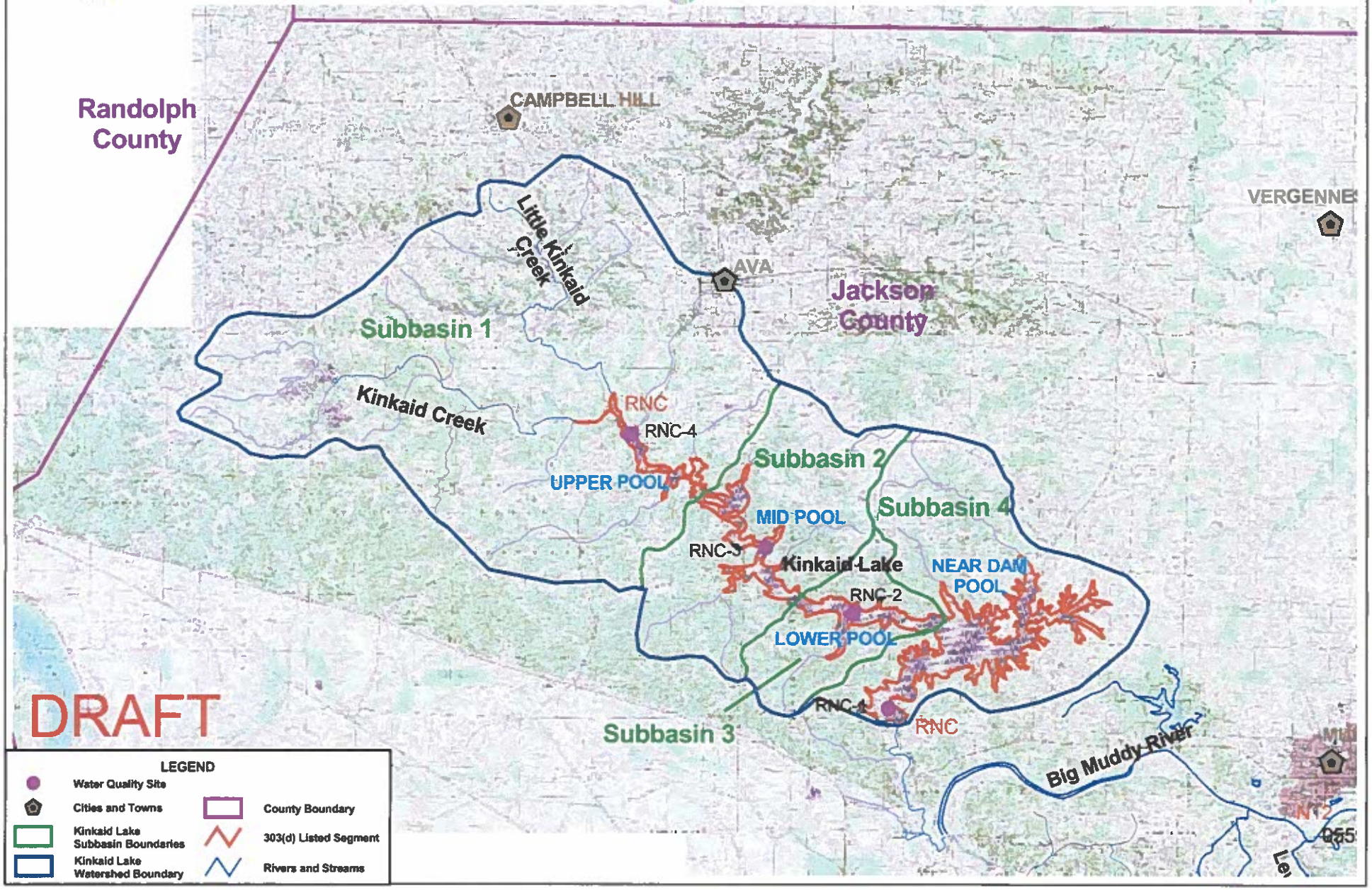


Figure 7-5
Kinkaid Lake Watershed, Historic Sampling Locations, and Modeling Divisions

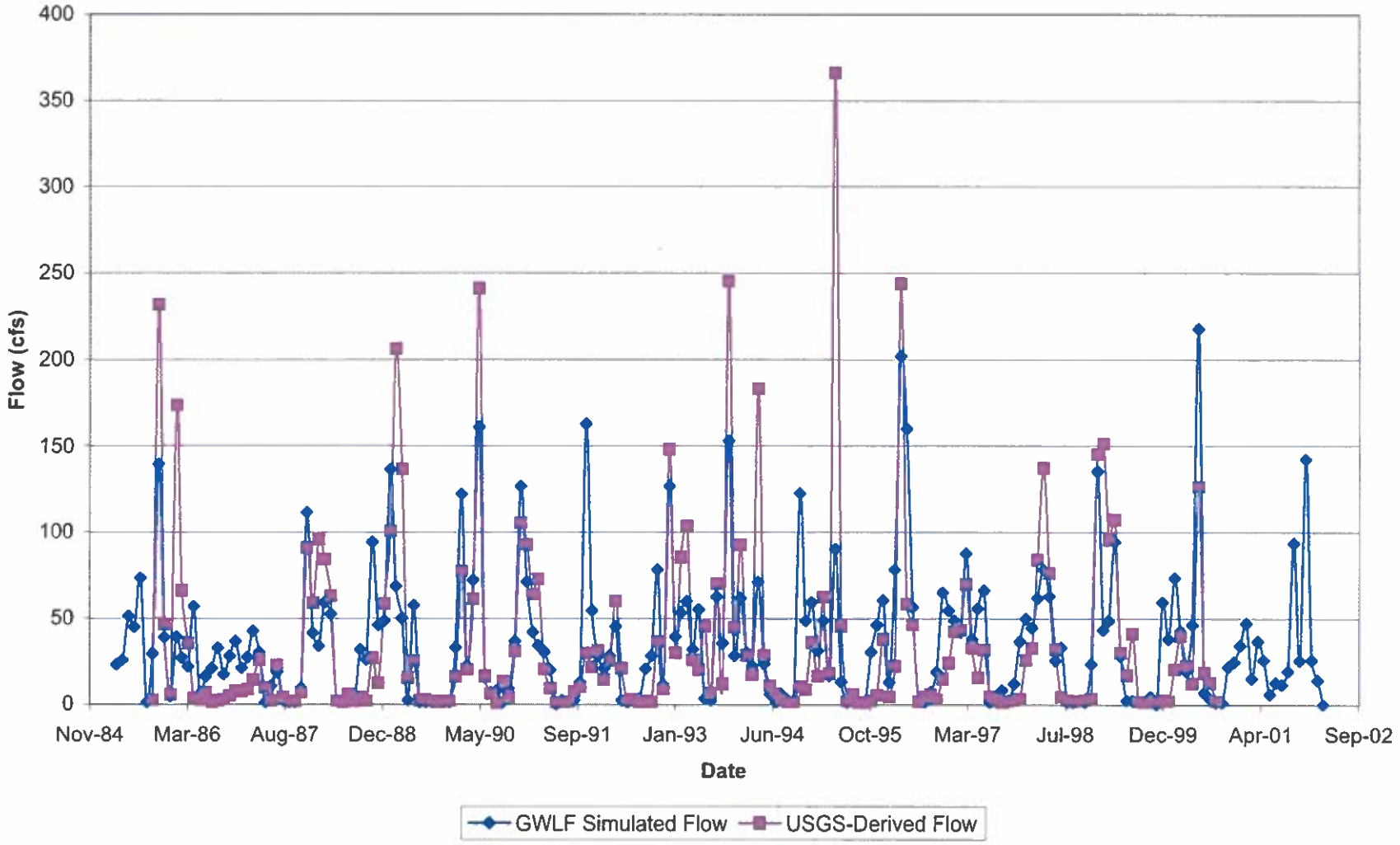
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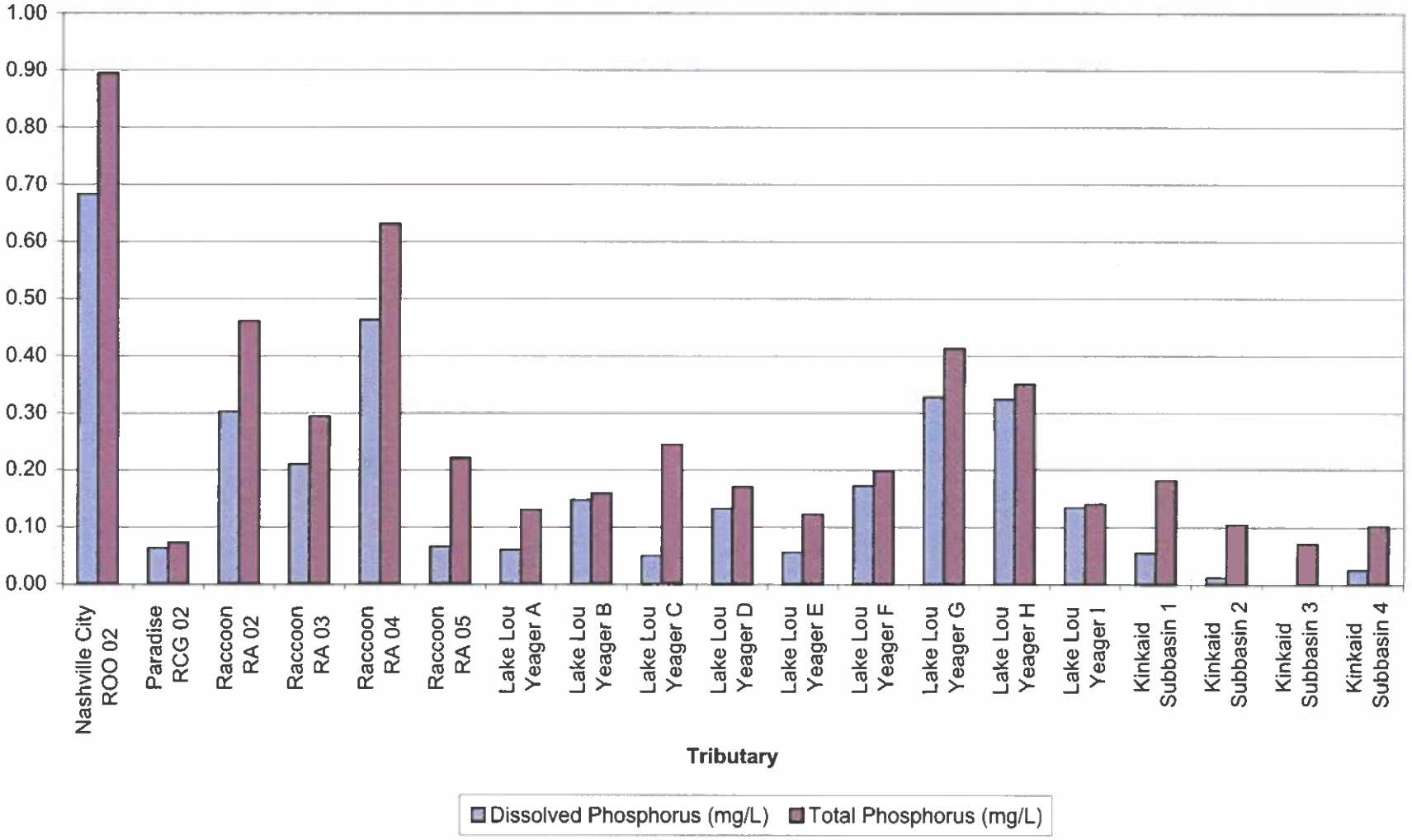
Figure 7-6: Kinkaid Lake Inflows
Subbasin 1 Monthly Flow Comparison



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Figure 7-7: Dissolved and Total Phosphorus Concentrations Measured in Clean Lake Study Tributaries and Estimated for Tributaries to Kinkaid Lake



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Section 8
Total Maximum Daily Load for Kinkaid Lake Watershed

8.1 TMDL Endpoints for Kinkaid Lake

The desired in-lake water quality standard for pH is between 6.5 and 9 and less than or equal to 0.05 mg/L for total phosphorus. Tables 5-5, 5-6, ad 5-7 summarized the average pH, total phosphorus, and chlorophyll "a" concentrations sampled in the Kinkaid Lake Watershed. As noted in Section 5.1.5.1.1, all observed in-lake averages meet these targets, but individual samples violate the TMDL endpoints. The range of pH values is set to prevent eutrophic conditions in Kinkaid Lake and maintain aquatic life. Phosphorus is a concern as nuisance plant growth and algal concentrations in many freshwater lakes are enhanced by the availability of phosphorus.

8.2 Pollutant Sources and Linkages

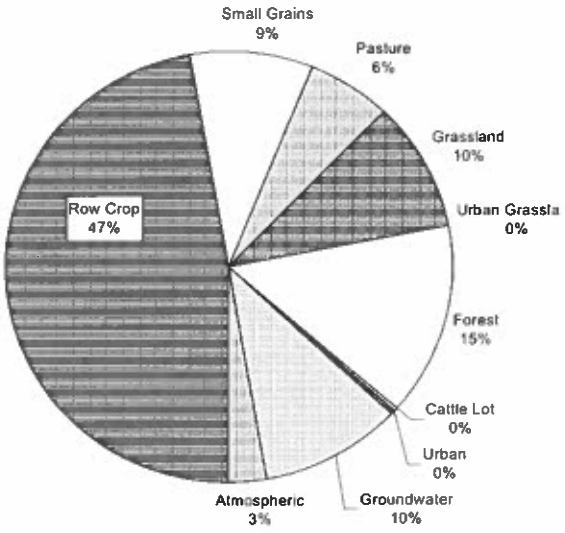
The TMDL for pH in Kinkaid Lake is dependent on a relationship between pH, chlorophyll "a," and phosphorus as explained in Sections 5.1.5.1.1 and 7.1. Relationships between phosphorus, chlorophyll "a," and pH were determined, but it is recognized that they only represent general trends.

Although Kinkaid Lake is not listed for phosphorus, sample concentrations do exceed the endpoint of 0.05 mg/L for total phosphorus in the most upstream pool. This TMDL is based on the assumption that trends in Kinkaid Lake will follow those observed in literature where the control of phosphorus results in acceptable pH values. The remainder of this section focuses on reductions in phosphorus to control pH.

Pollutant sources and their linkages to Kinkaid Lake were established through the GWLF and BATHTUB modeling techniques described in Section 7. Pollutant sources of phosphorus include nonpoint source runoff from agriculture. Atmospheric deposition is another potential source of loads. The predicted phosphorus loads from GWLF and BATHTUB modeling and their sources are presented in Table 8-1. The mean loads presented in Table 8-1 will be used in the overall TMDL calculation for the amount of reductions that need to occur in the Kinkaid Lake Watershed.

Table 8-1 Modeled Total Phosphorus Load by Source

Land Use	1994 (normal)		1997 (wet)		2000 (wet)		Mean	
	lb/yr	Percent	lb/yr	Percent	Lb/yr	Percent	lb/yr	Percent
Row Crop	6,949	45%	9,276	47%	15,215	49%	10,480	47%
Small Grains	1,306	8%	1,707	9%	2,813	9%	1,942	9%
Rural Grassland								
Pasture	933	6%	1,101	6%	2,036	7%	1,357	6%
Grassland	1,446	9%	1,817	9%	3,241	10%	2,168	10%
Urban Grassland	0	0%	0	0%	27	0%	9	0%
Forest	2,006	13%	2,835	14%	4,795	16%	3,212	15%
Cattle Feedlot	23	0%	28	0%	54	0%	35	0%
Urban	70	0%	28	0%	27	0%	41	0%
Groundwater	2,262	15%	2,395	12%	2,223	7%	2,293	10%
Atmospheric	628	4%	628	3%	628	2%	628	3%
Total	**15,623**	**100%**	**19,815**	**100%**	**31,059**	**100%**	**22,165**	**100%**



The majority of the predicted phosphorus load is from agricultural nonpoint sources as shown in the pie chart to the right. The loads represented in Table 8-1 and the pie chart were entered into the BATHTUB model as explained in Section 7 to determine resulting in-lake total phosphorus concentration in mg/L. As explained in Section 7, these loads result in in-lake concentrations that exceed the total phosphorus target of 0.05 mg/L at the most upstream water quality site. The TMDL explained throughout the remainder of this section will examine how much the external loads need to be reduced in order to meet the total phosphorus water quality standard of 0.05 mg/L in Kinkaid Lake.

8.3 Allocation

As explained in Section 1, the TMDL for Kinkaid Lake will address the following equation:

$$TMDL = LC = \Sigma WLA + \Sigma LA + MOS$$

where: LC = Maximum amount of pollutant loading a water body can receive without violating water quality standards

WLA = The portion of the TMDL allocated to existing or future point sources

LA = Portion of the TMDL allocated to existing or future nonpoint sources and natural background

MOS = An accounting of uncertainty about the relationship between pollutant loads and receiving water quality

Each of these elements will be discussed in this section as well as consideration of seasonal variation in the TMDL calculation.

8.3.1 Loading Capacity

The loading capacity of Kinkaid Lake is the pounds per year of total phosphorus that can be allowed as input to the lake and still meet the water quality standard of 0.05 mg/L total phosphorus. The allowable phosphorus loads that can be generated in the watershed and still maintain water quality standards was determined with the models that were set up and calibrated as discussed in Section 7. To accomplish this, the loads presented in Table 8-1 were reduced by a percentage and entered into the BATHTUB model until the water quality standard of 0.05 mg/L total phosphorus was met in Kinkaid Lake. Only loads modeled from Subbasin 1 were reduced because this subbasin has the most impact on water quality at site RNC-4, which had observed phosphorus concentrations greater than 0.05 mg/L. Table 8-2 shows the allowable phosphorus loading determined for 1994, 1997, and 2000 by reducing modeled inputs to Kinkaid Lake through GWLF and BATHTUB. The output files to BATHTUB showing the results of the load reductions for 1994, 1997, and 2000 are contained in Appendix I.

Table 8-2 Allowable Total Phosphorus Load by Model Year for Kinkaid Lake

Model Year	Phosphorus (lb/yr)
1994	8,109
1997	10,697
2000	23,145
Mean	13,983

The allowable pounds per year resulting from the modeling show the effects of varying climatic conditions observed during these years. Therefore, an average value of these years was set as the target loading to meet the in-lake water quality standards of 0.05 mg/L.

The modeled total phosphorus and chlorophyll "a" concentrations resulting from the allowable loads are presented in Table 8-3. The pH values associated with the phosphorus and chlorophyll "a" concentrations shown in Table 8-3 were determined from the relationships provided in Figures 7-1 through 7-4. Only results at stations RNC-1 and RNC-3 are shown because, as mentioned previously, these are the only stations with samples that exceeded the pH standard. This analysis shows that violations of the pH water quality standard should be avoided. Therefore, the TMDL for Kinkaid Lake will focus on phosphorus as explained throughout the remainder of this section.

Table 8-3 Predicted Total Phosphorus, Chlorophyll "a," and pH Values in Kinkaid Lake

Year	Total Phosphorus (mg/L)	Chlorophyll "a" (µg/L)	pH (s.u.)
1994 (RNC-1)	0.02	16.6	8.2
1994 (RNC-3	0.02	13.1	8.3
1997 (RNC-1)	0.03	11.9	8.0
1997 (RNC-3	0.03	18.2	8.3
2000 (RNC-1)	0.02	19.1	8.2
2000 (RNC-3)	0.03	15.5	8.3

As discussed previously, modeled loads to the most upstream segment of Kinkaid Lake were reduced to attain a total phosphorus concentration of 0.05 mg/L, which in turn reduced modeled concentrations in downstream segments of the lake. Therefore, the values in Table 8-3 are much lower than the water quality standard, although the modeled concentrations in the most upstream segment are just below the phosphorus standard of 0.05 mg/L.

8.3.2 Seasonal Variation

A season is represented by changes in weather; for example, a season can be classified as warm or cold as well as wet or dry. Seasonal variation is represented in the Kinkaid Lake TMDL as conditions were modeled on an annual basis and by taking 15 years of daily precipitation data when calculating run-off through the GWLF model. This takes into account the seasonal effects the reservoir will undergo during a given year. Since the various pollutant sources are expected to contribute loadings in different quantities during different time periods (e.g., atmospheric deposition year round, spring run-off loads), the loadings for this TMDL will focus on average annual loadings rather than specifying different loadings by season. In addition, three data sets (wet, dry, average) were examined to assess the effects of varying precipitation on loading to the reservoir and resulting in-lake concentrations.

8.3.3 Margin of Safety

The MOS can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. The MOS for the Kinkaid Lake TMDL should be based on a combination of both. Model inputs were selected from the GWLF manual when site-specific data were unavailable. These default input values are assumed to be conservative, which implicitly includes a MOS in the modeling effort. Because the default input values are not site-specific, they are assumed more conservative and therefore a MOS can be implicitly assumed. Default input values include:

- Sediment delivery ratio – using literature value is assumed conservative as cropping practices have changed within Illinois since ratio was developed in 1975.
- Soil phosphorus concentration – phosphorus concentrations in the soil were not available therefore literature values were assumed conservative as the mid-point of the range of suggested literature range was used as a starting point for analyses.

In addition, averaging of a normal and dry year is assumed to be conservative and part of the implicit MOS.

Due to uncertainty with nutrient model inputs as explained in Section 7.4, an explicit MOS of 5 percent is also recommended. Due to unknowns regarding estimated versus actual measurements of loadings to the lake, an explicit MOS is included. The 5 percent MOS is appropriate based upon the generally good agreement between the GWLF loading model and observed flows, and in the BATHTUB water quality model and observed values in Kinkaid Lake (Section 7.4). Since these models reasonably

reflect the conditions in the watershed, a 5 percent MOS is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. The MOS can be reviewed in the future as new data is developed.

8.3.4 Waste Load Allocation

There are no point sources in the watershed; therefore, no WLA is recommended at this time.

8.3.5 Load Allocation and TMDL Summary

Table 8-4 shows a summary of the TMDL for Kinkaid Lake. On average, a total reduction of 43 percent of total phosphorus loads to Kinkaid Lake would result in compliance with the water quality standard of pH values between 6.5 and 9 based on modeling efforts.

Table 8-4 TMDL Summary for Total Phosphorus in Kinkaid Lake

LC (lb/yr)	WLA (lb/yr)	LA (lb/yr)	MOS (lb/yr)	Reduction Needed (lb/yr)	Reduction Needed (percent)
13,983	0	13,283	700	8,882	40%

Table 8-5 shows the respective reductions needed from atmospheric loads and nonpoint sources in the watershed to meet the TMDL. The reduction of atmospheric loads is zero because atmospheric contributions cannot be controlled by watershed management measures. An approximate 41 percent reduction of nonpoint sources from the watershed would be necessary to meet the load allocation presented in Table 8-4. Methods to meet these targets will be outlined in Section 9.

Table 8-5 Sources for Total Phosphorus Reductions

Source	Current Load (lb/yr)	Load Reduction (lb/yr)	Percent Reduction
Atmospheric	628	0	0%
Nonpoint Sources	21,537	8,882	41%

Section 9
Implementation Plan for Kinkaid Lake

9.1 Implementation Actions and Management Measures

As discussed in Sections 7.1 and 8.2, the TMDL for Kinkaid Lake is based on relationships between pH, chlorophyll "a," and phosphorus. The remainder of this section focuses on reductions in phosphorus to control pH. It was determined that reductions in phosphorus to the TMDL endpoint of 0.05 mg/L will result in pH concentrations that meet the water quality standard. Therefore, this implementation plan focuses on measures that will reduce phosphorus.

Phosphorus loads in the Kinkaid Lake Watershed originate from external sources, such as croplands. The annual averages of data collected during sampling of Kinkaid Lake indicate that only the upstream portion of Kinkaid Lake is impaired for phosphorus (detailed in Section 7). Land use for the entire watershed illustrates that 70 percent of the agricultural practices occur in the portion of the watershed upstream of Kinkaid Lake, which supports the data. Hence, implementation measures focus on the watershed area located upstream of Kinkaid Lake (subbasin 1 in Figure 7-5). However, the TMDL endpoints and load reductions apply to the entire Kinkaid Lake Watershed.

From modeling estimates, external loads from nonpoint source runoff from agricultural crops potentially account for 56 percent of the loading to Kinkaid Lake, and forest land, both deciduous and coniferous, accounts for approximately 15 percent of the nonpoint source phosphorus loaded to the lake. Grassland and pasture land account for approximately 16 percent of the modeled load, and the remaining 14 percent are contributed by atmospheric and groundwater loads. To achieve the 41 percent reduction for the load allocations established in Section 8 (Table 8-4), management measures must address nonpoint source loading through sediment and surface runoff controls. Phosphorus sorbs readily to soil particles and controlling sediment load into the reservoir helps control phosphorus loadings.

The pH level in lakes is tied to the plant, animal, and nutrient cycles of the lake. Plants and algae use CO_2 during photosynthesis, which causes pH levels to rise. The photosynthetic rate progressively decreases as the residual CO_2 concentration declines and ceases completely with the extinction of light. During the night, reaeration and respiration replenish CO_2 causing the pH levels to decrease overnight (Welch 1980). Plant and algae growth tend to increase significantly with the addition of phosphorus to the lake; therefore, the success of controlling pH levels in Kinkaid Lake is linked to the control of nonpoint source phosphorus loads.

Implementation actions, management measures, or BMPs are used to control the generation or distribution of pollutants. BMPs are either structural, such as wetlands, sediment basins, fencing, or filter strips; or managerial, such as conservation tillage, nutrient management plans, or crop rotation. Both types require good management to be effective in reducing pollutant loading to water resources (Osmond et al. 1995).

It is generally more effective to install a combination of BMPs or a BMP system. A BMP system is a combination of two or more individual BMPs that are used to control a pollutant from the same critical source. In other words, if the watershed has more than one identified pollutant, but the transport mechanism is the same, then a BMP system that establishes controls for the transport mechanism can be employed. (Osmond et al. 1995).

Implementation actions and management measures are described for each phosphorus source located in the upper Kinkaid Lake Watershed. Nonpoint sources include agricultural practices, such as cropland and a cattle feedlot.

9.1.1 Nonpoint Source Phosphorus and pH Management

The sources of nonpoint source pollution in subbasin 1 of the Kinkaid Lake Watershed consist of agricultural cropland and a cattle feedlot, although the feedlot in the upper watershed was designated as having no impact on the receiving waters. BMPs evaluated for treatment of these nonpoint sources are:

- conservation tillage practices,
- wetlands,
- filter strips,
- nutrient management.

Total phosphorus originating from cropland is most efficiently treated with a combination of no-till or conservation tillage practices and grass filter strips. Wetlands located upstream of the reservoir potentially provide further reductions in total and dissolved phosphorus in runoff from croplands and cattle operations. Nutrient management focuses on source control of nonpoint source contributions to Kinkaid Lake.

9.1.1.1 Conservation Tillage Practices

For the Kinkaid Lake Watershed, conservation tillage practices could help reduce nutrient loads in the lake. Nonpoint source runoff from 3,200 acres of row crops and small grain agriculture in subbasin 1 were estimated to contribute 27 percent of the phosphorus load to Kinkaid Lake. Total phosphorus loading from cropland is controlled through management BMPs, such as conservation tillage. Conservation tillage maintains at least 30 percent of the soil surface covered by residue after planting. Crop residuals or living vegetation cover on the soil surface protect against soil detachment from water and wind erosion. Conservation tillage practices can remove up to 45 percent of the dissolved and total phosphorus from runoff and approximately 75 percent of the sediment. Additionally, studies have found around 93 percent less erosion occurred from no-till acreage compared to acreage subject to moldboard plowing (North Carolina State University [NCSU] 2000). It is estimated that conventional till currently accounts for 20 percent of corn, 0 percent of soybean, and 20 percent of small grain tillage practices in Jackson County, and these percentages were assumed to apply to the Kinkaid Lake Watershed as well. To achieve the reductions needed, erosion control through conservation tillage could reduce

phosphorus loads. The watershed's modeled erosion rate from row crop and small grains average 10.5 tons/acre/year. To achieve a 19 percent reduction in phosphorus load, the erosion rate for the watershed would need to be reduced to 8.5 tons/acre/year. Similarly, the C-factors for corn, soybeans, and small grains would need to be reduced from 0.21, 0.08, and 0.13 to 0.17, 0.06, and 0.10, respectively.

9.1.1.2 Wetlands

The use of wetlands as a structural control is most applicable to nutrient reduction from agricultural lands in subbasin 1 of Kinkaid Lake. Therefore this section only focuses on the subbasin 1 watershed. Wetlands are an effective BMP for sediment and phosphorus control because they:

- prevent floods by temporarily storing water, allowing the water to evaporate or percolate into the ground,
- improve water quality through natural pollution control such as plant nutrient uptake,
- filter sediment,
- slow overland flow of water thereby reducing soil erosion (USDA 1996).

To treat loads from agricultural runoff from subbasin 1, which is estimated to contribute approximately 27 percent of the current total phosphorus load to Kinkaid Lake, a wetland system could be constructed on the upstream end of the reservoir. Treatment of sediment and phosphorus from agricultural runoff could be accomplished through a combination of no-till practices, wetlands, and filter strips.

While constructed wetlands have been demonstrated to effectively reduce nitrogen and sediment, literature shows mixed results for phosphorus removal. Studies have shown that artificial wetlands designed and constructed specifically to remove pollutants from surface water runoff have removal rates for suspended solids of greater than 90 percent, for total phosphorus of 0 to 90 percent, and for nitrogen species from 10 to 75 percent (Johnson, Evans, and Bass 1996; Moore 1993; USEPA 1993; Kovosic et al. 2000). In some cases, wetlands can be sources of phosphorus. Over the long term, it is generally thought that wetlands are neither sources nor sinks of phosphorus (Kovosic et al. 2000).

Efficiency of pollutant removal in wetlands can be addressed in the design and maintenance of the constructed wetland. Location, hydraulic retention time and space requirements should be considered in design. To maintain removal efficiency, sheet flow should be maintained and substrate should be monitored to assess whether the wetland is operating optimally. Sediment or vegetation removal may be necessary if the wetland removal efficiency is lessened over a period of time (USEPA 1993; NCSU 1994).

Guidelines for wetland design suggest a wetland to watershed ratio of 0.6 percent for nutrient and sediment removal from agricultural runoff. Since a wetland to treat

agricultural runoff from the 22,275-acre upper Kinkaid Lake Watershed would need to be approximately 134 acres based on these recommendations, it is recommended to build a wetland system composed of a series of wetlands on different tributaries around the basin to achieve the 134 acres of wetlands for treatment (Denison and Tilton 1993).

9.1.1.3 Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment, to Kinkaid Lake Watershed. Filter strips implemented along stream segments slow and filter nutrients and sediment out of runoff and provide bank stabilization decreasing erosion and deposition. Additionally, filter strips mitigate nutrient loads to lakes. The following paragraphs focus on the implementation of filter strips in subbasin 1 of the Kinkaid Lake Watershed. Finally, design criteria and size selection of filter strips are detailed.

Grass and riparian buffer strips filter out nutrients and organic matter associated with sediment loads to a water body. Reduction of nutrient concentrations, specifically phosphorus, in Kinkaid Lake will reduce the amount of algal growth in the lake system, which can cause more significant diurnal pH fluctuations from photosynthesis. Filter strips reduce nutrient and sediment loads to lakes by establishing ground depressions and roughness that settles sediment out of runoff and providing vegetation to filter nutrients out of overland flow. As much as 75 percent of sediment and 45 percent of total phosphorus can be removed from runoff by a grass filter strip (NCSU 2000). In addition, filter strips should be harvested periodically so that removal rate efficiencies over extended periods of time remain high (USEPA 1993).

Filter strip widths for the Kincaid Lake TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 9-1 outlines the guidance for filter strip flow length by slope (NRCS 1999). Based on this guidance, two filter strips were examined for the basin. Based on slope, the southern tributary would need a filter strip with 72 feet on each side of the tributary for a length of 902 feet. The northern tributary would need a filter strip that encompassed 108 feet on each side of the tributary for a length of 1,017 feet.

Filter strip widths for the Kinkaid Lake TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 9-1 outlines the guidance for filter strip flow length by slope (NRCS 1999).). Based on slope estimates near tributaries within the watershed, filter strips widths of 90 to 234 feet could be incorporated in locations throughout the watershed. The total acreage examined was 107 acres.

Table 9-1 Filter Strip Flow Lengths Based on Land Slope

Percent Slope	0.5%	1.0%	2.0%	3.0%	4.0%	5.0% or greater
Minimum	36	54	72	90	108	117
Maximum	72	108	144	180	216	234

The filter strip lengths and widths presented above are used to calculate an approximation of BMP costs in Section 9.2.2.6 and should only be used as a guideline for watershed planning. It is recommended that landowners evaluate their land near streams and lakes and create or extend filter strips according to the NRCS guidance presented in Table 9-1. Programs available to fund the construction of these buffer strips are discussed in Section 9.2.

9.1.1.4 Nutrient Management

Nutrient management could result in reduced phosphorus and nitrogen loads to Kinkaid Lake. Crop management of nitrogen and phosphorus can be accomplished through Nutrient Management Plans, which focus on increasing the efficiency with which applied nutrients are used by crops, thereby reducing the amount available to be transported to both surface and groundwater. In the past, nutrient management focused on application rates designed to meet crop nitrogen requirements but avoid groundwater quality problems created by excess nitrogen leaching. This results in buildup of soil phosphorus above amounts sufficient for optimal crop yields. Illinois, along with most Midwestern states, demonstrates high soil test phosphorus in greater than 50 percent of soil samples analyzed (Sharpley et al. 1999).

The overall goal of phosphorus reduction from agriculture should increase the efficiency of phosphorus use by balancing phosphorus inputs in feed and fertilizer with intakes of crops and animal produce as well as managing the level of phosphorus in the soil. Reducing phosphorus loss in agricultural runoff may be brought about by source and transport control measures, such as filter strips or grassed waterways. The Nutrient Management Plans account for all inputs and outputs of phosphorus to determine reductions. Elements of a Nutrient Management Plan include:

- Plan summary
- Manure summary, including annual manure generation, use, and export
- Nutrient application rates by field and crop
- Summary of excess manure utilization procedures
- Implementation schedule
- Manure management and stormwater BMPs

In Illinois, Nutrient Management Plans have successfully reduced phosphorus application to agricultural lands by 36-lb/acre. National reductions range from 11- to 106-lb/acre, with an average of 35-lb/acre (NCSU 2000).

9.1.2 Implementation Actions and Management Measures Summary

9.1.2.1 Kinkaid Lake Watershed

To meet the reductions outlined in Section 8 for Kinkaid Lake, 41 percent of phosphorus loaded from nonpoint source pollution would need to be reduced to meet the TMDL target of a total phosphorus concentration less than 0.05-mg/L. The GWLF model was used to model the following practices to estimate achievable reductions in total phosphorus:

- Conservation tillage
- Nutrient management (reduction of total phosphorus in sediment by 20 percent)
- Filter strips

These practices were only applied to subbasin 1 because reductions are only required in the upper pool of Kinkaid Lake. The modeling effort showed that filter strips do not provide much total phosphorus reduction, most likely due to routing constraints of the GWLF model as discussed in Section 7.3.2.1.1 and the small magnitude of area available for filter strip development.

Table 9-2 Summary of Total Phosphorus Load Reductions

Management Measure	Potential Percent Reduction
Nutrient Management Practices	10%
Conservation Tillage Practices	11%
Filter Strips*	22%
Wetland*	5%

* Literature Value

Reductions of external loads by conservation tillage, nutrient management, filter strips, and wetlands are summarized in Table 9-2. Wetlands were not modeled with GWLF because wetland performance is a result of placement in the watershed, and GWLF does not recognize spatial data due to routing constraints of the model. The lower bound of the literature value was used due to studies that have shown the long-term effectiveness of phosphorus removal in wetlands is negligible.

A combination of implementing these external load reduction practices would allow the Kinkaid Lake Watershed to meet its total goal of reducing phosphorus loads by 44 percent. Section 9.2 outlines planning level costs and programs available to help with cost sharing so that this goal can be achieved.

9.2 Reasonable Assurance

Reasonable assurance means that a demonstration is given that nonpoint source reductions in this watershed will be implemented. It should be noted that all programs discussed in this section are voluntary. The discussion in Section 9.1 provided a means for obtaining the reductions necessary. The remainder of this section discusses programs available to assist with funding of implementing practices and also an estimate of costs to the watershed for implementing these practices.

9.2.1 Available Programs

Approximately 24 percent of the Kinkaid Lake Watershed is classified as rural grassland (pasture land, Conservation Reserve Program [CRP], waterways, buffer strips, etc.), row crop, and small grains land. There are several voluntary conservation programs established through the 2002 U.S. Farm Bill, which encourage landowners to implement resource conserving practices for water quality and erosion control purposes. These programs would apply to crop fields and rural grasslands that are presently used as pasture land. Each program is discussed separately in the following paragraphs.

9.2.1.1 Illinois Department of Agriculture and Illinois EPA Nutrient Management Plan Project

The Illinois Department of Agriculture (IDA) and Illinois EPA are presently co-sponsoring a cropland Nutrient Management Plan project in watersheds that have or are developing a TMDL. Under this project, 4,327 acres of cropland have been targeted in the Kinkaid Lake Watershed. This voluntary project will supply incentive payments to producers to have Nutrient Management Plans developed and implemented. Additionally, if sediments or phosphorus have been identified as a cause for impairment in the watershed, then traditional erosion control practices will be eligible for cost-share assistance through the Nutrient Management Plan project as well.

9.2.1.2 Conservation Reserve Program (CRP)

This voluntary program encourages landowners to plant long-term resource-conserving cover to improve soils, water, and wildlife resources. CRP is the USDA's single largest environmental improvement program and one of its most productive and cost-efficient. It is administered through the Farm Service Agency (FSA) by USDA's Commodity Credit Corporation (CCC). The program was initially established in the Food Security Act of 1985. The duration of the contracts under CRP range from 10 to 15 years.

Eligible land must be one of the following:

1. Cropland that is planted or considered planted to an agricultural commodity two of the five most recent crop years (including field margins). Must be physically and legally capable of being planted in a normal manner to an agricultural commodity.

2. Certain marginal pastureland enrolled in the Water Bank Program.

The CCC bases rental rates on the relative productivity of soils within each county and the average of the past three years of local dry land cash-rent or cash-rent equivalent. The maximum rental rate is calculated in advance of enrollment. Producers may offer land at the maximum rate or at a lower rental rate to increase likelihood of offer acceptance. In addition, the CCC provides cost-share assistance for up to 50 percent of the participant's costs in establishing approved conservation practices. CCC also encourages restoration of wetlands by offering a one-time incentive payment equal to 25 percent of the costs incurred. This incentive is in addition to the 50 percent cost share provided to establish cover (USDA 1999).

Finally, CCC offers additional financial incentives of up to 20 percent of the annual payment for certain continuous sign-up practices. Continuous sign-up provides management flexibility to farmers and ranchers to implement certain high-priority conservation practices on eligible land. The land must be determined by NRCS to be eligible and suitable for any of the following practices:

- Riparian buffers
- Filter strips

- Grass waterways
- Shelter belts
- Field windbreaks
- Living snow fences
- Contour grass strips
- Salt tolerant vegetation
- Shallow water areas for wildlife
- Eligible acreage within an USEPA-designated wellhead protection area (FSA 1997)

9.2.1.3 Wetlands Reserve Program (WRP)

WRP is a voluntary program that provides technical and financial assistance to eligible landowners to restore, enhance, and protect wetlands. The goal of WRP is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. At least 70 percent of each project area will be restored to the original natural condition, to the extent practicable. The remaining 30 percent of each area may be restored to other than natural conditions. Landowners have the option of enrolling eligible lands through permanent easements, 30-year easements, or restoration cost-share agreements. The program is offered on a continuous sign-up basis and is available nationwide. WRP offers landowners an opportunity to establish, at minimal cost, long-term conservation and wildlife habitat enhancement practices and protection. It is administered through the NRCS (2002b).

The 2002 Farm Bill reauthorized the program through 2007. Increasing the acreage enrollment cap to 2,275,000 acres with an annual enrollment of 250,000 acres per calendar year. The program is limited by the acreage cap and not by program funding. Since the program began in 1985, the average cost per acre is $1,100 in restorative costs and the average project size is 177 acres. The costs for each enrollment option follow in Table 9-3 (USDA 1996).

Table 9-3 Costs for Enrollment Options of WRP

Option	Permanent Easement	30-year Easement	Restoration Agreement
Payment for Easement	100% Agricultural Value	75% Agricultural Value	NA
Payment Options	Lump Sum	Lump Sum	NA
Restoration Payments	100% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements

9.2.1.4 Environmental Quality Incentive Program (EQIP)

EQIP is a voluntary USDA conservation program for farmers and private landowners engaged in livestock or agricultural production who are faced with serious threats to soil, water, and related natural resources. It provides technical, financial, and educational assistance primarily in designated "priority areas." Priority areas are defined as watershed, regions, or areas of special environmental sensitivity that have significant soil, water, or natural resource related concerns. The program goal is to maximize environmental benefits per dollar expended and provides "(1) flexible

technical and financial assistance to farmers and ranchers that face the most serious natural resource problems; (2) assistance to farmers and ranchers in complying with Federal, State, and tribal environmental laws, and encourage environmental enhancement; (3) assistance to farmers and ranchers in making beneficial, cost-effective changes to measures needed to conserve and improve natural resources; and (4) for the consolidation and simplification of the conservation planning process." As of 2001, 379,000 acres have been protected in Illinois using EQIP (NRCS 2002d,e).

Landowners, with the assistance of a local NRCS or other service provider, are responsible for development of a site-specific conservation plan, which addresses the primary natural resource concerns of the priority area. Conservation practices include but are not limited to erosion control, filter strips, buffers, and grassed waterways. If the plan is approved by NRCS, a five- to 10-year contract that provides cost-share and incentive payments is developed.

Cost-share assistance may pay landowners up to 75 percent of the costs of conservation practices, such as grassed waterways, filter strips, manure management, capping abandoned wells, and other practices important to improving and maintaining the health of natural resources in the area. Total incentive and cost-share payments are limited to $10,000 per person per year and $50,000 over the life of the contract.

9.2.1.5 Conservation Practices Program

The Conservation Practices Program (CPP) is a 10-year program. The practices consist of waterways, water and sediment control basins (WASCOBS), pasture/hayland establishment, critical area, terrace system, no-till system, diversions, and grade stabilization structures. The CPP is State funded through the Department of Agriculture. There is a project cap of $5,000 per landowner and costs per acre vary significantly from project to project.

9.2.1.6 Wildlife Habitat Incentives Program (WHIP)

WHIP is a voluntary program that encourages the creation of high quality wildlife habitat of national, state, tribal, or local significance. WHIP is administered through NRCS, which provides technical and financial assistance to landowners for development of upland, riparian, and aquatic habitat areas on their property. NRCS works with the participant to develop a wildlife habitat development plan that becomes the basis of the cost-share agreement between NRCS and the participant. Most contracts are five to 10 years in duration, depending upon the practices to be installed. However, longer term contracts of 15 years or greater may also be funded. Under the agreement:

- The landowner agrees to maintain the cost-shared practices and allow NRCS or its agent access to monitor its effectiveness.
- NRCS agrees to provide technical assistance and pay up to 75 percent of the cost of installing the wildlife habitat practices. Additional financial or technical assistance may be available through cooperating partners (NRCS 2002c).

The FSA administers the CRP. NRCS administers the EQIP, WRP, and WHIP. Local NRCS and FSA contact information in Jackson County are listed in the Table 9-4 below.

Table 9-4 Local NRCS and FSA Contact Information

Contact	Address	Phone
Local NRCS Office		
W. Scott Martin	1213 N. 14th Street, Murphysboro, Illinois 62966	618-684-3064 x3
Local FSA Office		
Murphysboro Service Center	1213 N. 14th Street, Murphysboro, Illinois 62966	618-684-3471

9.2.2 Cost Estimates of BMPs

Cost estimates for different BMPs and individual practice prices such as filter strip installation are detailed in the following sections. Table 9-5 outlines the cost of implementation measures per acre. Finally, an estimate of the total order of magnitude costs for implementation measures in the Kinkaid Lake Watershed are presented in Section 9.2.2.6 and Table 9-6.

9.2.2.1 Wetland

The price to establish a wetland is site specific. In general, the cost to construct a wetland includes creation of wetland hydrology, site preparation for planting, shrub or tree planting, and labor costs. The average project cost to establish a wetland in Jackson County is $1,280/acre. It should be noted that the larger the wetland acreage to be established the more cost-effective the project.

9.2.2.2 Filter Strips and Riparian Buffers

Jackson County NRCS estimates an average cost per acre to install and maintain a grass filter strip with a 10-year life span at $90/acre. This price quote accounts for seeding and mowing every other year to remove woody sprouts. A riparian buffer strip established with bare root stock has a life span of 10-years and an installation cost of $384/acre.

9.2.2.3 Nutrient Management Plan – NRCS

Generally, agricultural land in Jackson County is comprised of cropland; therefore, nutrient management concentrates on nitrogen, phosphorus, potassium, lyme, and pest management residuals. The Nutrient Management Program in Jackson County consists of soil testing every three years using University of Illinois Guidelines and site specific recommendations for fertilizer application based on determined credits and realistic crop yields. The service averages $10/acre.

9.2.2.4 Nutrient Management Plan – IDA and Illinois EPA

The costs associated with development of Nutrient Management Plans co-sponsored by the IDA and the Illinois EPA is estimated as $5/acre paid to the producer and

$2/acre for a third party vendor who develops the plans. The total plan development cost is estimated at $7/acre.

9.2.2.5 Conservation Tillage

Conservation tillage is assumed to include tillage practices that preserve at least 30 percent residue cover of the soil after crops are planted. The installation cost for conservation tillage is $17/acre, and the average annual cost for maintaining conservation tillage is $17.35/acre/year (NCSU 2000).

9.2.2.6 Planning Level Cost Estimates for Implementation Measures

Cost estimates for different implementation actions are presented in Table 9-5. The column labeled *Program or Sponsor* lists the financial assistance program or sponsor available for various BMPs. The programs represented in the table are the WRP and the CRP.

Table 9-5 Cost Estimate of Various BMP Measures in Jackson County

Source	Program or Sponsor	BMP	Life Span	Installation Mean $/acre	Maintenance $/ac/yr
Nonpoint	WRP	Wetland	10	$1,280	$128.00
	CRP	Grass Filter Strips	10	$90	$9.00
	CRP	Riparian Buffer	10	$384	$38.40
	NRCS	Nutrient Management Plan		$10	
	IDA and Illinois EPA	Nutrient Management Plan		$7	
	CRP	Conservation Tillage	1	$17	$17.35

A total order of magnitude cost for implementation measures in the watershed was estimated to be $266,000. The total cost is calculated as the number of acres over which a BMP or structural measure is applied by the cost per acre. Table 9-6 summarizes the number of acres each measure is applied to in the basin and the corresponding cost. The acreages reported in Table 9-6 are a preliminary estimate in order to provide an overall understanding of cost of implementation in the watershed. The total only represents capital costs and annual maintenance costs. These do not represent the costs of operating the measure over its life cycle. The IDA and Illinois EPA sponsored nutrient management plan is applied to all cropland acres in the Kinkaid Lake Watershed, whereas the costs for conservation tillage were only developed for Subbasin 1.

Table 9-6 Cost Estimate of Implementation Measures for Kinkaid Lake Watershed

BMP	Treated Acres	Capital Costs		Maintenance Costs	
		Mean $/acre	Watershed $	$/ac/yr	Watershed $/yr
Wetland on River	134	$1,280	$172,000	$128.00	$17,000
Grass Filter Strips	107	$90	$10,000	$9.00	$1,000
Nutrient Management Plan	4,327	$7	$30,000		
Conservation Tillage	3,200	$17	$54,000	$17.35	$56,000
Total			**$266,000**		**$74,000**

9.3 Monitoring Plan

The purpose of the monitoring plan for Kinkaid Lake is to assess the overall implementation of management actions outlined in this section. This can be accomplished by conducting the following monitoring programs:

- Track implementation of management measures in the watershed
- Estimate effectiveness of management measures
- Continue ambient monitoring of Kinkaid Lake
- Tributary monitoring

Tracking the implementation of management measures can be used to address the following goals (NCSU 2000):

- Determine the extent to which management measures and practices have been implemented compared to action needed to meet TMDL endpoints
- Establish a baseline from which decisions can be made regarding the need for additional incentives for implementation efforts
- Measure the extent of voluntary implementation efforts
- Support workload and costing analysis for assistance or regulatory programs
- Determine the extent to which management measures are properly maintained and operated

Estimating the effectiveness of the BMPs implemented in the watershed could be completed by monitoring before and after the BMP is incorporated into the watershed. Additional monitoring could be conducted on specific structural systems such as a constructed wetland. Inflow and outflow measurements could be conducted to determine site-specific removal efficiency.

Illinois EPA monitors Kinkaid Lake from April through October approximately every three years. Continuation of this monitoring will assess in-lake water quality as improvements in the watershed are completed. This data will also be used to assess whether water quality standards in the reservoir are being attained. Additionally, Illinois EPA conducted a Clean Lakes Study on Kinkaid Lake, which would provide instream nutrient data for Kinkaid Lake tributaries including dissolved and total phosphorus, during the summer of 2003.

Tributary monitoring is needed to better assess the contribution of internal loading to Kinkaid Lake. By having further knowledge on actual contributions from external loads, a better estimate of internal loads could occur. Along with this tributary monitoring, a stage discharge relationship could be developed with the reservoir spillway so that flows into the reservoir could be paired with tributary water quality data to determine total phosphorus load from the watershed. Data on the different

forms of phosphorus (dissolved, total, or orthophosphate) would also be beneficial to better assess reservoir response to phosphorus loading.

9.4 Implementation Time Line

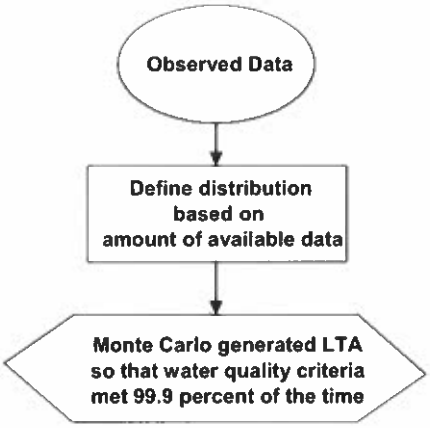
Implementing the actions outlined in this section for the Kinkaid Lake Watershed should occur in phases and the effectiveness of the management actions should be assessed as improvements are made. It is assumed that it may take up to five years to secure funding for actions needed in the watershed and five to seven years after funding to implement the measures. Once improvements are implemented, it may take Kinkaid Lake 10 years or more to reach the water quality standard target of 0.05 g/L for total phosphorus and associated targets between 6.5 and 9 for pH (Wetzel 1983). In summary, to meet water quality standards in Kinkaid Lake may take up to 20 years to complete.

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Section 10
Methodology Development for the Big Muddy River Watershed

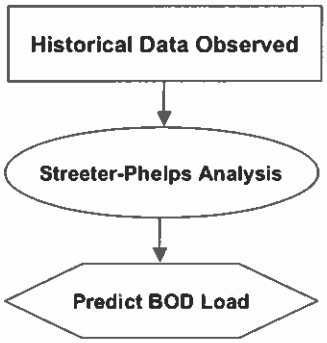
10.1 Methodology Overview

Methodologies were utilized in the TMDL analysis of the Big Muddy River segment N12. For manganese and sulfates, a Monte Carlo simulation was utilized to estimate a long-term average instream concentration needed to meet water quality standards. Investigation of DO required a Streeter-Phelps analysis.



Schematic 1

The schematic to the left shows how the Monte Carlo analysis was utilized to analyze manganese and sulfates. A distribution based on existing data is inputted in the Monte Carlo simulation program. This distribution is based on the amount of existing data available. Using this defined distribution, the computer simulation program randomly generates values to determine what long-term average (LTA) would be needed so that water quality criteria are met 99.9 percent of the time or so that water quality criteria are exceeded less than once every three years. The TMDL for manganese and sulfates will be based on this LTA. The randomly generated values generated by the Monte Carlo simulation are available in Appendix J.



Schematic 2

The Streeter-Phelps analysis was conducted as illustrated in the schematic to the right. Observed data were utilized to set up a Streeter-Phelps analysis to predict stream coefficients that would be required to result in observed DO concentrations. This Streeter-Phelps analysis was based on USEPA's Screening Procedures (Mills et al. 1985). The 5-day biochemical oxygen demand (BOD_5) load and reaeration coefficient (k_a) utilized in the Streeter-Phelps analysis were examined in the TMDL for DO for segment N12.

The procedure used to develop the TMDL for pH was based on an analytical procedure (Kentucky Department of Environmental Protection [KDEP] 2001). The procedure calculates a maximum allowable hydrogen ion loading in the water column to maintain pH standards.

10.2 Watershed Delineation

A watershed for the area contributing directly to Big Muddy River segment N12 was delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation suggests that segment N12 captures flows from a directly contributing watershed of approximately 28 square miles. Figure 10-1 at the end of this section shows the location of the water quality stations in the Big Muddy River segment N12 and the boundary of the GIS-delineated watershed contributing to the segment N12.

10.3 Methodology Development and Results

This section discusses the methodologies utilized to examine manganese, sulfates, DO, and pH levels in the Big Muddy River Watershed.

10.3.1 Monte Carlo Analysis Development and Results

For each constituent exceeding water quality standards, the available data was analyzed and an appropriate distribution was chosen to represent the data. A lognormal distribution, defined as a distribution of a random variables whose logarithm is normally distributed, was chosen to analyze segment N12 since sufficient data for this site was available to utilize this distribution.

Each constituent was evaluated separately using @RISK, which is a Microsoft® *Excel* add-in for the Monte Carlo analysis. The @RISK analysis package performed 10,000 iterations to determine the required percent reduction such that the water quality criteria would be met at least 99.9 percent of the time. The 99.9 percent of time value matches the Illinois EPA's 303(d) listing criteria of less than once in a three-year allowable excursion of water quality standards. For each simulation, the required percent reduction is:

$$PR = \text{maximum } \{0, (1-Cc/Cd)\}$$

where: PR = Required percent reduction for the current iteration
Cc = Water quality criterion in mg/L
Cd = Randomly generated pollutant source concentration in mg/L based on the lognormal distribution

An allowable LTA instream concentration was determined for each impaired constituent. The Monte Carlo simulation analysis is designed to identify a LTA value that will meet the water quality criterion for that parameter 99.9 percent of the time. The Monte Carlo simulation was run using 10,000 iterations with the triangular distribution. For each iteration, a concentration, Cd, is randomly generated according to a specified distribution determined by observed data. For each concentration generated, a percent reduction was calculated, if necessary, to meet water quality criteria. The mean concentration value is multiplied by the inverse of the required percent reduction to compute the long-term daily average concentration that needs to be met to achieve the water quality standard.

The overall percent reduction required is the 99.9th percentile value of the probability distribution generated by the 10,000 iterations, so that the allowable LTA concentration is:

LTA = Mean * (1 - PR99.9)

10.3.1.1 Monte Carlo Results for Big Muddy River Segment N12

Manganese values in Segment N12 ranged from 0.1 to 2.5 mg/L and sulfates values ranged from 59 to 660 mg/L as shown in Table 5-8. Two of the output model concentrations are significant to the TMDL analysis of segment N12. The first is the average concentration calculated from the triangular distribution of the observed data. The second concentration is the LTA, which represents the average concentration that should be observed over the long term to ensure that the water quality standard is exceeded fewer than once every three years. Table 10-1 shows the average concentration calculated from the distribution utilized in the Monte Carlo analysis and the LTA concentration needed so that water quality standards will be achieved in Big Muddy River segment N12. Calculation details are presented in Appendix E.

Table 10-1 LTA Manganese and Sulfates Concentrations Required to Meet Water Quality Standards in Big Muddy River Segment N12

Constituent	Average Concentration Calculated from Distribution (mg/L)	LTA Concentration (mg/L)
Manganese	0.6	0.2
Sulfates	247	104

Table 10-1 shows that the concentration required to meet water quality reductions, the LTA, is lower than the observed average concentration for manganese and sulfates; therefore, the TMDL for segment N12 requires that a load reduction be made for manganese and sulfates based upon the available data. The TMDL will be discussed in Section 11.

10.3.2 DO Analysis Development and Results

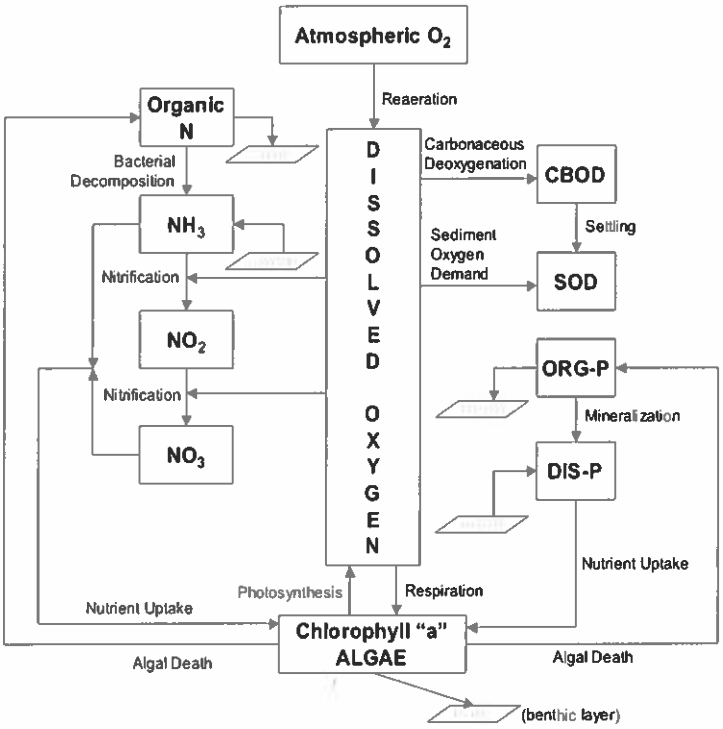
A Streeter-Phelps analysis was utilized for investigation of DO in the Big Muddy River segment N12 Watershed. Data availability useful for analyzing DO for this watershed is described in Table 10-2. The historic water quality data were investigated from 1990 to 2000.

Table 10-2 Data Availability from 1990 to 2000

Model Parameter	Historic data available (yes/no)
Flow	Yes
Stream Temperature	Yes
DO	Yes
5-Day Carbonaceous Biochemical Oxygen Demand ($CBOD_5$)	No
BOD_5	No
Total Nitrogen	No
Total Organic Carbon	Yes
Ammonia	Yes
Nitrate + Nitrite	Yes
Total Kjeldahl Nitrogen	Yes
Total Phosphorus	Yes
Dissolved Phosphorus	Yes
Orthophosphate	Yes
pH	Yes
20-Day Carbonaceous Biochemical Oxygen Demand ($CBOD_{20}$)	No
Daily Minimum And Maximum DO	No
Chlorophyll "a"	No
Stream Depth	Yes

The lack of various constituent samples from historic data sites in the Big Muddy River Watershed limits the modeling tools available for DO. Therefore, a Streeter-Phelps analysis was developed to examine the DO relationship with BOD_5 in the Big Muddy River. The diagram on the following page shows the interactions of DO with different processes within the water column of the stream (USEPA 1997b). The consumers of DO include:

- Deoxygenation of biodegradable organics whereby bacteria and fungi (decomposers) utilize oxygen in the bioxidation-decomposition process
- Sediment oxygen demand (SOD), where oxygen is utilized by organisms inhabiting the upper layers of the bottom sediment deposits
- Nitrification, in which oxygen is utilized during oxidation of ammonia and organic nitrogen to nitrates
- Respiration by algae and aquatic vascular plants that use oxygen during night and early morning hours to sustain their living processes

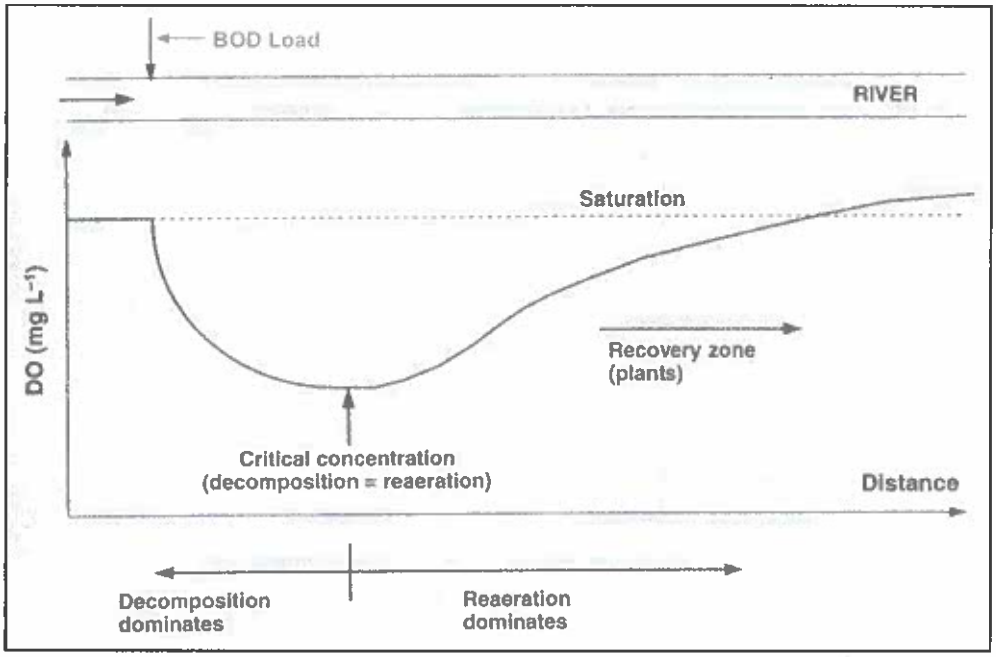


Major oxygen sources are:

- Atmospheric reaeration, where oxygen is transported from the air into the water through turbulence at the air-water interface
- Photosynthesis, where chlorophyll-containing organisms (producers such as algae and aquatic plants) convert carbon dioxide to organic matter with a consequent production of oxygen

Streeter and Phelps (1925) proposed the basic concept of the DO balance in streams. The Streeter-Phelps equation predicts the DO "sag" that occurs after biodegradable constituents are discharged into streams. A biodegradable constituent is anything that can be broken down by microorganisms. BOD is the measure of the quantity of oxygen consumed by microorganisms during the decomposition of organic matter. When nutrients such as nitrate and phosphate are released into the water, growth of algae and aquatic plants is stimulated. The result is an increase in microbial populations, higher levels of BOD, and increased oxygen demand from the photosynthetic organisms during the dark hours. This results in a reduction in DO concentrations, especially during the early morning hours just before dawn.

In addition to natural sources of BOD, such as leaf fall from vegetation near the water's edge, aquatic plants, and drainage from organically rich areas like swamps and bogs, there are also anthropogenic (human) sources of organic matter. Point sources, which may contribute high levels of BOD, include wastewater treatment facilities. Organic matter also comes from nonpoint sources such as agricultural runoff, urban runoff, and livestock operations. Both point and nonpoint sources can contribute significantly to the oxygen demand in a water body. The DO sag is shown in the following figure (Chapra 1997):



Water quality models have built upon the Streeter-Phelps equation to evaluate the DO balance in streams. The analysis for segment N12 is based on BOD_5 and reaeration only. There is not enough coincident nutrient and algal historical data from this site to assess impacts of nutrient loads on algal growth that also impact DO levels. Free floating and attached algae as well as aquatic plants are of concern. The extent to which algae impact the DO resources of a river is dependent on many factors, such as turbidity, which can decrease light transmittance through the water column. Additionally, the photosynthetic rate constantly changes in response to variations in sunlight intensity and is not constant. This results in diurnal fluctuations in DO levels (Mills et al. 1985). In addition, there is not enough data available to estimate the impacts of SOD at these sites.

The Streeter-Phelps analysis was based on the following equation (Mills et al. 1985):

where: DO_o = Calculated DO concentration (mg/L)
D_S = DO at saturation (mg/L)
D_o = Initial DO deficit (mg/L)
k_a = Reaeration rate (1/day)
k_d = BOD_5 decay rate (1/day)
x = Distance downstream of discharge (ft)
v = Stream velocity (ft/day)
L_0 = Initial BOD_5 (mg/L) at x = 0

The initial BOD_5 concentration (L_o) was calculated from observed TOC data. Literature states that the ratio of BOD_5 to TOC is typically between 1.0 and 1.6

(Metcalf and Eddy, Inc. 1991). For analysis, a ratio of 1.3 was used to calculate BOD_5 for each sample date.

Literature provides equations to calculate both the BOD_5 decay rate coefficient (k_d) and reaeration rate coefficient (k_a). The decay rate coefficient is dependent on stream depth, and the reaeration coefficient is dependent on depth and velocity. Due to the limits of the data set shown in Table 5-10, the decay rate coefficient was calculated from either known depths or rating curves allowing the reaeration coefficient to be calculated from the Streeter-Phelps equation presented above as the only unknown variable. The rating curves used to determine depths are available in Appendix K.

The BOD_5 decay rate coefficient (k_d) at 20°C was calculated based on the following equation (USEPA 1997b):

$$k_{d20} = 0.3\left[\frac{H}{8}\right]^{-0.434} \quad \text{for } 0 < H < 8$$

$$= 0.3 \text{ for } H > 8$$

The BOD_5 decay rate coefficient was corrected for temperature with the following equation (Novotny and Olem 1994):

$$k_{dT} = k_{d20}\theta^{(T-20)}$$

where k_{dT} = BOD_5 decay rate coefficient at temperature T; T in °C
θ = Thermal factor

The thermal factor (θ) in the above equation has an accepted value of 1.047 for the BOD_5 decay rate coefficient (Novotny and Olem 1994). The decay rate coefficient typically falls between 0.02 and 3.4 day^{-1}. The reaeration rate coefficient typically ranges between 0 and 100 day^{-1} (USEPA 1997b).

For comparison purposes, the reaeration coefficient (k_a) was calculated based on the following equation (USEPA 1997b):

$$k_a = \frac{12.9\, v^{0.5}}{H^{1.5}} \text{ at } 20^{\circ}C$$

where: v = Stream velocity (feet/s)
H = Stream depth (feet)

Like the BOD_5 decay rate coefficient, the reaeration coefficient is corrected for temperature with the following equation (Novotny and Olem 1994):

$$k_{aT} = k_{a20}\theta^{(T-20)}$$

where: k_{dT} = Reaeration rate coefficient at temperature T; T in °C
θ = Thermal factor

The thermal factor (θ) for the reaeration coefficient has an accepted value of 1.025 (Novotny and Olem 1994).

Table 10-3 shows the observed TOC data and the BOD_5 concentrations (L_0) calculated from observed TOC data. It also shows the k_a and k_d coefficients calculated with the above equations. In addition, the estimated BOD_5 load was calculated based on the calculated BOD_5 concentration and average daily flow on the day the sample was taken. Revised k_a and k_d values are also shown in Table 10-3. These values were utilized in the Streeter-Phelps equation described above and the resulting calculated DO was compared to observed DO readings. If there was not a match between the calculated DO and observed DO, k_a and k_d were revised within their accepted ranges so that calculated DO more closely matched observed DO. If possible, only k_a was revised as it was calculated based on estimated depth and flow while k_d was based on estimated depth. As shown in Table 10-3, the reaeration coefficient was much lower for the impaired sample date than for the non-impaired date. Additionally, the flow for the impaired date was below average as discussed in Section 5.1.5.2.2. Analysis details are contained in Appendix L. In addition to lower flow condtions, there are many factors that may contribute to depressed DO in the Big Muddy River including nutrients stimulating algal activity and other organic loads which could exert an oxygen demand within the system.

Table 10-3 Streeter-Phelps Calculated BOD_5 Concentrations (L_0) and Loads Associated with DO Concentrations

Sample Location and Date	N12 7/24/2000	N12 9/6/2000
Measured DO (mg/L)	7.9	4.7
Measured TOC (mg/L)	5.6	5.5
Calculated BOD_5 Concentration (mg/L)	7.3	7.2
Calculated BOD_5 Load (lb/day)	81,071	15,526
Calculated k_a (1/day)	0.6	1.2
Revised k_a (1/day)	45.4	3.2
Calculated k_d (1/day)	0.36	0.46
Revised k_d (1/day)	0.36	0.46
Flow (cfs)	2,060	400

In addition to the analysis described above, analyses were conducted examining the Big Muddy River during 7Q10 flows or critical low flows with the Carbondale WWTP at its average design flow and BOD limit of 30 mg/L BOD. During these critical conditions, the discharge of the WWTP should not cause DO levels to fall below the 6.0 mg/L standard within segment N12. This was determined by assessing what BOD concentration would need to discharged from the facility to depress DO concentrations below 6 mg/L. It was estimated that a BOD concentration of over 450 mg/L would

have to be discharged in order for DO concentrations to fall below 6.0 mg/L. Therefore, no wasteload allocation will be recommended for this facility in Section 11. Analyses details are also contained in Appendix L.

An error analysis was run on the literature ranges of values for k_a and k_d for each sample date to validate their use for the Streeter-Phelps analysis. This analysis is contained in Appendix M.

10.3.3 pH Analysis Development and Results

An analytical method was used to analyze pH in segment N12 of the Big Muddy River. The method incorporates TDS concentrations, ionic strength, an activity coefficient, and flows to calculate a maximum hydrogen ion loading that will maintain a pH value between 6.5 and 9.0 within segment N12.

The ionic strength is calculated with the following equation:

$$\mu = (2.5 \times 10^{-5}) \times TDS$$

where: μ = ionic strength
TDS = 95th percentile concentration, mg/L or ppm

The 95th percentile concentration of TDS is used to provide a conservative estimate (Snoeyink and Jenkins 1980).

Activity coefficients are used to convert measured H^+ ion activity to molar H^+ ion concentration. The coefficient is dependent on ionic strength and is determined from literature (Snoeyink and Jenkins 1980). The maximum hydrogen ion loading for a particular flow and pH can then be calculated with the following equation:

$$[H^+] = \frac{10^{-pH} \times 1\,\text{gram/mole} \times 28.37\,\text{L/ft}^3 \times Q \times 86400\,\text{s/day}}{\gamma}$$

where: $[H^+]$ = ion load, lb/d
Q = flow, cfs
γ = activity coefficient

This equation can be used to develop the maximum allowable hydrogen ion concentration for a specific pH and varying flow regimes. Figure 10-2 shows the maximum allowable H^+ ion loading at a pH of 6.5 for various flows. Using a pH of 6.5 and the three-year peak flow in the above equation will result in the maximum hydrogen ion concentration allowed to maintain a pH of at least 6.5. The three-year peak flow is utilized because pH is considered a potential cause of use impairment if the water quality standard is at least once in the most recent three-year period (Illinois EPA 2000) allowable excursion.

The 95th percentile of the TDS concentrations in segment N12 is 1,194 mg/L resulting in an ionic strength of 0.02. An activity coefficient of 0.9 was determined from literature for segment N12. The chart used to determine the activity coefficient is provided in Appendix N. As mentioned in Section 5.1.3, flows for segment N12 were obtained from USGS gage 05599500. A lognormal distribution was used to develop the three-year peak flow through segment N12 of 16,426 cfs. Using this flow in the above equation, a maximum allowable hydrogen ion concentration of 14,200 g/day or 31 lb/day was calculated. Analysis details are contained in Appendix O.

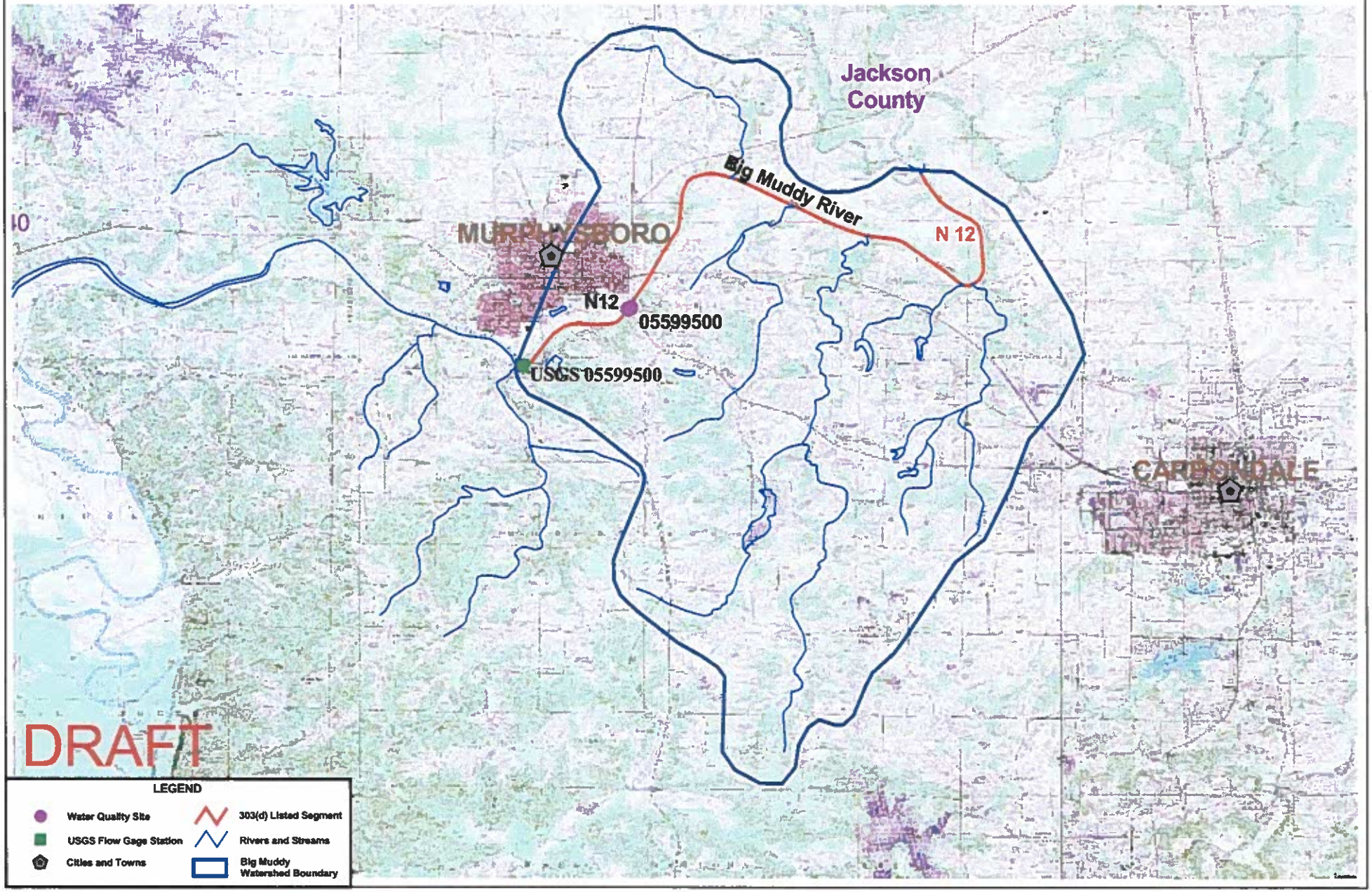


Figure 10-1
Big Muddy River #1 Watershed &
Historic Sampling Locations

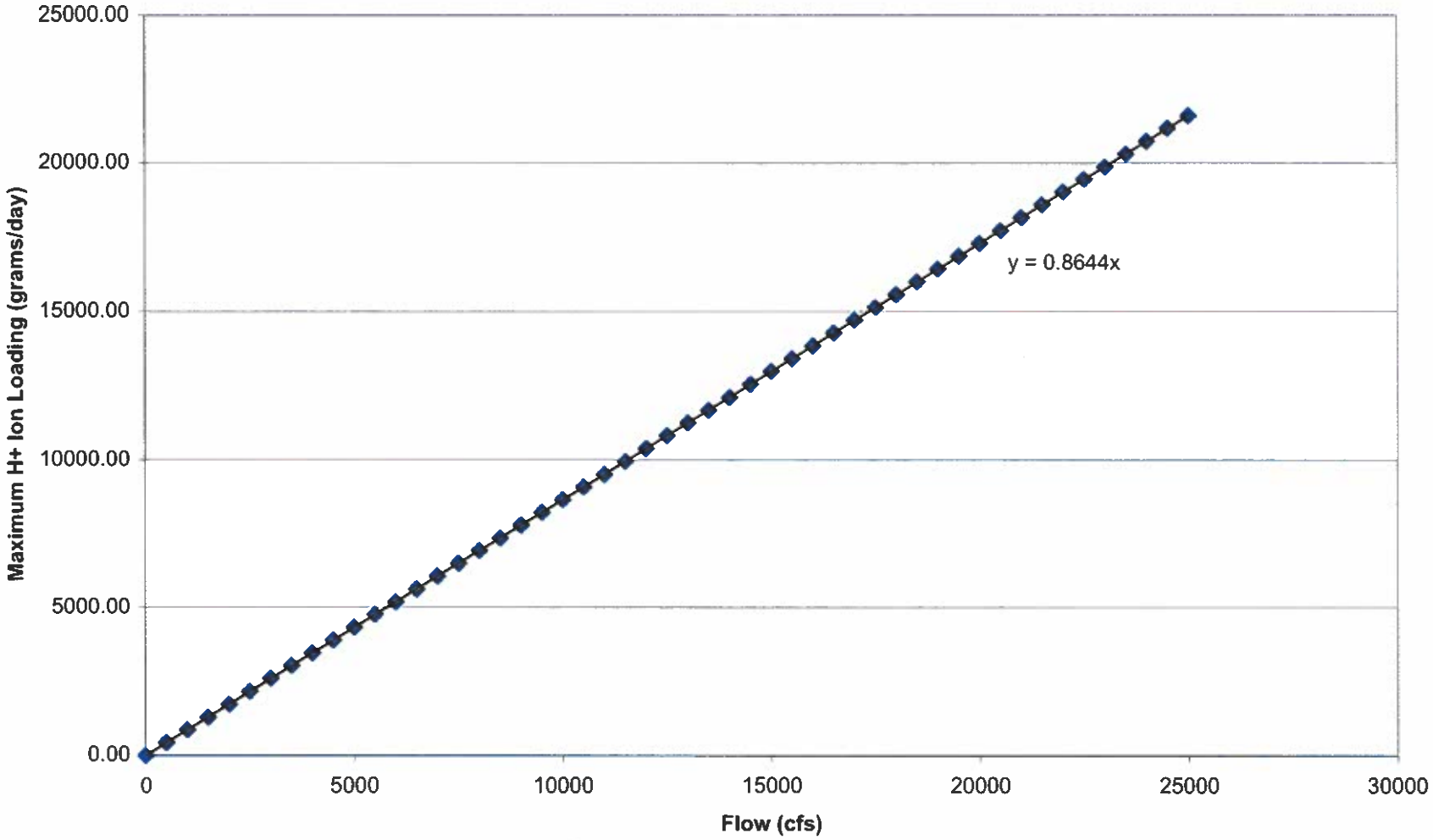
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Figure 10-2: Flow versus Maximum H^+ Ion Loading at a Constant pH of 6.5



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Section 11
Total Maximum Daily Load for Big Muddy River Watershed

11.1 TMDL Endpoints for the Big Muddy River

The TMDL endpoints for manganese, sulfates, pH, and DO in a stream segment are summarized in Table 11-1. For manganese and sulfates, the concentrations must be below the TMDL endpoint. For DO, concentrations must be greater than 6.0 mg/L for 16 hours of any 24-hour period. For pH, the desired measurement is between the endpoint limits. These endpoints are based on protection of aquatic life in the Big Muddy River and its tributaries. Some of the average concentrations, which are based on a limited data set, meet the desired endpoints. However, the data set has maximum or minimum values, presented in Section 5.1.5.2.4, that do not meet the desired endpoints and this was the basis for TMDL analysis. Further monitoring as outlined in the monitoring plan presented in Section 12, will help further define when impairments are occurring in the watershed and support the TMDL allocations outlined in the remainder of this section.

Table 11-1 TMDL Endpoints and Average Observed Concentrations for Impaired Constituents in the Big Muddy River Watershed

Constituent	TMDL Endpoint	Average Observed Value for N12
Manganese	1.0 mg/L	0.6 mg/L
Sulfates	500 mg/L	250 mg/L
DO	6.0 mg/L (16 hours of any 24-hour period)	8.5 mg/L
pH	6.5 - 9 s.u.	7.3 s.u.

11.2 Pollutant Source and Linkages

Pollutant sources for the Big Muddy River were identified through the existing data review described in Section 5. Based on the data review, the source of manganese and sulfates in the Big Muddy River segment N12 is groundwater potentially contaminated by abandoned coal mines. The likely source of oxygen demanding constituents is primarily factors occurring during low flow conditions, such as slow-moving waters and increased water temperatures promoting algal growth. Nonpoint source loads in the watershed may also contribute to low DO in the stream. Sources of low pH include acid mine drainage and fluctuations due to algal growth in aquatic systems.

11.3 Allocation

As explained in Section 1, the TMDL for Big Muddy River segment N12 will address the following equation:

$$TMDL = LC = \Sigma WLA + \Sigma LA + MOS$$

where: LC = Maximum amount of pollutant loading a water body can receive without violating water quality standards
WLA = The portion of the TMDL allocated to existing or future point sources
LA = Portion of the TMDL allocated to existing or future nonpoint sources and natural background
MOS = An accounting of uncertainty about the relationship between pollutant loads and receiving water quality

Each of these elements will be discussed in this section as well as consideration of seasonal variation in the TMDL calculation.

11.3.1 Manganese and Sulfates TMDL

11.3.1.1 Loading Capacity

The loading capacity for manganese and sulfates for impaired segment N12 was based on the Monte Carlo analysis described in Section 10. The LTA, determined by analysis to meet water quality standards generated from the Monte Carlo analysis, is the basis for loading capacity for segment N12. This LTA was multiplied by average flow in each segment to determine an average load. These average loads are shown in Table 11-2.

Table 11-2 Average Loads Based on LTA for Manganese and Sulfates

Constituent	LTA (mg/L)	Allowable Load (lb/day)
Manganese	0.2	2,244
Sulfates	103.7	1,163,422

11.3.1.2 Seasonal Variation

A season is represented by changes in weather; for example, a season can be classified as warm or cold as well as wet or dry. Seasonal variation is represented in the Big Muddy River segment N12 TMDL as conditions were investigated during all seasons of the year. Section 5.1.3 discusses the flow data available for Segment NC12 and Section 5.1.5 and Appendix A contain the water quality data available for manganese and sulfate. A review of the flow data and water quality data (Figures 5-4 and 5-5) show that the water quality data were gathered at various times during the year, thus capturing seasonal variations in loadings into the river. Since the various pollutant sources are expected to contribute loadings in different quantities during different time periods (e.g., spring run-off loads), the loadings for this TMDL will focus on a LTA loading rather than specifying different loadings by season. As more data are gathered, further refinement of the seasonal variation may be possible.

11.3.1.3 Margin of Safety

The MOS can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a

combination of both. An explicit MOS of 10 percent is recommended for manganese and sulfates in the Big Muddy River segment N12 Watershed because of the limited data set available for analysis and because Monte Carlo analysis incorporates uncertainty to some degree into the LTA.

Uncertainty in water quality is accounted for in the Monte Carlo analysis based upon how the analysis is done. The distribution of the water quality data is estimated and numerous iterations are run to determine the reduction needed to meet the target of one exceedence in three years. A data set with significant variation will result in a final target (LTA) that is significantly lower than the water quality standard as compared to a data set with little variation that would likely result in a LTA being slightly lower than the water quality standard. By this process, uncertainty in the data is addressed. For these reasons, an explicit 10 percent MOS is considered appropriate based upon the data available. As more data become available such as a regression analysis between flow and in-stream concentrations, the MOS could be revisited and revised if appropriate.

11.3.1.4 Waste Load Allocation

TMDLs completed in upstream watersheds that relate to mining activity will help reduce pollutant loads to segment N12. This also applies to the next section discussing Load Allocation.

11.3.1.5 Load Allocation and Summary TMDLs

Table 11-3 shows a summary of the TMDL for manganese and sulfates in the Big Muddy River segment N12 watershed. The calculated allowable loads (LC) necessary to maintain the water quality standard are reduced by the MOS, representing the uncertainty in the data analysis, to determine the allowable loading from the watershed, the LA. The LC was calculated from the LTA presented in Section 10.3.1. Reductions of 70 percent for manganese and 62 percent for sulfates were estimated as the required decreases in loadings so that water quality standards will be met in the stream segments.

Table 11-3 TMDL Summary for Manganese and Sulfates

Constituent	LC (lb/day)	WLA (lb/day)	LA (lb/day)	MOS (lb/day)	Reduction Needed (lb/day)	Reduction Needed (percent)
Manganese	2,244	0	2,020	224	4,662	70%
Sulfates	1,163,422	0	1,047,080	116,342	1,722,615	62%

Table 11-4 LTAs Required Based on TMDL MOS

Constituent	Monte Carlo LTA (mg/L)	Recalculated LTA (mg/L)
Manganese	0.20	0.18
Sulfates	103.7	93

The required LTAs presented in Section 10 and in Table 11-2 were reduced because of the applied MOS and are presented in Table 11-4. The recalculated LTA represents the LA in Table 11-3. Methods to meet these LTAs will be outlined in Section 12.

11.3.2 DO TMDL

11.3.2.1 Loading Capacity

As discussed in Section 10.3.2, the analysis suggests that the principle cause of DO impairments in segment N12 is a lack of aeration caused by low flows. Table 11-5 shows the aeration coefficient calculated from the observed DO in Section 10.3 for sample dates that did not meet the TMDL endpoint and the coefficient that would be required to meet the TMDL endpoint of 6.0 mg/L DO (16 hours of any 24-hour period) for sampling events that had DO measurements less than 6.0 mg/L. Increasing aeration in the stream is not a parameter for which a TMDL can be developed. Therefore, no loading capacity will be developed at this time. Methods to achieve elevated reaeration coefficients will be outlined in Section 10.

Table 11-5 Calculated Reaeration Coefficients and Required Reaeration Coefficients in the Big Muddy River Segment N12 Watershed Based on TMDL Endpoint for DO

Segment	Date	Measured DO Concentration (mg/L)	Modeled k_a (1/day)	Required k_a (1/day)
N12	9/6/00	4.7	3.2	11.5

Based on the data analysis, increases of aeration would be required in summer months but not during winter conditions. Monitoring data to make the analysis more robust will be discussed in Section 12 as well as management measures to increase aeration and reduce nonpoint source loads contributing to non-attainment of the DO water quality standard.

To confirm that reductions in BOD_5 loads to meet the water quality standard are not an appropriate measure for controlling DO in this watershed, the Streeter-Phelps equations presented in Section 10.3.2 were used to estimate the BOD_5 loading required to meet the water quality standard on each sample date impaired for DO.

Table 11-6 shows the BOD_5 loads estimated from TOC as discussed in Section 10.3.2 and the BOD_5 loading that would be necessary to meet water quality standards.

Table 11-6 Calculated BOD_5 Loads and Required Loads in the Big Muddy River Segment N12 Watershed Based on TMDL Endpoint for DO

Segment	Date	Measured DO Concentration (mg/L)	Calculated BOD_5 (lb/d)	Required BOD_5 (lb/d)
N12	9/6/00	4.7	7.2	0

Table 11-6 shows that the reductions in BOD_5 loads necessary for compliance with the DO loads are not a feasible option for increasing DO in the Big Muddy River Watershed.

11.3.3 pH TMDL

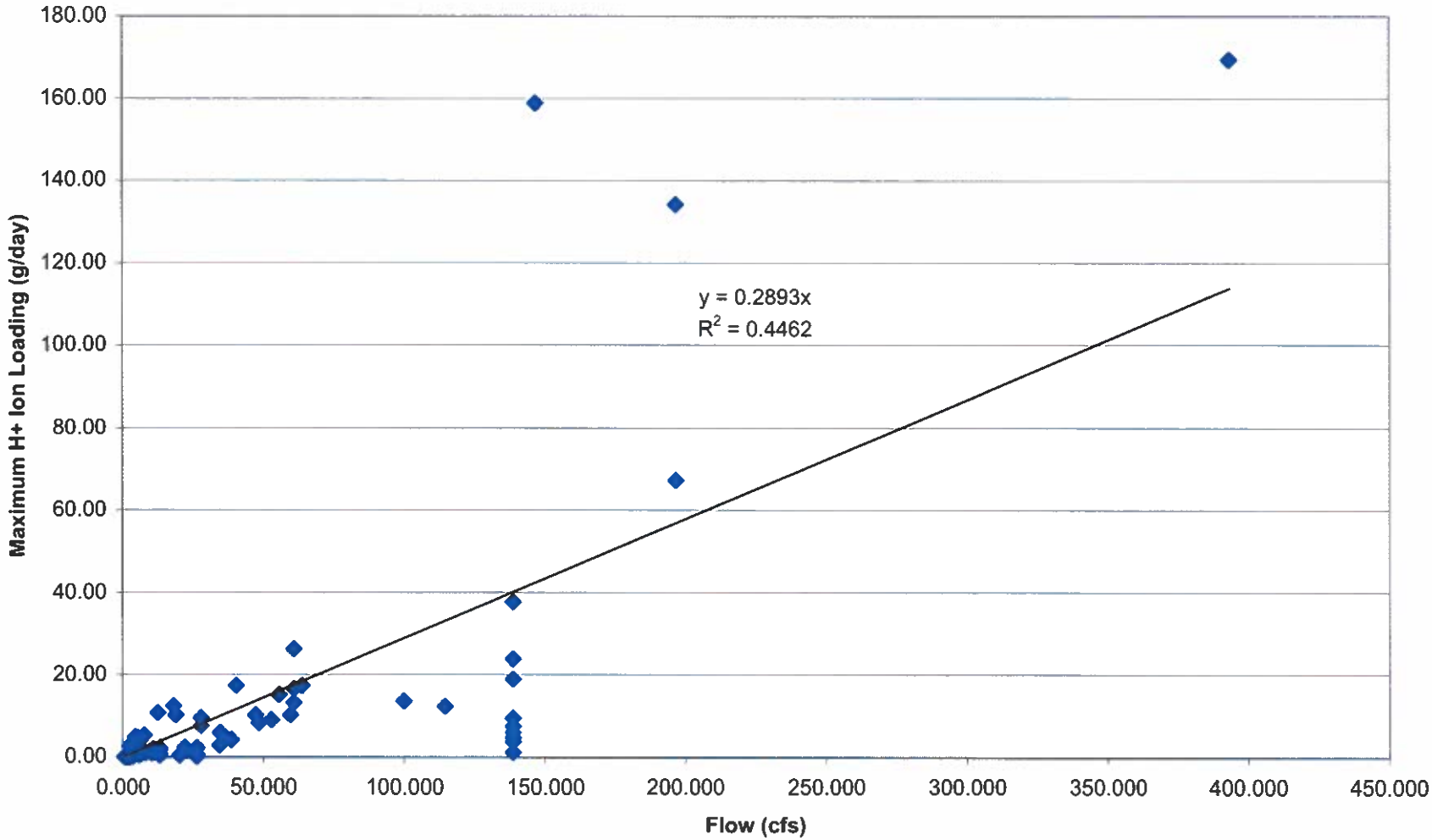
Figure 11-1 shows the existing maximum hydrogen ion concentration versus flow using hydrogen concentrations calculated from the pH sample data for segment N12 and the equation presented in Section 10.3.3. From this figure, the maximum hydrogen

ion concentration for the three-year peak flow of 16,426 cfs was determined as 10.5 lb/day. The allowable maximum hydrogen ion concentration calculated in Section 10 is 31 lb/day. The existing concentration is below the allowable concentration indicating that no allocations are necessary at this time to meet the TMDL endpoint for pH in Big Muddy River segment N12. Because the relationship between hydrogen ion concentration and pH is an inverse log-arithmetic function, since the maximum load is greater than the allowable load no allocations are needed to increase the pH within the watershed.

Since current pH loadings are less than the allowable loading predicted from analysis, no TMDL for pH is recommended at this time. Although no TMDL is recommended, the implementation strategies outlined in Section 12 will also help control pH in the Big Muddy River segment N12 Watershed.

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Figure 11-1: Flow versus Maximum H^+ Ion Loading for Segment N12 of the Big Muddy River



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Section 12
Implementation Plan for Big Muddy River Watershed

12.1 Implementation Actions and Management Measures for Manganese and Sulfates

An adaptive management or phased approach is recommended for the manganese and sulfates TMDL for this watershed, because of the limited amount of longitudinal data available for the TMDL analysis of segment N12 in the Big Muddy River Watershed. Longitudinal data would be represented by multiple sampling locations in segment N12. Adaptive management is a systematic process for continually improving management policies and practices through learning from the outcomes of operational programs. Some of the differentiating characteristics of adaptive management are:

- acknowledgement of uncertainty about what policy or practice is "best" for the particular management issue,
- thoughtful selection of the policies or practices to be applied (the assessment and design stages of the cycle),
- careful implementation of a plan of action designed to reveal the critical knowledge that is currently lacking.
- monitoring of key response indicators,
- analysis of the management outcomes in consideration of the original objectives, and incorporation of the results into future decisions (British Columbia Ministry of Forests 2000).

Based on existing data review, presented in Section 10, the likely sources of manganese and sulfates in the Big Muddy River segment N12 watershed are from abandoned mines. Further source identification is required as outlined in the next section. Acid mine drainage and excessive algal growth could cause pH impairments, but as explained in Section 11, no TMDL for pH is recommended at this time. BMPs recommended for DO, manganese, and sulfates should also help mitigate pH impairments.

12.1.1 Source Identification for Manganese and Sulfates

It is recommended that further source identification activities take place within the watershed because the current data regarding sources of manganese and sulfates in the segment N12 watershed is limited. The GIS data and mapping provided in Section 5 (Figure 5-1) should be the basis for the start of the source investigation. Collection of data during various flow conditions may also be beneficial in determining the source of these constituents. For the segment N12 watershed, the location of the potential

discharge from the abandoned coal mines should be identified in addition to other mining activity, which could contribute manganese and sulfate concentrations in the receiving waters. Once potential sources are identified and located, sampling stations should be placed in appropriate locations to assess water quality downstream of these sources. The potential source identification and station sampling placement should be the result of field investigations.

Although the watershed delineation through mined areas may not be exact, the implementation actions and management measures remain applicable to the entire Big Muddy River Watershed.

12.1.2 Manganese and Sulfates Management Measures

It is likely that the main contributors to impairments within the watershed are abandoned mine sites. If the major source of manganese and sulfates in the segment N12 watershed is attributed to abandoned mining, active chemical treatment methods, passive treatment methods, and mine reclamation are available. Active chemical treatment typically involves the addition of alkaline chemicals, such as calcium carbonate, sodium hydroxide, sodium bicarbonate, and anhydrous ammonia to acid mine drainage. These chemicals raise the pH to acceptable levels and decrease the solubility of dissolved metals. Metal precipitates form and settle out of the solution. Active chemical treatment is not a viable option for the segment N12 watershed because the chemicals are expensive, and the treatment system requires additional costs associated with operation and maintenance as well as the disposal of metal-laden sludge.

Reclamation of abandoned mines is another method of controlling pollutants. Reclamation of abandoned mine land involves clearing site vegetation, removing contaminated topsoil and coal, and restoring functionality of the site for recreational, agricultural, or wildlife habitat purposes. The environmental benefits realized from abandoned mine reclamation projects are numerous and significant, including restoring land for future use and improving water quality. Restoration of the land can result in increased and enhanced pasture land, recreational areas, or wildlife habitat (Pennsylvania Department of Environmental Protection [PDEP] 2002). However, reclamation projects tend to be costly and resource intensive and may not be appropriate for abandoned mine sites in segment N12 watershed.

Passive methods could be utilized until full reclamation of a mine occurs. Chemical addition and energy consuming treatment processes are virtually eliminated with passive treatment systems. The operation and maintenance requirements of passive systems are considerably less than active treatment systems (PDEP 2002). Therefore, passive treatment systems would be the best solution for controlling manganese and sulfates from abandoned coal mines in segment N12 of the Big Muddy River Watershed.

Following are examples of the passive treatment technologies:

- Aerobic wetland
- Compost or anaerobic wetland
- Open limestone channels
- Diversion wells
- Anoxic limestone drains
- Vertical flow reactors
- Pyroclastic process

The remainder of this section discusses these technologies.

12.1.2.1 Aerobic Wetland

An aerobic wetland consists of a large surface area pond with horizontal surface flow. The pond may be planted with cattails and other wetland species. Aerobic wetlands can only effectively treat water that is net alkaline (pH greater than 7). In aerobic wetland systems, metals are precipitated through oxidation reactions to form oxides and hydroxides. A typical aerobic wetland will have a water depth of 6 to 18 inches (PDEP 2002).

12.1.2.2 Compost or Anaerobic Wetland

Compost wetlands, or anaerobic wetlands as they are sometimes called, consist of a large pond with a lower layer of organic substrate. The flow is horizontal within the substrate layer of the basin. Piling the compost a little higher than the free water surface can encourage the flow within the substrate. Typically, the compost layer consists of spent mushroom compost that contains about 10 percent calcium carbonate. Other compost materials include peat moss, wood chips, sawdust, or hay. A typical compost wetland will have 12 to 24 inches of organic substrate and be planted with cattails or other emergent vegetation (PDEP 2002).

12.1.2.3 Open Limestone Channels

Open limestone channels may be the simplest passive treatment method. Open limestone channels are constructed in two ways. In the fist method, a drainage ditch constructed of limestone collects contaminated acid mine drainage water. The other method consists of placing limestone fragments directly in a contaminated stream. Dissolution of the limestone adds alkalinity to the water and raises the pH. This treatment requires large quantities of limestone for long-term success (PDEP 2002).

12.1.2.4 Diversion Wells

Diversion wells are another simple way to increase the alkalinity of contaminated waters. Acidic water is conveyed by a pipe to a downstream "well," which contains crushed limestone aggregate. The hydraulic force of the pipe flow causes the limestone to turbulently mix and abrade into fine particles preventing armoring (PDEP 2002).

12.1.2.5 Anoxic Limestone Drains

An anoxic limestone drain is a buried bed of limestone constructed to intercept subsurface mine water flow and prevent contact with atmospheric oxygen. Keeping

oxygen out of the water prevents oxidation of metals and armoring of the limestone. An anoxic limestone drain can be considered a pretreatment step to increase alkalinity and raise pH before the water enters a constructed aerobic wetland (PDEP 2002).

12.1.2.6 Vertical Flow Reactors

Vertical flow reactors were conceived as a way to overcome the alkalinity producing limitations of anoxic limestone drains and the large area requirements of compost wetlands. The vertical flow reactor consists of a treatment cell with an underdrained limestone base topped with a layer of organic substrate and standing water. The water flows vertically through the compost and limestone and is collected and discharged through a system of pipes. The vertical flow reactor increases alkalinity by limestone dissolution and bacterial sulfate reduction (PDEP 2002).

12.1.2.7 Pyrolusite Process

This is a patented process, which utilizes site-specific cultured microbes to remove iron, manganese, and aluminum from acid mine drainage. The treatment process consists of a shallow bed of limestone aggregate inundated with acid mine drainage. After laboratory testing determines the proper combination, microorganisms are introduced to the limestone bed by inoculation ports located throughout the bed. The microorganisms grow on the surface of the limestone chips and oxidize the metal contaminants while etching away limestone, which in turn increases the alkalinity and raises the pH of water. This process has been used on several sites in western Pennsylvania with promising results (PDEP 2002).

12.2 Implementation Actions and Management Measures for Dissolved Oxygen

DO impairments are addressed by focusing on organic loads that consume oxygen through decomposition and nutrient loads that can cause algal growth, which can also deplete DO. Analysis provided in Section 10 established a relationship between reaeration, BOD_5, and DO concentrations in Big Muddy River segment N12, so management measures for segment N12 will focus on increasing reaeration decreasing BOD_5 loads to increase DO concentrations.

DO impairments in Big Muddy River segment N12 are mostly attributed to low flow or stagnant conditions within the creek. Runoff from nonpoint sources may also contribute a BOD_5 load in Big Muddy River segment N12. An additional contributor to low DO is increased water temperatures. Therefore, management measures for the segment N12 watershed will focus on reducing nonpoint source loading through sediment and surface runoff controls, reducing stream temperatures, and reducing stagnant conditions through reaeration.

Implementation actions, management measures, or BMPs are used to control the generation or distribution of pollutants. BMPs are either structural, such as wetlands, sediment basins, fencing, reaeration structures, or filter strips; or managerial, such as conservation tillage, nutrient management plans, or crop rotation. Both types require

good management to be effective in reducing pollutant loading to water resources (Osmond et al. 1995).

It is generally more effective to install a combination of BMPs or a BMP system. A BMP system is a combination of two or more individual BMPs that are used to control a pollutant from the same critical source. In other words, if the watershed has more than one identified pollutant, but the transport mechanism is the same, then a BMP system that establishes controls for the transport mechanism can be employed. (Osmond et al. 1995).

Implementation actions and management measures are described for each nonpoint source in the watershed. Nonpoint sources include cropland, rural grassland, and animal management facilities.

12.2.1 DO Concentration Management

The sources of nonpoint source pollution in the Big Muddy River TMDL are divided between agricultural cropland and rural grasslands. There are three animal management facilities in the watershed. Although, two have been classified as no impact facilities, the third has not been assessed. BMPs evaluated for treatment of these nonpoint sources are:

- Filter strips
- Wetlands
- Reaeration

Organic and nutrient loads originating from cropland is most efficiently treated with a combination of riparian buffer or grass filter strips. Wetlands can be used to treat pollutant loads originating from animal management operations. Instream management measures for DO focus on reaeration techniques. The Streeter-Phelps equations presented in Section 10 utilizes a reaeration coefficient. Increasing the reaeration coefficient by physical means will increase DO in Big Muddy River segment N12.

12.2.1.1 Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment, to the Big Muddy River segment N12. Filter strips implemented along stream segments slow and filter nutrients and sediment out of runoff, help reduce stream water temperatures thereby increasing the water body DO saturation level, and provide bank stabilization decreasing erosion and deposition. The following paragraphs focus on the implementation of filter strips in Big Muddy River segment N12 watershed. Finally, design criteria and size selection of filter strips are detailed.

Organic debris in topsoil contributes to the BOD_5 load to water bodies (USEPA 1997). Increasing the length of stream bordered by grass and riparian buffer strips will decrease the amount of BOD_5 and nutrient load associated with sediment loads to Big Muddy River segment N12. Nutrient criteria, currently being developed and expected

to be adopted around 2007 by the Illinois EPA, will assess the instream nutrient concentrations required for the watershed. As stated previously, excess nutrients in streams can cause excessive algal growth, which can deplete DO in streams. Adoption of nutrient criteria will potentially affect this DO TMDL and help control exceedences of DO water quality criteria in Big Muddy River segment N12.

Filter strips will help control BOD_5 levels by removing organic loads associated with sediment from runoff; however, no studies were identified as providing an estimate of removal efficiency. Grass filter strips can remove as much as 75 percent of sediment and 45 percent of total phosphorus from runoff, so it is assumed that the removal of BOD_5 falls within this range (NCSU 2000). Riparian buffer strips also help reduce water temperatures increasing the water body DO saturation level as explained in Section 10.

Riparian vegetation, specifically shade, plays a significant role in controlling stream temperature change. The shade provided will reduce solar radiation loading to the stream. Furthermore, riparian vegetation provides bank stability that reduces sediment loading to the stream and the stream width-to-depth ratio. Research in California (Ledwith 1996), Washington (Dong et al. 1998), and Maine (Hagan and Whitman 2000) show that riparian buffers effect microclimate factors such as air temperature and relative humidity proximal to the stream. Ledwith (1996) found that a 500-foot buffer had an air temperature decrease of 12°F at the stream over a zero-foot buffer. The greatest change occurred in the first 100 feet of the 500-foot buffer where the temperature decreased 2°F per 30 feet from the stream bank. A decrease in the air temperature proximal to the stream would result in a smaller convective flux to the stream during the day.

Filter strip widths for the Big Muddy River TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 12-1 outlines the guidance for filter strip flow length by slope (NRCS 1999). Based on slope estimates near tributaries within the watershed, filter strips widths of 72 to 144 feet could be incorporated in locations throughout the watershed. The total acreage examined was 112 acres.

Table 12-1 Filter Strip Flow Lengths Based on Land Slope

Percent Slope	0.5%	1.0%	2.0%	3.0%	4.0%	5.0% or greater
Minimum	36	54	72	90	108	117
Maximum	72	108	144	180	216	234

The acreages provided above are used to calculate an approximation of BMP cost in Section 12.3 and should only be used as a guideline for watershed planning. It is recommended that landowners evaluate their land near streams and lakes and create or extend filter strips, where applicable, according to the NRCS guidance presented in

Table 12-1. Programs available to fund the construction of these buffer strips are discussed in Section 9.3.

12.2.1.2 Wetlands

Wetlands can be used as a structural control to treat loads from animal management operations located in the segment N12 watershed. Two of the three animal management facilities in the watershed have been designated as having no impact on receiving waters and the third has not been assessed. In the event that the third facility is found to have a negative impact on water quality, a constructed wetland could be used to treat organic, nutrient, and sediment loads from the animal management operations between the operation and the creek. Wetlands are an effective BMP for sediment, nutrient, and organic load control because they:

- prevent floods by temporarily storing water, allowing the water to evaporate, or percolate into the ground,
- improve water quality through natural pollution control such as plant nutrient uptake,
- filter sediment,
- slow overland flow of water thereby reducing soil erosion (USDA 1996).

While constructed wetlands have been demonstrated to effectively reduce nitrogen and sediment, literature shows mixed results for phosphorus removal. Studies have shown that artificial wetlands designed and constructed specifically to remove pollutants from surface water runoff have removal rates for suspended solids of greater than 90 percent, for total phosphorus of 0 to 90 percent, and for nitrogen species from 10 to 75 percent (Johnson, Evans, and Bass 1996; Moore 1993; USEPA 1993; Kovosic et al. 2000). In some cases, wetlands can be sources of phosphorus. Over the long term, it generally thought that wetlands are neither sources nor sinks of phosphorus (Kovosic et al. 2000).

Efficiency of pollutant removal in wetlands can be addressed in the design and maintenance of the constructed wetland. Location, hydraulic retention time and space requirements should be considered in design. To maintain removal efficiency, sheet flow should be maintained and substrate should be monitored to assess whether the wetland is operating optimally. Sediment or vegetation removal may be necessary if the wetland removal efficiency is lessened over a period of time (USEPA 1993; NCSU 1994).

It is recommended that further investigation take place within the watershed to confirm the impact of animal management facilities on Big Muddy River segment N12. Due to data illustrating the lack of impacts of nonpoint source runoff from these facilities, wetlands were not analyzed as a treatment for this TMDL. However, it is recommended that animal control facility managers consider wetlands to treat nonpoint source runoff from control facilities.

12.2.1.3 Reaeration

The purpose of reaeration is to increase DO concentrations in streams. Physical measures that will assist in increasing reaeration of a stream include bank stabilization, channel modifications, and the addition of riprap or pool and riffle sequences. Bank stabilization reduces erosion by planting vegetation along the bank or modification of the channel to decrease the slope of the bank. Riprap or pool and riffle sequences would increase reaeration by increasing turbulence. Turbulence creates an increase in the interaction between air and water, which draws air into the river increasing aeration. Expanding monitoring to several locations along the impaired segments could help identify reaches that would benefit the most from an increase of turbulence.

12.3 Reasonable Assurance

Reasonable assurance means that a demonstration is given that the pollutant reductions in this watershed will be implemented. It should be noted that all programs discussed in this section are voluntary. The discussion in Sections 12.1 and 12.2 provided a means for obtaining the reductions necessary. The remainder of this section discusses the programs available to assist with funding and an estimate of costs to the watershed for implementing these practices.

12.3.1 Available Programs for Manganese and Sulfates TMDL

The state agency primarily responsible for reclamation of pre-law coal mine areas is the IDNR, Office of Mines and Minerals, Abandoned Mined Lands Reclamation Division (AMLRD). The AMLRD contracts or oversees reclamation of pre-law mine sites utilizing funds from a "reclamation fee" (tax) on every ton of coal mined in Illinois since the implementation of the Surface Mining Control and Reclamation Act of 1977. The fee monies are sent to the U.S. Department of Interior and are then partially reallocated back to the states for several purposes, which include the reclamation of pre-law abandoned mined lands. This reclamation fee funds almost all of the reclamation of pre-law mine sites in Illinois. The AMLRD also has the responsibility to reclaim permitted mine sites where the operator has deserted the site and all of the bond money has been forfeited. This adds to the overall number of projects that the AMLRD has to complete (Muir et al. 1997).

Abandoned mine sites are reclaimed through the ALMRD according to a priority list as monies become available. Because the federally designated first priority for ALMRD projects is safety, most of the early reclamation projects were not environmentally oriented. Even so, the AMLRD has completed a large number of environmentally oriented reclamation projects (Muir et al. 1997). Due to the uncertainty of sources of manganese and sulfates in the Big Muddy River segment N12 Watershed, no cost estimates were developed for mitigation of the potential sources provided in this report. If the abandoned mines in the segment N12 watershed are shown to contribute to impairment of segments within the watershed, funds from the ALMRD focused on environmental projects should be directed towards water bodies with TMDLs.

12.3.2 Available Programs for DO TMDL

Approximately 42 percent of the Big Muddy River segment N12 watershed is classified as rural grassland (pasture land, CRP, waterways, buffer strips, etc.), row crop, and small grains land. There are several voluntary conservation programs established through the 2002 U.S. Farm Bill that encourage landowners to implement resource-conserving practices for water quality and erosion control purposes. These programs would apply to crop fields and rural grasslands that are presently used as pasture land. Each program is discussed separately in the following sections.

12.3.2.1 Clean Water Act Section 319 Grants

Section 319 was added to the CWA to establish a national program to address nonpoint sources of water pollution. Through this program, each state is allocated section 319 funds on an annual basis according to a national allocation formula based on the total annual appropriation for the section 319 grant program. The total award consists of two categories of funding; incremental funds and base funds. A state is eligible to receive EPA 319(h) grants upon USEPA's approval of the state's Nonpoint Source Assessment Report and Nonpoint Source Management Program. States may reallocate funds through subawards (e.g., contracts, subgrants) to both public and private entities, including local governments, tribal authorities, cities, counties, regional development centers, local school systems, colleges and universities, local nonprofit organizations, state agencies, federal agencies, watershed groups, for-profit groups, and individuals. Subawards to individuals are limited to demonstration projects (USEPA 2003, 2002).

USEPA designates incremental funds, a $100-million award, for the restoration of impaired water through the development and implementation of watershed-based plans and TMDLs for impaired waters. Base funds, funds other than incremental funds, are used to provide staffing and support to manage and implement the state Nonpoint Source Management Program. Section 319 funding can be used to implement activities which improve water quality, such as filter strips, streambank stabilization, etc (USEPA 2003, 2002).

12.3.2.2 Streambank Stabilization and Restoration Practice

The Streambank Stabilization and Restoration Practice (SSRP) was established to address problems associated with streambank erosion; such as loss or damage to valuable farmland, wildlife habitat, roads; stream capacity reduction through sediment deposition; and degraded water quality, fish, and wildlife habitat. The primary goals of the SSRP are to develop and demonstrate vegetative, stone structure and other low cost bio-engineering techniques for stabilizing streambanks and to encourage the adoption of low-cost streambank stabilization practices by making available financial incentives, technical assistance, and educational information to landowners with critically eroding streambanks. A cost share of 75 percent is available for approved project components; such as willow post installation, bendway weirs, rock riffles, stream barbs/rock, vanes, lunker structures, gabion baskets, and stone toe protection techniques. There is no limit on the total program payment for cost-share projects that a landowner can receive in a fiscal year. However, maximum cost per foot of bank

treated is used to cap the payment assistance on a per foot basis and maintain the program's objectives of funding low-cost techniques (IDA 2000).

12.3.2.3 Conservation Reserve Program

This voluntary program encourages landowners to plant long-term resource-conserving cover to improve soils, water, and wildlife resources. CRP is the USDA's single largest environmental improvement program and one of its most productive and cost-efficient. It is administered through the FSA by USDA's CCC. The program was initially established in the Food Security Act of 1985. The duration of the contracts under CRP range from 10 to 15 years.

Eligible land must be one of the following:

1. Cropland that is planted or considered planted to an agricultural commodity two of the five most recent crop years (including field margins), and must be physically and legally capable of being planted in a normal manner to an agricultural commodity.

2. Certain marginal pasture land enrolled in the Water Bank Program.

The CCC bases rental rates on the relative productivity of soils within each county and the average of the past three years of local dryland cash-rent or cash-rent equivalent. The maximum rental rate is calculated in advance of enrollment. Producers may offer land at the maximum rate or at a lower rental rate to increase likelihood of offer acceptance. In addition, the CCC provides cost-share assistance for up to 50 percent of the participant's costs in establishing approved conservation practices. CCC also encourages restoration of wetlands by offering a one-time incentive payment equal to 25 percent of the costs incurred. This incentive is in addition to the 50 percent cost share provided to establish cover (USDA 1999).

Finally, CCC offers additional financial incentives of up to 20 percent of the annual payment for certain continuous sign-up practices. Continuous sign-up provides management flexibility to farmers and ranchers to implement certain high-priority conservation practices on eligible land. The land must be determined by NRCS to be eligible and suitable for any of the following practices:

- Riparian buffers
- Filter strips
- Grass waterways
- Shelter belts
- Field windbreaks
- Living snow fences
- Contour grass strips
- Salt tolerant vegetation
- Shallow water areas for wildlife
- Eligible acreage within an USEPA-designated wellhead protection area (FSA 1997)

12.3.2.4 Wetlands Reserve Program

The WRP is a voluntary program that provides technical and financial assistance to eligible landowners to restore, enhance, and protect wetlands. The goal of WRP is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. At least 70 percent of each project area will be restored to the original natural condition to the extent practicable. The remaining 30 percent of each area may be restored to other than natural conditions. Landowners have the option of enrolling eligible lands through permanent easements, 30-year easements, or restoration cost-share agreements. The program is offered on a continuous sign-up basis and is available nationwide. WRP offers landowners an opportunity to establish, at minimal cost, long-term conservation and wildlife habitat enhancement practices and protection. It is administered through the NRCS (2002b).

The 2002 Farm Bill reauthorized the program through 2007. Increasing the acreage enrollment cap to 2,275,000 acres with an annual enrollment of 250,000 acres per calendar year. The program is limited by the acreage cap and not by program funding. The program offers three enrollment options: permanent easements, 30-year conservation easements, and 10-year restoration cost-share agreements. Since the program began in 1985, the average cost per acre is $1,100 in restorative costs and the average project size is 177 acres. The costs for each enrollment options follow in Table 12-2 (USDA 1996).

Table 12-2 Costs for Enrollment Options of WRP Program

Option	Permanent Easement	30-year Easement	Restoration Agreement
Payment for Easement	100% Agricultural Value	75% Agricultural Value	NA
Payment Options	Lump Sum	Lump Sum	NA
Restoration Payments	100% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements

12.3.2.5 Environmental Quality Incentive Program

The EQIP is a voluntary USDA conservation program for farmers and private landowners engaged in livestock or agricultural production who are faced with serious threats to soil, water, and related natural resources. It provides technical, financial, and educational assistance primarily in designated "priority areas." Priority areas are defined as watershed, regions, or areas of special environmental sensitivity that have significant soil, water, or natural resource related concerns. The program goal is to maximize environmental benefits per dollar expended and provides "(1) flexible technical and financial assistance to farmers and ranchers that face the most serious natural resource problems; (2) assistance to farmers and ranchers in complying with federal, state, and tribal environmental laws, and encourage environmental enhancement; (3) assistance to farmers and ranchers in making beneficial, cost-effective changes to measures needed to conserve and improve natural resources; and (4) for the consolidation and simplification of the conservation planning process." As of 2001, 379,000 acres have been protected in Illinois using EQIP (NRCS 2002d,e).

Landowners, with the assistance of a local NRCS or other service provider, are responsible for development of a site-specific conservation plan that addresses the primary natural resource concerns of the priority area. Conservation practices include but are not limited to erosion control, filter strips, buffers, and grassed waterways. If the plan is approved by NRCS, a five- to 10-year contract that provides cost-share and incentive payments is developed.

Cost-share assistance may pay landowners up to 75 percent of the costs of conservation practices, such as grassed waterways, filter strips, manure management, capping abandoned wells, and other practices important to improving and maintaining the health of natural resources in the area. Total incentive and cost-share payments are limited to $10,000 per person per year and $50,000 over the life of the contract.

12.3.2.6 Wildlife Habitat Incentives Program

The WHIP is a voluntary program that encourages the creation of high quality wildlife habitat of national, state, tribal, or local significance. WHIP is administered through NRCS, which provides technical and financial assistance to landowners for development of upland, riparian, and aquatic habitat areas on their property. NRCS works with the participant to develop a wildlife habitat development plan that becomes the basis of the cost-share agreement between NRCS and the participant. Most contracts are five to 10 years in duration, depending upon the practices to be installed. However, longer term contracts of 15 years or greater may also be funded. Under the agreement:

- The landowner agrees to maintain the cost-shared practices and allow NRCS or its agent access to monitor its effectiveness.
- NRCS agrees to provide technical assistance and pay up to 75 percent of the cost of installing the wildlife habitat practices. Additional financial or technical assistance may be available through cooperating partners (NRCS 2002c).

12.3.2.7 Illinois Department of Agriculture and Illinois EPA Nutrient Management Plan Project

As discussed in Section 9.2.1.1, the IDA and Illinois EPA are co-sponsoring a Cropland Nutrient Management Plan project in watersheds that have or are developing a TMDL. Under this project, 2,480 acres of cropland have been targeted in the Big Muddy River segment N12 watershed.

The FSA administers the CRP. NRCS administers the EQIP, WRP, and WHIP. Local NRCS and FSA contact information in Jackson County are listed in Table 12-3 below.

Table 12-3 Local NRCS and FSA Contact Information

Contact	Address	Phone
Local NRCS Office		
W. Scott Martin	1213 N. 14th Street Murphysboro, Illinois 62966	618-684-3064 x 3
Local FSA Office		
Murphysboro Service Center	1213 N. 14th Street Murphysboro, Illinois 62966	618-684-3471 x 3

12.3.3 Cost Estimates for BMPs

Cost estimates for different BMPs and individual practice prices such as filter strip installation are detailed in the following sections. Table 12-4 outlines the cost of implementation measures per acre. Finally, an estimate of the total order of magnitude costs for implementation measures in the Big Muddy River segment N12 Watershed are presented in Section 12.3.3.3 and Table 12-5.

12.3.3.1 Streambank Stabilization

Cost information of streambank stabilization was taken from Johnson County NRCS. Johnson County NRCS estimates an average cost per foot to implement streambank stabilization measures at $40.00/foot. This price includes grading and shaping of the bank and critical area and dormant stub planting.

12.3.3.2 Filter Strips and Riparian Buffers

The Jackson County NRCS estimates an average cost per acre to install a grass filter strip with a 10-year life span at $90/acre. A riparian buffer strip established with bare root stock has a life span of 10 years and an installation cost of $384/acre. Based on this preliminary estimate, it appears that grass filter strips would be a more cost-effective way to control BOD and nutrient loads in the watershed.

12.3.3.3 Planning Level Cost Estimates for Implementation Measures

Cost estimates for different implementation actions are presented in Table 12-4. The column labeled *Program* lists the financial assistance program available for various BMPs. The programs represented in the table are the WRP and the CRP.

Table 12-4 Cost Estimate of Various BMP Measures in the Big Muddy River Watershed

Source	Program or Sponsor	BMP	Life Span	Installation Mean $/acre	Maintenance $/ac/yr
Nonpoint	CRP	Grass Filter Strips	10	$90.00	$9.00
	CRP	Riparian Buffer	10	$384.00	$40.00
	319 or SSRP	Streambank Stabilization *	10	$40.00	$4.00

* Streambank stabilization cost calculated on linear foot basis.

The total order of magnitude capital costs for implementation measures in the watershed were estimated to be $1,700,000. The total cost is calculated as the number of acres over which a BMP or structural measure is applied by the cost per acre. Table 12-5 summarizes the number of acres each measure is applied to in the basin and the

corresponding cost. The acreages reported in Table 12-5 are a preliminary estimate in order to provide an overall understanding of cost of implementation in the watershed. The total only represents capital costs and annual maintenance costs. These do not represent the total costs of operating the measure over its life cycle.

Table 12-5 Cost Estimate of Implementation Measures for the Big Muddy Watershed

BMP	Treated Acres	Capital Costs		Maintenance Costs	
		Mean $/acre	Watershed $	$/ac/yr	Watershed $/yr
Grass Filter Strips	112	$90.00	$10,080.00	$9.00	$1,000.00
Streambank Stabilization *	42,240	$40.00	$1,689,600.00	$4.00	$168,960.00
Total			**$1,699,680.00**		**$169,960.00**

* Streambank stabilization cost calculated on linear foot basis.

12.4 Monitoring Plan

The purpose of the monitoring plan for the Big Muddy River segment N12 Watershed is to assess the overall implementation of management actions outlined in this section. This can be accomplished by conducting the following monitoring programs:

- track implementation of management measures in the watershed and in upstream contributing watersheds,
- estimate effectiveness of management measures,
- continued ambient monitoring.

Tracking the implementation of management measures can be used to address the following goals (NCSU 2000):

- determine the extent to which management measures and practices have been implemented compared to action needed to meet TMDL endpoints.
- establish a baseline from which decisions can be made regarding the need for additional incentives for implementation efforts,
- measure the extent of voluntary implementation efforts,
- support workload and cost analysis for assistance or regulatory programs,
- determine the extent to which management measures are properly maintained and operated,

Estimating the effectiveness of the BMPs implemented in the watershed could be completed by monitoring before and after the BMP is incorporated into the watershed. Additional monitoring could be conducted on specific structural systems such as a constructed wetland. Inflow and outflow measurements could be conducted to determine site-specific removal efficiency.

Illinois EPA monitors segment N12 yearly through the Ambient Water Quality Monitoring Network program and conducts Intensive Basin Surveys every 5 years. Continuation of this monitoring will assess instream water quality as improvements in the watershed are completed. This data will also be used to assess whether water quality standards in the watershed are being attained. To further support DO modeling and to plan for future nutrient criteria in the watershed, the following parameters should be added to the monitoring list:

- BOD_5
- BOD_{20}
- Chlorophyll "a" or algae monitoring

Monitoring to assess groundwater concentrations of manganese should be conducted to determine source locations of subsurface abandoned mine activity. Location of groundwater contamination would help prioritize areas that will require remediation so that water quality standards can be achieved in the future.

12.5 Implementation Time Line

Implementing the actions outlined in this section for the Big Muddy River segment N12 Watershed should occur in phases and the effectiveness of the management actions should be assessed as improvements are made. It is assumed that it may take up to one to two years for further source identification in the watershed. It is also assumed that it may take up to five years to secure funding for actions needed in the watershed and five to seven years after funding to implement the measures. The length of time required to meet water quality standards will be based on the types of BMPs implemented in the watershed. In summary, meeting water quality standards in the segment N12 watershed may take 15 to 20 years to complete.

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Section 13
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Appendix A
Historic Water Quality Data

Primary Station ID	Start Date	Parameter Long Name	Result Value
5599500	1/9/1990	MANGANESE, TOTAL (UG/L AS MN)	470
5599500	2/8/1990	MANGANESE, TOTAL (UG/L AS MN)	373
5599500	4/16/1990	MANGANESE, TOTAL (UG/L AS MN)	337
5599500	5/22/1990	MANGANESE, TOTAL (UG/L AS MN)	112
5599500	5/22/1990	MANGANESE, TOTAL (UG/L AS MN)	109
5599500	7/9/1990	MANGANESE, TOTAL (UG/L AS MN)	783
5599500	8/21/1990	MANGANESE, TOTAL (UG/L AS MN)	617
5599500	9/24/1990	MANGANESE, TOTAL (UG/L AS MN)	560
5599500	11/13/1990	MANGANESE, TOTAL (UG/L AS MN)	765
5599500	1/8/1991	MANGANESE, TOTAL (UG/L AS MN)	138
5599500	2/12/1991	MANGANESE, TOTAL (UG/L AS MN)	222
5599500	4/9/1991	MANGANESE, TOTAL (UG/L AS MN)	472
5599500	6/4/1991	MANGANESE, TOTAL (UG/L AS MN)	590
5599500	6/4/1991	MANGANESE, TOTAL (UG/L AS MN)	600
5599500	7/16/1991	MANGANESE, TOTAL (UG/L AS MN)	682
5599500	8/20/1991	MANGANESE, TOTAL (UG/L AS MN)	2473
5599500	10/15/1991	MANGANESE, TOTAL (UG/L AS MN)	782
5599500	11/12/1991	MANGANESE, TOTAL (UG/L AS MN)	460
5599500	1/7/1992	MANGANESE, TOTAL (UG/L AS MN)	300
5599500	2/20/1992	MANGANESE, TOTAL (UG/L AS MN)	646
5599500	4/14/1992	MANGANESE, TOTAL (UG/L AS MN)	860
5599500	5/18/1992	MANGANESE, TOTAL (UG/L AS MN)	680
5599500	7/13/1992	MANGANESE, TOTAL (UG/L AS MN)	1000
5599500	8/17/1992	MANGANESE, TOTAL (UG/L AS MN)	1900
5599500	1/12/1993	MANGANESE, TOTAL (UG/L AS MN)	160
5599500	2/16/1993	MANGANESE, TOTAL (UG/L AS MN)	340
5599500	1/6/1994	MANGANESE, TOTAL (UG/L AS MN)	470
5599500	3/2/1994	MANGANESE, TOTAL (UG/L AS MN)	280
5599500	4/6/1994	MANGANESE, TOTAL (UG/L AS MN)	820
5599500	5/23/1994	MANGANESE, TOTAL (UG/L AS MN)	860
5599500	7/6/1994	MANGANESE, TOTAL (UG/L AS MN)	350
5599500	8/4/1994	MANGANESE, TOTAL (UG/L AS MN)	400
5599500	9/19/1994	MANGANESE, TOTAL (UG/L AS MN)	890
5599500	11/1/1994	MANGANESE, TOTAL (UG/L AS MN)	1200
5599500	12/7/1994	MANGANESE, TOTAL (UG/L AS MN)	590
5599500	1/30/1995	MANGANESE, TOTAL (UG/L AS MN)	360
5599500	2/21/1995	MANGANESE, TOTAL (UG/L AS MN)	310
5599500	4/12/1995	MANGANESE, TOTAL (UG/L AS MN)	710
5599500	5/10/1995	MANGANESE, TOTAL (UG/L AS MN)	282
5599500	6/15/1995	MANGANESE, TOTAL (UG/L AS MN)	540
5599500	7/20/1995	MANGANESE, TOTAL (UG/L AS MN)	820
5599500	8/22/1995	MANGANESE, TOTAL (UG/L AS MN)	380
5599500	10/31/1995	MANGANESE, TOTAL (UG/L AS MN)	1200
5599500	12/18/1995	MANGANESE, TOTAL (UG/L AS MN)	550
5599500	1/31/1996	MANGANESE, TOTAL (UG/L AS MN)	290
5599500	2/29/1996	MANGANESE, TOTAL (UG/L AS MN)	1200
5599500	3/25/1996	MANGANESE, TOTAL (UG/L AS MN)	480
5599500	5/1/1996	MANGANESE, TOTAL (UG/L AS MN)	230
5599500	6/25/1996	MANGANESE, TOTAL (UG/L AS MN)	1200
5599500	7/31/1996	MANGANESE, TOTAL (UG/L AS MN)	530

5599500	4/24/1997	MANGANESE, TOTAL (UG/L AS MN)	470
N12	10/27/1997	MANGANESE, TOTAL (UG/L AS MN)	640
N12	11/20/1997	MANGANESE, TOTAL (UG/L AS MN)	370
N12	2/3/1998	MANGANESE, TOTAL (UG/L AS MN)	500
N12	3/5/1998	MANGANESE, TOTAL (UG/L AS MN)	260
N12	4/16/1998	MANGANESE, TOTAL (UG/L AS MN)	460
N12	5/14/1998	MANGANESE, TOTAL (UG/L AS MN)	380
N12	6/17/1998	MANGANESE, TOTAL (UG/L AS MN)	240
N12	7/21/1998	MANGANESE, TOTAL (UG/L AS MN)	670
N12	8/27/1998	MANGANESE, TOTAL (UG/L AS MN)	470
N12	10/8/1998	MANGANESE, TOTAL (UG/L AS MN)	1100
N12	12/1/1998	MANGANESE, TOTAL (UG/L AS MN)	970
N12	1/4/1999	MANGANESE, TOTAL (UG/L AS MN)	430
N12	2/8/1999	MANGANESE, TOTAL (UG/L AS MN)	190
N12	3/22/1999	MANGANESE, TOTAL (UG/L AS MN)	180
N12	4/27/1999	MANGANESE, TOTAL (UG/L AS MN)	600
N12	6/10/1999	MANGANESE, TOTAL (UG/L AS MN)	400
N12	9/16/1999	MANGANESE, TOTAL (UG/L AS MN)	1900
N12	11/1/1999	MANGANESE, TOTAL (UG/L AS MN)	870
N12	12/6/1999	MANGANESE, TOTAL (UG/L AS MN)	510
N12	1/3/2000	MANGANESE, TOTAL (UG/L AS MN)	360
N12	3/8/2000	MANGANESE, TOTAL (UG/L AS MN)	570
N12	4/12/2000	MANGANESE, TOTAL (UG/L AS MN)	640
N12	5/1/2000	MANGANESE, TOTAL (UG/L AS MN)	550
N12	7/24/2000	MANGANESE, TOTAL (UG/L AS MN)	450
N12	9/6/2000	MANGANESE, TOTAL (UG/L AS MN)	260

Primary Station ID	Start Date	Parameter Long Name	Result Value
5599500	1/9/1990	SULFATE, TOTAL (MG/L AS SO4)	450
5599500	1/9/1990	SULFATE, TOTAL (MG/L AS SO4)	460
5599500	2/8/1990	SULFATE, TOTAL (MG/L AS SO4)	164
5599500	2/8/1990	SULFATE, TOTAL (MG/L AS SO4)	170
5599500	4/16/1990	SULFATE, TOTAL (MG/L AS SO4)	120
5599500	4/16/1990	SULFATE, TOTAL (MG/L AS SO4)	117
5599500	5/22/1990	SULFATE, TOTAL (MG/L AS SO4)	64
5599500	5/22/1990	SULFATE, TOTAL (MG/L AS SO4)	63
5599500	7/9/1990	SULFATE, TOTAL (MG/L AS SO4)	350
5599500	7/9/1990	SULFATE, TOTAL (MG/L AS SO4)	364
5599500	8/21/1990	SULFATE, TOTAL (MG/L AS SO4)	181
5599500	8/21/1990	SULFATE, TOTAL (MG/L AS SO4)	179
5599500	8/21/1990	SULFATE, TOTAL (MG/L AS SO4)	180
5599500	9/24/1990	SULFATE, TOTAL (MG/L AS SO4)	231
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	500
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	557
5599500	1/8/1991	SULFATE, TOTAL (MG/L AS SO4)	83
5599500	1/8/1991	SULFATE, TOTAL (MG/L AS SO4)	85
5599500	2/12/1991	SULFATE, TOTAL (MG/L AS SO4)	110
5599500	2/12/1991	SULFATE, TOTAL (MG/L AS SO4)	114
5599500	4/9/1991	SULFATE, TOTAL (MG/L AS SO4)	230
5599500	4/9/1991	SULFATE, TOTAL (MG/L AS SO4)	195
5599500	6/4/1991	SULFATE, TOTAL (MG/L AS SO4)	265
5599500	6/4/1991	SULFATE, TOTAL (MG/L AS SO4)	240
5599500	7/16/1991	SULFATE, TOTAL (MG/L AS SO4)	360
5599500	7/16/1991	SULFATE, TOTAL (MG/L AS SO4)	360
5599500	8/20/1991	SULFATE, TOTAL (MG/L AS SO4)	380
5599500	8/20/1991	SULFATE, TOTAL (MG/L AS SO4)	380
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	360
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	290
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	350
5599500	1/7/1992	SULFATE, TOTAL (MG/L AS SO4)	170
5599500	1/7/1992	SULFATE, TOTAL (MG/L AS SO4)	165
5599500	2/20/1992	SULFATE, TOTAL (MG/L AS SO4)	230
5599500	4/14/1992	SULFATE, TOTAL (MG/L AS SO4)	206
5599500	5/18/1992	SULFATE, TOTAL (MG/L AS SO4)	203
5599500	7/13/1992	SULFATE, TOTAL (MG/L AS SO4)	300
5599500	7/13/1992	SULFATE, TOTAL (MG/L AS SO4)	303
5599500	8/17/1992	SULFATE, TOTAL (MG/L AS SO4)	330
5599500	1/12/1993	SULFATE, TOTAL (MG/L AS SO4)	78
5599500	2/16/1993	SULFATE, TOTAL (MG/L AS SO4)	191
5599500	1/6/1994	SULFATE, TOTAL (MG/L AS SO4)	270
5599500	3/2/1994	SULFATE, TOTAL (MG/L AS SO4)	168
5599500	4/6/1994	SULFATE, TOTAL (MG/L AS SO4)	240
5599500	5/23/1994	SULFATE, TOTAL (MG/L AS SO4)	170
5599500	7/6/1994	SULFATE, TOTAL (MG/L AS SO4)	163
5599500	8/4/1994	SULFATE, TOTAL (MG/L AS SO4)	260
5599500	9/19/1994	SULFATE, TOTAL (MG/L AS SO4)	440
5599500	11/1/1994	SULFATE, TOTAL (MG/L AS SO4)	660
5599500	12/7/1994	SULFATE, TOTAL (MG/L AS SO4)	172

5599500	1/30/1995	SULFATE, TOTAL (MG/L AS SO4)	162
5599500	2/21/1995	SULFATE, TOTAL (MG/L AS SO4)	164
5599500	4/12/1995	SULFATE, TOTAL (MG/L AS SO4)	210
5599500	5/10/1995	SULFATE, TOTAL (MG/L AS SO4)	186
5599500	6/15/1995	SULFATE, TOTAL (MG/L AS SO4)	91
5599500	7/20/1995	SULFATE, TOTAL (MG/L AS SO4)	162
5599500	8/22/1995	SULFATE, TOTAL (MG/L AS SO4)	146
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	197
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	376
5599500	1/31/1996	SULFATE, TOTAL (MG/L AS SO4)	173
5599500	2/29/1996	SULFATE, TOTAL (MG/L AS SO4)	513
5599500	3/25/1996	SULFATE, TOTAL (MG/L AS SO4)	171
5599500	5/1/1996	SULFATE, TOTAL (MG/L AS SO4)	58.7
5599500	6/25/1996	SULFATE, TOTAL (MG/L AS SO4)	147
5599500	7/31/1996	SULFATE, TOTAL (MG/L AS SO4)	226
5599500	4/24/1997	SULFATE, TOTAL (MG/L AS SO4)	227
N12	########	SULFATE, TOTAL (MG/L AS SO4)	566
N12	########	SULFATE, TOTAL (MG/L AS SO4)	653
N12	2/3/1998	SULFATE, TOTAL (MG/L AS SO4)	303
N12	4/16/1998	SULFATE, TOTAL (MG/L AS SO4)	201
N12	5/14/1998	SULFATE, TOTAL (MG/L AS SO4)	82
N12	6/17/1998	SULFATE, TOTAL (MG/L AS SO4)	109
N12	7/21/1998	SULFATE, TOTAL (MG/L AS SO4)	162
N12	8/27/1998	SULFATE, TOTAL (MG/L AS SO4)	196
N12	10/8/1998	SULFATE, TOTAL (MG/L AS SO4)	340
N12	12/1/1998	SULFATE, TOTAL (MG/L AS SO4)	566
N12	1/4/1999	SULFATE, TOTAL (MG/L AS SO4)	104
N12	2/8/1999	SULFATE, TOTAL (MG/L AS SO4)	81.8
N12	3/22/1999	SULFATE, TOTAL (MG/L AS SO4)	91.9
N12	4/27/1999	SULFATE, TOTAL (MG/L AS SO4)	154
N12	6/10/1999	SULFATE, TOTAL (MG/L AS SO4)	160
N12	9/16/1999	SULFATE, TOTAL (MG/L AS SO4)	435
N12	11/1/1999	SULFATE, TOTAL (MG/L AS SO4)	601
N12	12/6/1999	SULFATE, TOTAL (MG/L AS SO4)	639
N12	1/3/2000	SULFATE, TOTAL (MG/L AS SO4)	401
N12	3/8/2000	SULFATE, TOTAL (MG/L AS SO4)	184
N12	4/12/2000	SULFATE, TOTAL (MG/L AS SO4)	363
N12	5/1/2000	SULFATE, TOTAL (MG/L AS SO4)	229
N12	7/24/2000	SULFATE, TOTAL (MG/L AS SO4)	68
N12	9/6/2000	SULFATE, TOTAL (MG/L AS SO4)	140

Primary Station ID	Start Date	Parameter Long Name	Result Value
5599500	1/9/1990	PH (STANDARD UNITS)	7.8
5599500	1/9/1990	PH (STANDARD UNITS)	7.8
5599500	2/8/1990	PH (STANDARD UNITS)	8.3
5599500	2/8/1990	PH (STANDARD UNITS)	8.3
5599500	2/8/1990	PH (STANDARD UNITS)	7.5
5599500	2/8/1990	PH (STANDARD UNITS)	8.3
5599500	2/8/1990	PH (STANDARD UNITS)	8.8
5599500	2/8/1990	PH (STANDARD UNITS)	8.8
5599500	2/8/1990	PH (STANDARD UNITS)	8
5599500	4/16/1990	PH (STANDARD UNITS)	7
5599500	4/16/1990	PH (STANDARD UNITS)	7
5599500	5/22/1990	PH (STANDARD UNITS)	6.9
5599500	5/22/1990	PH (STANDARD UNITS)	6.6
5599500	7/9/1990	PH (STANDARD UNITS)	7.9
5599500	7/9/1990	PH (STANDARD UNITS)	7.3
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.3
5599500	7/9/1990	PH (STANDARD UNITS)	7.3
5599500	8/21/1990	PH (STANDARD UNITS)	7.5
5599500	8/21/1990	PH (STANDARD UNITS)	7.2
5599500	8/21/1990	PH (STANDARD UNITS)	7.2
5599500	9/24/1990	PH (STANDARD UNITS)	7.8
5599500	11/13/1990	PH (STANDARD UNITS)	8.2
5599500	11/13/1990	PH (STANDARD UNITS)	8.2
5599500	1/8/1991	PH (STANDARD UNITS)	6.4
5599500	1/8/1991	PH (STANDARD UNITS)	6.4
5599500	2/12/1991	PH (STANDARD UNITS)	7.1
5599500	2/12/1991	PH (STANDARD UNITS)	7.1
5599500	2/12/1991	PH (STANDARD UNITS)	7
5599500	2/12/1991	PH (STANDARD UNITS)	7.1
5599500	2/12/1991	PH (STANDARD UNITS)	7.1
5599500	2/12/1991	PH (STANDARD UNITS)	6.8
5599500	2/12/1991	PH (STANDARD UNITS)	6.8
5599500	2/12/1991	PH (STANDARD UNITS)	7
5599500	2/12/1991	PH (STANDARD UNITS)	7
5599500	4/9/1991	PH (STANDARD UNITS)	7.4
5599500	4/9/1991	PH (STANDARD UNITS)	7.4
5599500	6/4/1991	PH (STANDARD UNITS)	7.3
5599500	6/4/1991	PH (STANDARD UNITS)	7.2
5599500	7/16/1991	PH (STANDARD UNITS)	7.9
5599500	7/16/1991	PH (STANDARD UNITS)	7.7
5599500	7/16/1991	PH (STANDARD UNITS)	7.9
5599500	7/16/1991	PH (STANDARD UNITS)	7.8
5599500	7/16/1991	PH (STANDARD UNITS)	7.8
5599500	7/16/1991	PH (STANDARD UNITS)	7.8
5599500	7/16/1991	PH (STANDARD UNITS)	7.8

5599500	8/20/1991	PH (STANDARD UNITS)	6.9
5599500	8/20/1991	PH (STANDARD UNITS)	6.9
5599500	10/15/1991	PH (STANDARD UNITS)	7.05
5599500	11/12/1991	PH (STANDARD UNITS)	7
5599500	11/12/1991	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	6.9
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	2/20/1992	PH (STANDARD UNITS)	7.2
5599500	2/20/1992	PH (STANDARD UNITS)	7.2
5599500	4/14/1992	PH (STANDARD UNITS)	7.3
5599500	4/14/1992	PH (STANDARD UNITS)	7.3
5599500	4/14/1992	PH (STANDARD UNITS)	7.44
5599500	4/14/1992	PH (STANDARD UNITS)	7.33
5599500	4/14/1992	PH (STANDARD UNITS)	7.29
5599500	4/14/1992	PH (STANDARD UNITS)	7.29
5599500	5/18/1992	PH (STANDARD UNITS)	7.1
5599500	7/13/1992	PH (STANDARD UNITS)	7.1
5599500	7/13/1992	PH (STANDARD UNITS)	7.1
5599500	8/17/1992	PH (STANDARD UNITS)	7.7
5599500	1/12/1993	PH (STANDARD UNITS)	7.4
5599500	2/16/1993	PH (STANDARD UNITS)	7.6
5599500	1/6/1994	PH (STANDARD UNITS)	7.7
5599500	3/2/1994	PH (STANDARD UNITS)	8
5599500	4/6/1994	PH (STANDARD UNITS)	7.8
5599500	5/23/1994	PH (STANDARD UNITS)	7.7
5599500	7/6/1994	PH (STANDARD UNITS)	7.6
5599500	8/4/1994	PH (STANDARD UNITS)	7.7
5599500	9/19/1994	PH (STANDARD UNITS)	8.5
5599500	11/1/1994	PH (STANDARD UNITS)	8
5599500	12/7/1994	PH (STANDARD UNITS)	7.9
5599500	1/30/1995	PH (STANDARD UNITS)	7.6
5599500	2/21/1995	PH (STANDARD UNITS)	7.9
5599500	4/12/1995	PH (STANDARD UNITS)	7.2
5599500	5/10/1995	PH (STANDARD UNITS)	7
5599500	6/15/1995	PH (STANDARD UNITS)	7.3
5599500	7/20/1995	PH (STANDARD UNITS)	7.9
5599500	8/22/1995	PH (STANDARD UNITS)	7.3
5599500	10/31/1995	PH (STANDARD UNITS)	7.1
5599500	12/18/1995	PH (STANDARD UNITS)	7.2
5599500	1/31/1996	PH (STANDARD UNITS)	7.4
5599500	2/29/1996	PH (STANDARD UNITS)	7.4
5599500	3/25/1996	PH (STANDARD UNITS)	6.6
5599500	5/1/1996	PH (STANDARD UNITS)	6.8
5599500	6/25/1996	PH (STANDARD UNITS)	6.8
5599500	7/31/1996	PH (STANDARD UNITS)	7.3

5599500	4/24/1997	PH (STANDARD UNITS)	7.2
N12	10/27/1997	PH (STANDARD UNITS)	7.2
N12	11/20/1997	PH (STANDARD UNITS)	6.4
N12	2/3/1998	PH (STANDARD UNITS)	7.5
N12	3/5/1998	PH (STANDARD UNITS)	7.5
N12	4/16/1998	PH (STANDARD UNITS)	7.2
N12	5/14/1998	PH (STANDARD UNITS)	7
N12	6/17/1998	PH (STANDARD UNITS)	7.1
N12	7/21/1998	PH (STANDARD UNITS)	6.7
N12	8/27/1998	PH (STANDARD UNITS)	6.4
N12	10/8/1998	PH (STANDARD UNITS)	7.3
N12	12/1/1998	PH (STANDARD UNITS)	7.3
N12	1/4/1999	PH (STANDARD UNITS)	8.1
N12	2/8/1999	PH (STANDARD UNITS)	7.3
N12	3/22/1999	PH (STANDARD UNITS)	7.2
N12	4/27/1999	PH (STANDARD UNITS)	7.4
N12	6/10/1999	PH (STANDARD UNITS)	6.5
N12	9/16/1999	PH (STANDARD UNITS)	7.3
N12	11/1/1999	PH (STANDARD UNITS)	7.4
N12	12/6/1999	PH (STANDARD UNITS)	7
N12	1/3/2000	PH (STANDARD UNITS)	6.6
N12	3/8/2000	PH (STANDARD UNITS)	6.6
N12	4/12/2000	PH (STANDARD UNITS)	7.1
N12	5/1/2000	PH (STANDARD UNITS)	7.6
N12	7/24/2000	PH (STANDARD UNITS)	6.9
N12	9/6/2000	PH (STANDARD UNITS)	6.5

Primary Station ID	Start Date	Parameter Long Name	Result Value
5599500	1/9/1990	OXYGEN, DISSOLVED MG/L	20.8
5599500	1/9/1990	OXYGEN, DISSOLVED MG/L	20.8
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12.5
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12.3
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	11.6
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	11.4
5599500	4/16/1990	OXYGEN, DISSOLVED MG/L	8.5
5599500	4/16/1990	OXYGEN, DISSOLVED MG/L	8.5
5599500	5/22/1990	OXYGEN, DISSOLVED MG/L	4.3
5599500	5/22/1990	OXYGEN, DISSOLVED MG/L	4.5
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	3.7
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.4
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.5
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.5
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.5
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.3
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.3
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.3
5599500	8/21/1990	OXYGEN, DISSOLVED MG/L	5.6
5599500	8/21/1990	OXYGEN, DISSOLVED MG/L	4.4
5599500	8/21/1990	OXYGEN, DISSOLVED MG/L	4.4
5599500	9/24/1990	OXYGEN, DISSOLVED MG/L	7.1
5599500	11/13/1990	OXYGEN, DISSOLVED MG/L	9.1
5599500	11/13/1990	OXYGEN, DISSOLVED MG/L	9.1
5599500	1/8/1991	OXYGEN, DISSOLVED MG/L	12.9
5599500	1/8/1991	OXYGEN, DISSOLVED MG/L	12.9
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.1
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	13
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.2
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.4
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	13.3
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	12
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.8
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.8
5599500	4/9/1991	OXYGEN, DISSOLVED MG/L	7.6
5599500	4/9/1991	OXYGEN, DISSOLVED MG/L	7.6
5599500	6/4/1991	OXYGEN, DISSOLVED MG/L	4.8
5599500	6/4/1991	OXYGEN, DISSOLVED MG/L	4.7
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.67
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.6
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.7
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	7
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	7.2
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.8
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.8

5599500	8/20/1991	OXYGEN, DISSOLVED MG/L	9.2
5599500	8/20/1991	OXYGEN, DISSOLVED MG/L	9.2
5599500	10/15/1991	OXYGEN, DISSOLVED MG/L	9.45
5599500	11/12/1991	OXYGEN, DISSOLVED MG/L	10.8
5599500	11/12/1991	OXYGEN, DISSOLVED MG/L	10.8
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.6
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.6
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	2/20/1992	OXYGEN, DISSOLVED MG/L	10.1
5599500	2/20/1992	OXYGEN, DISSOLVED MG/L	10.1
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.8
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.8
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	9
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.7
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.73
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.69
5599500	5/18/1992	OXYGEN, DISSOLVED MG/L	6.9
5599500	7/13/1992	OXYGEN, DISSOLVED MG/L	4.3
5599500	7/13/1992	OXYGEN, DISSOLVED MG/L	4.3
5599500	8/17/1992	OXYGEN, DISSOLVED MG/L	9.6
5599500	1/12/1993	OXYGEN, DISSOLVED MG/L	10.4
5599500	2/16/1993	OXYGEN, DISSOLVED MG/L	11.3
5599500	1/6/1994	OXYGEN, DISSOLVED MG/L	11.6
5599500	3/2/1994	OXYGEN, DISSOLVED MG/L	11.6
5599500	4/6/1994	OXYGEN, DISSOLVED MG/L	9.3
5599500	5/23/1994	OXYGEN, DISSOLVED MG/L	5.4
5599500	7/6/1994	OXYGEN, DISSOLVED MG/L	5.5
5599500	8/4/1994	OXYGEN, DISSOLVED MG/L	5.8
5599500	9/19/1994	OXYGEN, DISSOLVED MG/L	5.6
5599500	11/1/1994	OXYGEN, DISSOLVED MG/L	10.5
5599500	12/7/1994	OXYGEN, DISSOLVED MG/L	7.9
5599500	1/30/1995	OXYGEN, DISSOLVED MG/L	12
5599500	2/21/1995	OXYGEN, DISSOLVED MG/L	11.7
5599500	4/12/1995	OXYGEN, DISSOLVED MG/L	8.6
5599500	5/10/1995	OXYGEN, DISSOLVED MG/L	5.9
5599500	6/15/1995	OXYGEN, DISSOLVED MG/L	3.9
5599500	7/20/1995	OXYGEN, DISSOLVED MG/L	4.7
5599500	8/22/1995	OXYGEN, DISSOLVED MG/L	4.1
5599500	10/31/1995	OXYGEN, DISSOLVED MG/L	7.3
5599500	12/18/1995	OXYGEN, DISSOLVED MG/L	10.8
5599500	1/31/1996	OXYGEN, DISSOLVED MG/L	12.2
5599500	2/29/1996	OXYGEN, DISSOLVED MG/L	10.7
5599500	3/25/1996	OXYGEN, DISSOLVED MG/L	11
5599500	5/1/1996	OXYGEN, DISSOLVED MG/L	6.9
5599500	6/25/1996	OXYGEN, DISSOLVED MG/L	6.2
5599500	7/31/1996	OXYGEN, DISSOLVED MG/L	6.8

5599500	4/24/1997	OXYGEN, DISSOLVED MG/L	8.3
N12	10/27/1997	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.2
N12	11/20/1997	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.8
N12	2/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.3
N12	3/5/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.6
N12	4/16/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.8
N12	5/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.7
N12	6/17/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.8
N12	7/21/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.2
N12	8/27/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.3
N12	10/8/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.1
N12	12/1/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.2
N12	1/4/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12.4
N12	2/8/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.3
N12	3/22/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.5
N12	4/27/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.2
N12	6/10/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.8
N12	9/16/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.6
N12	11/1/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.7
N12	12/6/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.2
N12	1/3/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.5
N12	3/8/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.8
N12	4/12/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.5
N12	5/1/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.2
N12	7/24/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.9
N12	9/6/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.7

Secondary ID .1	Start Date	Parameter Long Name	Result Value
RNC-1	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	5/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	6/6/1990	DEPTH OF POND OR RESERVOIR IN FEET	54
RNC-1	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	6/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	52
RNC-1	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	65
RNC-1	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	65
RNC-1	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	65
RNC-1	7/23/1990	DEPTH OF POND OR RESERVOIR IN FEET	37
RNC-1	8/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	76
RNC-1	5/21/1991	DEPTH OF POND OR RESERVOIR IN FEET	59
RNC-1	6/4/1991	DEPTH OF POND OR RESERVOIR IN FEET	64
RNC-1	6/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	88
RNC-1	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	64
RNC-1	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	64
RNC-1	6/19/1991	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	70
RNC-1	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	70
RNC-1	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	70
RNC-1	7/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	9/16/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	5/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	80
RNC-1	5/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	78
RNC-1	6/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	78
RNC-1	7/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	84
RNC-1	7/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	81
RNC-1	8/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	81
RNC-1	5/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	72

RNC-1	5/31/1993	DEPTH OF POND OR RESERVOIR IN FEET	73
RNC-1	6/14/1993	DEPTH OF POND OR RESERVOIR IN FEET	74
RNC-1	6/29/1993	DEPTH OF POND OR RESERVOIR IN FEET	71
RNC-1	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	75
RNC-1	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	5/11/1994	DEPTH OF POND OR RESERVOIR IN FEET	85
RNC-1	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	56.5
RNC-1	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	56.5
RNC-1	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	56.5
RNC-1	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	8/3/1994	DEPTH OF POND OR RESERVOIR IN FEET	70
RNC-1	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/27/1994	DEPTH OF POND OR RESERVOIR IN FEET	72
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	6/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	6/16/1996	DEPTH OF POND OR RESERVOIR IN FEET	63
RNC-1	7/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	62
RNC-1	7/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	66
RNC-1	8/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	65
RNC-1	8/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	9/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	62
RNC-1	9/18/1996	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	10/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	59.5
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	50
RNC-1	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	59.5
RNC-1	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	59.5
RNC-1	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	59.5
RNC-1	5/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	59
RNC-1	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	6/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	71
RNC-1	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	56.5
RNC-1	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	8/5/1997	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	8/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	9/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	55

RNC-1	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	55.2
RNC-1	6/3/1998	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	6/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	7/7/1998	DEPTH OF POND OR RESERVOIR IN FEET	54
RNC-1	7/31/1998	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	8/14/1998	DEPTH OF POND OR RESERVOIR IN FEET	56.6
RNC-1	9/4/1998	DEPTH OF POND OR RESERVOIR IN FEET	62
RNC-1	9/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	4/28/2000	DEPTH OF POND OR RESERVOIR IN FEET	24
RNC-1	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-1	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-2	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	5/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	47
RNC-2	6/6/1990	DEPTH OF POND OR RESERVOIR IN FEET	49
RNC-2	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	51
RNC-2	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	7/23/1990	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	8/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	4/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	46
RNC-2	5/21/1991	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	6/4/1991	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	6/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	6/19/1991	DEPTH OF POND OR RESERVOIR IN FEET	43
RNC-2	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	38.5
RNC-2	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	38.5
RNC-2	7/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	39

RNC-2	8/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	38.5
RNC-2	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	38.5
RNC-2	9/16/1991	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	5/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-2	5/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-2	6/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-2	7/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	18
RNC-2	7/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-2	8/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-2	5/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	21
RNC-2	5/31/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
RNC-2	6/14/1993	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-2	6/29/1993	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-2	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	24
RNC-2	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	40.5
RNC-2	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	40.5
RNC-2	5/11/1994	DEPTH OF POND OR RESERVOIR IN FEET	21
RNC-2	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	8/3/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
RNC-2	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	39.5
RNC-2	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	39.5
RNC-2	8/27/1994	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	6/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/16/1996	DEPTH OF POND OR RESERVOIR IN FEET	43
RNC-2	7/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	7/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	8/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	44
RNC-2	8/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	41.5
RNC-2	9/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	9/18/1996	DEPTH OF POND OR RESERVOIR IN FEET	37.5
RNC-2	10/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	5/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	41.5
RNC-2	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	43
RNC-2	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	46
RNC-2	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	46
RNC-2	8/5/1997	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	8/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	39

RNC-2	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	9/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	37
RNC-2	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	36
RNC-2	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	36
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	35.5
RNC-2	6/3/1998	DEPTH OF POND OR RESERVOIR IN FEET	41.2
RNC-2	6/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	7/7/1998	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	7/31/1998	DEPTH OF POND OR RESERVOIR IN FEET	33
RNC-2	8/14/1998	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	9/4/1998	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	9/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-3	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RNC-3	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RNC-3	5/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	20
RNC-3	6/6/1990	DEPTH OF POND OR RESERVOIR IN FEET	21
RNC-3	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	25.5
RNC-3	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	25.5
RNC-3	6/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-3	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	7/23/1990	DEPTH OF POND OR RESERVOIR IN FEET	18
RNC-3	8/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	4/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-3	5/21/1991	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-3	6/4/1991	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	6/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	6/19/1991	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	7/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	8/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-3	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	9/16/1991	DEPTH OF POND OR RESERVOIR IN FEET	15

RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	5/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
RNC-3	5/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	13
RNC-3	6/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	13
RNC-3	7/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
RNC-3	7/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	8/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
RNC-3	5/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-3	5/31/1993	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	6/14/1993	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-3	6/29/1993	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-3	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
RNC-3	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
RNC-3	5/11/1994	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	8/3/1994	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RNC-3	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RNC-3	8/27/1994	DEPTH OF POND OR RESERVOIR IN FEET	14
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	6/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-3	6/16/1996	DEPTH OF POND OR RESERVOIR IN FEET	36
RNC-3	7/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-3	7/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	44
RNC-3	8/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-3	8/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	39.5
RNC-3	9/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	37
RNC-3	9/18/1996	DEPTH OF POND OR RESERVOIR IN FEET	32.5
RNC-3	10/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	31.5
RNC-3	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	31
RNC-3	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	31
RNC-3	5/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RNC-3	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	6/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	31
RNC-3	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	31
RNC-3	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RNC-3	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RNC-3	8/5/1997	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	8/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RNC-3	9/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	26

RNC-3	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-3	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	24.5
RNC-3	6/3/1998	DEPTH OF POND OR RESERVOIR IN FEET	33.3
RNC-3	6/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	7/7/1998	DEPTH OF POND OR RESERVOIR IN FEET	33
RNC-3	7/31/1998	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	8/14/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	9/4/1998	DEPTH OF POND OR RESERVOIR IN FEET	19
RNC-3	9/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	29
RNC-3	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-4	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	5/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	12
RNC-4	6/6/1990	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RNC-4	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	6/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	7/23/1990	DEPTH OF POND OR RESERVOIR IN FEET	4.5
RNC-4	8/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	5
RNC-4	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	4/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	5/21/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	6/4/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	6/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	6/19/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	8/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	2.5
RNC-4	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	2
RNC-4	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	2
RNC-4	9/16/1991	DEPTH OF POND OR RESERVOIR IN FEET	2
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	5/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	5/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	4

RNC-4	6/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	7/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	8/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	5/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	5/31/1993	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	6/14/1993	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	6/29/1993	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	2.5
RNC-4	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	2
RNC-4	5/11/1994	DEPTH OF POND OR RESERVOIR IN FEET	5
RNC-4	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	8/3/1994	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	8/27/1994	DEPTH OF POND OR RESERVOIR IN FEET	5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RNC-4	6/16/1996	DEPTH OF POND OR RESERVOIR IN FEET	17
RNC-4	7/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-4	7/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	8/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	10
RNC-4	8/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RNC-4	9/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	9/18/1996	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	10/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	12.5
RNC-4	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	12.5
RNC-4	5/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RNC-4	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	11.5
RNC-4	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	11.5
RNC-4	6/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	20
RNC-4	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-4	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-4	8/5/1997	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	8/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RNC-4	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	9/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RNC-4	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	4.5
RNC-4	6/3/1998	DEPTH OF POND OR RESERVOIR IN FEET	11.2
RNC-4	6/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	10

RNC-4	7/7/1998	DEPTH OF POND OR RESERVOIR IN FEET	13
RNC-4	7/31/1998	DEPTH OF POND OR RESERVOIR IN FEET	11.5
RNC-4	8/14/1998	DEPTH OF POND OR RESERVOIR IN FEET	13
RNC-4	9/4/1998	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	9/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	10
RNC-4	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	10
RNC-4	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-4	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	11

Secondary ID .1	Start Date	Parameter Long Name	Result Value	ample Depth (ft)
5599540	1/8/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	2/5/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	
5599540	4/16/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	5/16/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	6/28/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	7/31/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	
5599540	9/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.023	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.100	
5599540	12/4/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	1/29/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	2/28/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.032	
5599540	3/25/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	5/23/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	6/25/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	8/7/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	9/25/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	
5599540	2/3/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	3/10/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	4/15/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	5/7/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	7/1/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	
5599540	8/12/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	9/23/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	1/27/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	9/29/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	1/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	
5599540	3/3/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.060	
5599540	4/21/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	
5599540	5/19/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	7/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	9/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	11/7/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	12/8/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	
5599540	1/9/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	2/8/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	3/23/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	5/3/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	6/29/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	8/2/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	
5599540	9/7/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	1/11/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.021	
5599540	2/28/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	3/19/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	4/25/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	6/20/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	
5599540	8/13/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	

5599540	3/24/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	4/29/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
RNC-1	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.001	1
RNC-1	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.001	Lake Bottom
RNC-1	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.021	1
RNC-1	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	Lake Bottom
RNC-1	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	1
RNC-1	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.075	Lake Bottom
RNC-1	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-1	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.100	Lake Bottom
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.584	1
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.083	Lake Bottom
RNC-1	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.031	1
RNC-1	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	Lake Bottom
RNC-1	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-1	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	Lake Bottom
RNC-1	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-1	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.067	Lake Bottom
RNC-1	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1
RNC-1	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	Lake Bottom
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	1
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.031	Lake Bottom
RNC-1	5/18/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	
RNC-1	6/29/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	
RNC-1	7/28/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	
RNC-1	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.038	1
RNC-1	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.037	Lake Bottom
RNC-1	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	1
RNC-1	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.011	Lake Bottom
RNC-1	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	1
RNC-1	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	Lake Bottom
RNC-1	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.022	1
RNC-1	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.031	Lake Bottom
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.022	Lake Bottom
RNC-1	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-1	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	Lake Bottom
RNC-1	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.028	1
RNC-1	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.035	Lake Bottom
RNC-1	7/10/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.033	
RNC-1	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-1	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.117	Lake Bottom
RNC-1	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.021	1
RNC-1	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.059	Lake Bottom
RNC-1	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	1
RNC-1	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.174	Lake Bottom
RNC-1	11/3/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.021	
RNC-1	8/25/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.036	
RNC-1	9/21/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.034	
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	
RNC-1	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.011	1

RNC-1	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	12
RNC-1	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	Lake Bottom
RNC-1	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	1
RNC-1	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	13
RNC-1	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.008	Lake Bottom
RNC-1	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1
RNC-1	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.100	Lake Bottom
RNC-1	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.009	1
RNC-1	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.038	Lake Bottom
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	1
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.095	Lake Bottom
RNC-2	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.001	1
RNC-2	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.018	1
RNC-2	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-2	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.018	1
RNC-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	1
RNC-2	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.024	1
RNC-2	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1
RNC-2	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.018	1
RNC-2	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-2	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	1
RNC-2	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-2	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-2	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	1
RNC-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	1
RNC-2	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	1
RNC-2	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.039	1
RNC-2	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.024	1
RNC-2	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.026	1
RNC-2	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	1
RNC-2	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.011	1
RNC-2	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-2	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-2	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	1
RNC-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-3	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.001	1
RNC-3	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-3	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.025	1
RNC-3	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.024	1
RNC-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-3	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.036	1
RNC-3	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.024	1
RNC-3	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	1
RNC-3	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	1
RNC-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.029	1
RNC-3	5/18/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-3	6/29/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.069	1
RNC-3	7/28/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	1
RNC-3	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.084	1
RNC-3	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1

RNC-3	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	1
RNC-3	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.032	1
RNC-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.025	1
RNC-3	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.043	1
RNC-3	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.059	1
RNC-3	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.037	1
RNC-3	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	1
RNC-3	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.034	1
RNC-3	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-3	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.023	1
RNC-3	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-3	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.022	1
RNC-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.023	1
RNC-4	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.046	1
RNC-4	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.152	1
RNC-4	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.109	1
RNC-4	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.116	1
RNC-4	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.036	1
RNC-4	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.097	1
RNC-4	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.106	1
RNC-4	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.130	1
RNC-4	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.090	1
RNC-4	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.072	1
RNC-4	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.185	1
RNC-4	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.136	1
RNC-4	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.123	1
RNC-4	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.155	1
RNC-4	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.078	1
RNC-4	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.121	1
RNC-4	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.072	1
RNC-4	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.063	1
RNC-4	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.245	1
RNC-4	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.147	1
RNC-4	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.047	1
RNC-4	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.070	1
RNC-4	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.077	1
RNC-4	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.047	1
RNC-4	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.033	1

Secondary ID .1	Start Date	Parameter Long Name	Result Value
RNC-1	4/30/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	4.9
RNC-1	6/14/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.3
RNC-1	7/13/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.9
RNC-1	8/17/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.4
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	3.56
RNC-1	4/22/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.86
RNC-1	6/11/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	6.68
RNC-1	7/9/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.66
RNC-1	8/15/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.6
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.22
RNC-1	4/13/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	10.4
RNC-1	6/6/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.4
RNC-1	7/12/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	23.5
RNC-1	8/16/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.2
RNC-1	4/11/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.7
RNC-1	6/19/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	19
RNC-1	7/23/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.1
RNC-1	8/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	19.2
RNC-1	9/15/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.35
RNC-1	10/9/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.47
RNC-1	11/3/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.21
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	7.63
RNC-1	6/9/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	14.41
RNC-1	6/23/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	16.55
RNC-1	8/25/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	35.6
RNC-1	9/21/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	28.2
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	14.5
RNC-1	4/26/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	3.61
RNC-1	6/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	12.4
RNC-1	7/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.13
RNC-1	8/2/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	58.7
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.07
RNC-2	4/30/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.84
RNC-2	6/14/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	16
RNC-2	7/13/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	22.3
RNC-2	8/17/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.1
RNC-2	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	4.79
RNC-2	4/22/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.64
RNC-2	6/11/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	6.68
RNC-2	7/9/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.6
RNC-2	8/15/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	14.1
RNC-2	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	7.7
RNC-2	4/13/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	20.5
RNC-2	6/6/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	10
RNC-2	7/12/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.6
RNC-2	8/16/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.5
RNC-2	4/11/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.2
RNC-2	6/19/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	25.1
RNC-2	7/23/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	29
RNC-2	8/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	22.4
RNC-2	10/9/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.41
RNC-2	4/26/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.64
RNC-2	6/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.6

RNC-2	7/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.01
RNC-2	8/2/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.5
RNC-2	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	20.5
RNC-3	4/30/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.1
RNC-3	6/14/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11
RNC-3	7/13/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	23.5
RNC-3	8/17/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.1
RNC-3	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.61
RNC-3	4/22/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	17.1
RNC-3	6/11/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.4
RNC-3	7/9/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	30.7
RNC-3	8/15/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.4
RNC-3	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	12.8
RNC-3	4/13/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	32.9
RNC-3	6/6/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.61
RNC-3	7/12/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	28
RNC-3	8/16/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	27.7
RNC-3	4/11/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.2
RNC-3	6/19/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	29.8
RNC-3	7/23/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	33
RNC-3	8/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	40.8
RNC-3	10/9/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.5
RNC-3	4/26/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	20.7
RNC-3	6/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.6
RNC-3	7/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	12.4
RNC-3	8/2/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.75
RNC-3	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	25.5
RNC-4	4/30/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	27.62
RNC-4	6/14/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	38.84
RNC-4	7/13/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	30.92
RNC-4	8/17/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	35.04
RNC-4	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.15
RNC-4	4/22/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	26.7
RNC-4	6/11/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	74.17
RNC-4	7/9/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	50.73
RNC-4	8/15/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	47.12
RNC-4	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	16.69
RNC-4	4/13/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.31
RNC-4	6/6/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	51.62
RNC-4	7/12/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	69.83
RNC-4	8/16/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	75.65
RNC-4	4/11/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	3.98
RNC-4	6/19/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	46.44
RNC-4	7/23/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	79.63
RNC-4	8/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	58.99
RNC-4	10/9/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	55.63
RNC-4	4/26/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	29.1
RNC-4	6/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	49.9
RNC-4	7/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	41.5
RNC-4	8/2/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	53.1
RNC-4	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	16.4

Secondary ID .1	Start Date	Parameter Long Name		Result Value	Sample Depth (ft)
5599540	01/08/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	02/05/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	04/16/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
5599540	05/16/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
5599540	06/28/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	07/31/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	09/17/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4	
5599540	10/24/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	12/04/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	01/29/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
5599540	02/28/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	03/25/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2	
5599540	05/23/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	06/25/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	08/07/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2	
5599540	09/25/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.3	
5599540	11/14/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	12/16/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3	
5599540	02/03/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	03/10/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7	
5599540	04/15/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2	
5599540	05/07/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	07/01/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	08/12/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	09/23/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	11/16/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3	
5599540	12/21/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9	
5599540	01/27/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
5599540	03/01/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	04/12/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	
5599540	05/11/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
5599540	06/29/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	08/18/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	09/29/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	11/10/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	12/08/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	01/13/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	03/03/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	04/21/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	05/19/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
5599540	07/06/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
5599540	08/03/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	09/06/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	11/07/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4	
5599540	12/08/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	01/09/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	02/08/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.6	
5599540	03/23/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3	
5599540	05/03/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	06/29/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	08/02/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
5599540	09/07/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
5599540	10/18/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.5	
5599540	12/14/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.2	
5599540	01/11/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.3	
5599540	02/28/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
5599540	03/19/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	04/25/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	06/20/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
5599540	08/13/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
5599540	09/03/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.6	
5599540	11/12/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	12/11/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
5599540	01/14/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.5	
5599540	02/18/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
5599540	03/24/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	
5599540	04/29/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	06/09/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7	

5599540	07/16/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	08/28/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
RNC-1	4/30/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2	
RNC-1	4/30/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	6/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
RNC-1	6/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
RNC-1	7/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	
RNC-1	7/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
RNC-1	8/17/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
RNC-1	8/17/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9	
RNC-1	10/22/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3	
RNC-1	10/22/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
RNC-1	4/22/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
RNC-1	4/22/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	6/11/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
RNC-1	6/11/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9	
RNC-1	7/9/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
RNC-1	7/9/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
RNC-1	8/15/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4	
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RNC-1	10/11/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	10/11/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9	
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RNC-1	8/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.6	
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RNC-2	7/12/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.9	
RNC-2	8/16/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.8	
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RNC-2	8/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
RNC-2	10/9/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
RNC-2	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1
RNC-2	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.9
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RNC-3	6/6/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3
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RNC-3	7/23/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.5
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RNC-3	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2
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RNC-4	8/2/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4
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Appendix B
Directory of Coal Mines for Jackson County, Illinois May 4, 2002

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR JACKSON COUNTY, ILLINOIS (IDNR 2000)
MAY 3, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC
13	BIG MUDDY COAL & IRON C	BIG MUDDY	9	SHAFT	MRP	1906-21	MURPHYSBORO	JACKSON	8S	2W	34
13	CONSOLIDATED C C OF ST LOUIS	C C C	9	SHAFT		1921-26	MURPHYSBORO	JACKSON	8S	2W	34
15	CARBONDALE C C EARLIER 78?	HARRISON		SHAFT		1878-91	MURPHYSBORO	JACKSON	8S	2W	33
15	ST LOUIS ORE & STEEL	HARRISON		SHAFT	RPP	1891-94	MURPHYSBORO	JACKSON	8S	2W	33
15	BIG MUDDY COAL & IRON C	HARRISON		SHAFT		1894-16	MURPHYSBORO	JACKSON	8S	2W	33
604	TEMPLETON C C	TEMPLETON	1	SLOPE	MRP	1927-44	MURPHYSBORO	JACKSON	9S	2W	16
2493	BIG MUDDY COAL & IRON C	BIG MUDDY	6	SHAFT		1898-09	MURPHYSBORO	JACKSON	9S	2W	10

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR JACKSON COUNTY, ILLINOIS (IDNR 2000)
MAY 3, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR JACKSON COUNTY, ILLINOIS (IDNR 2000)
MAY 3, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC

Appendix C
GWLF and BATHTUB Input and Output Files

GWLF Input Data Files

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Nutrient.dat

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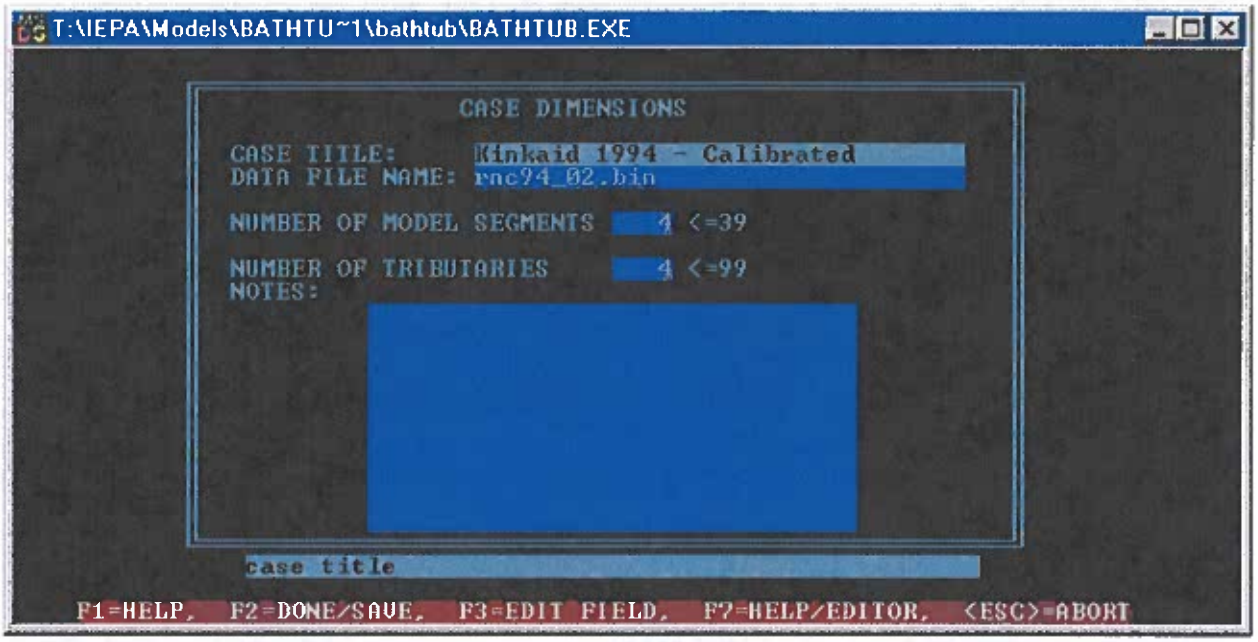
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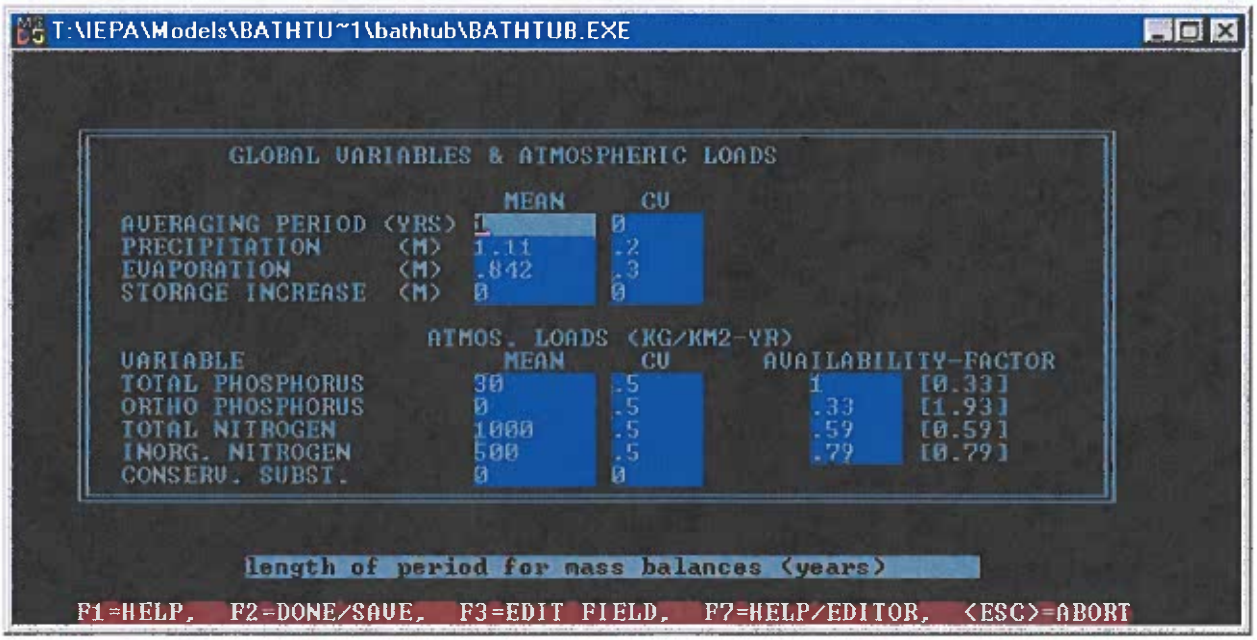
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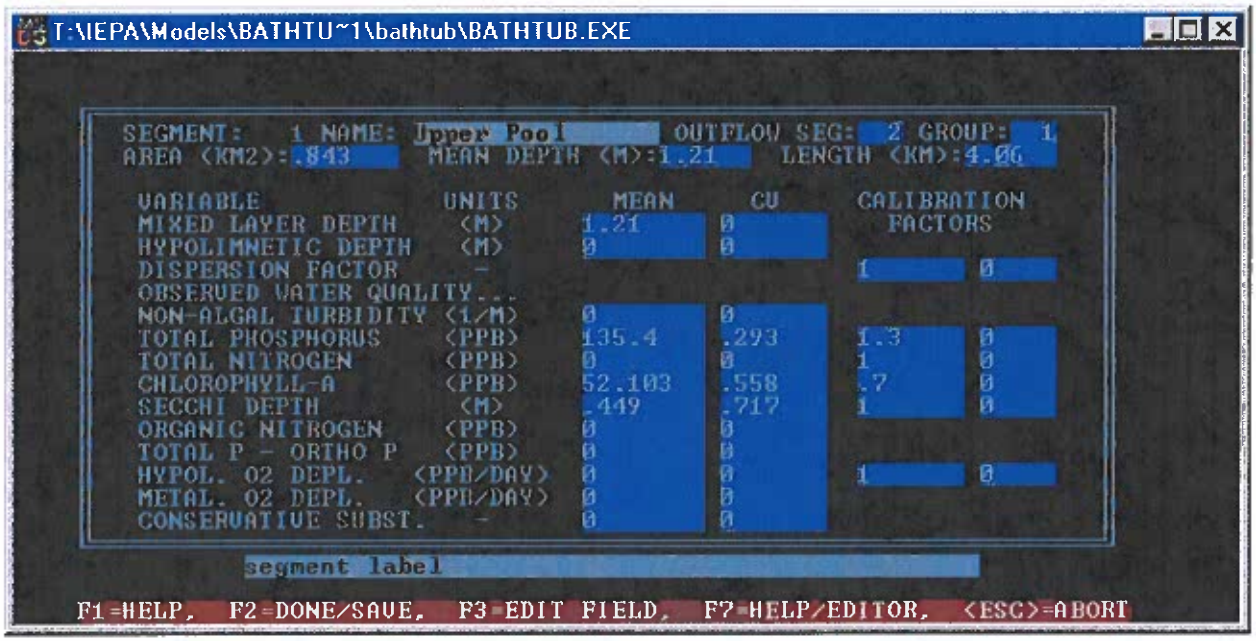
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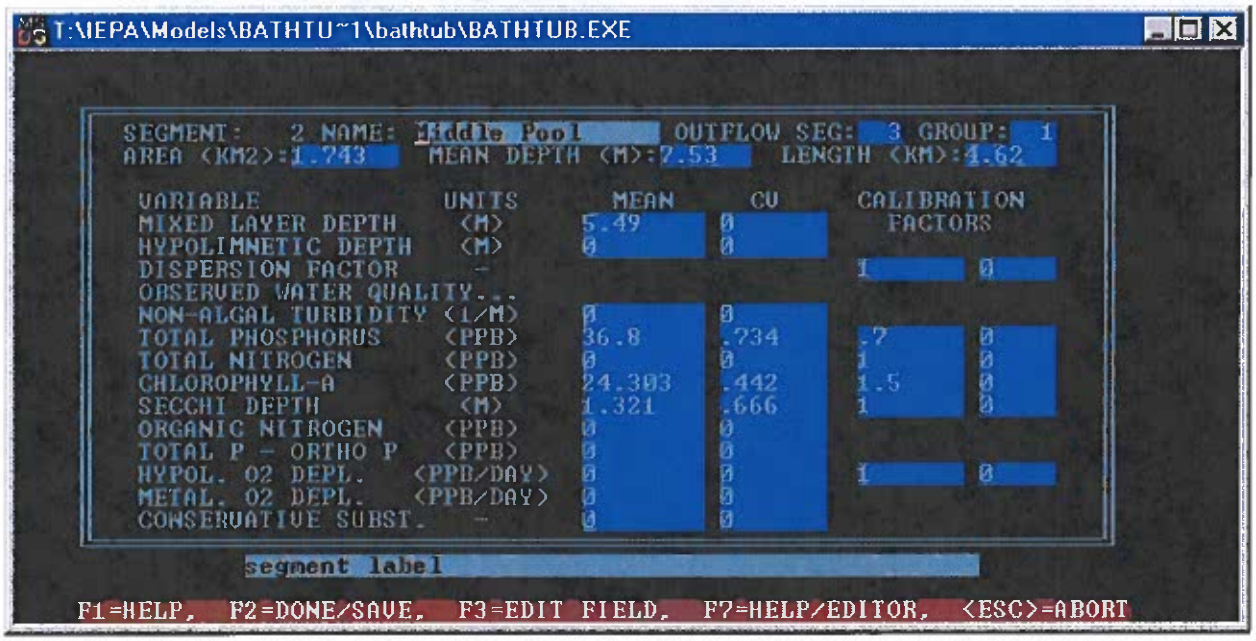
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22.22,0.00
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20.56,0.00
23.06,0.91
21.94,0.00
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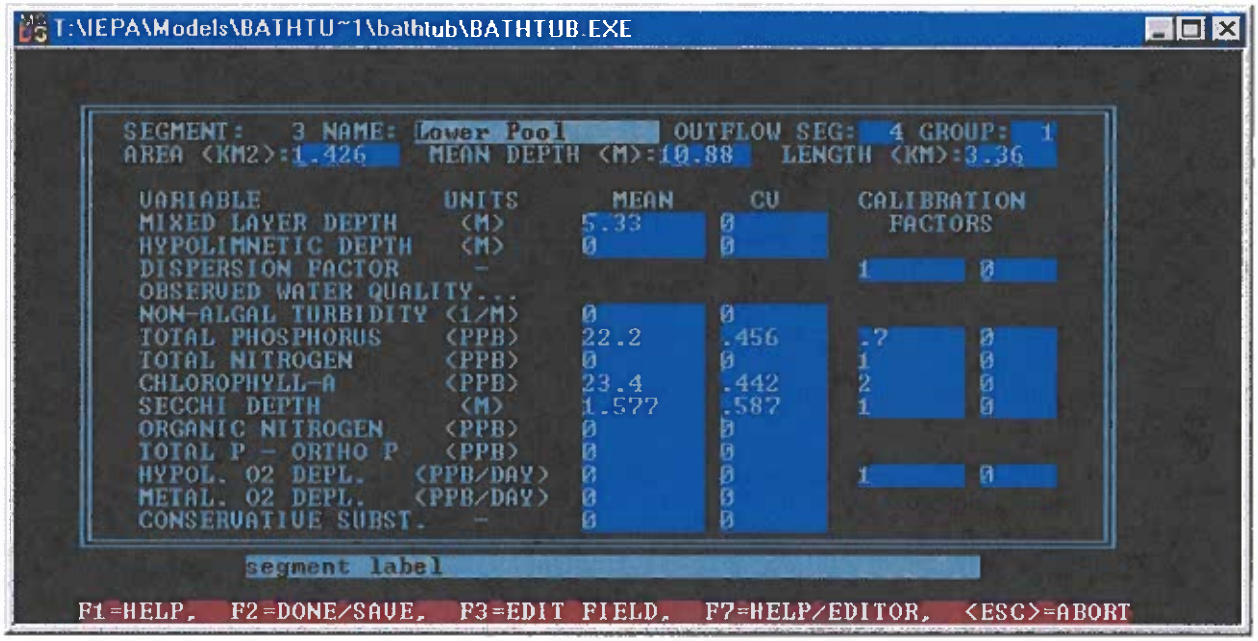
BATHTUB Model Input Screens for 1994 Simulation

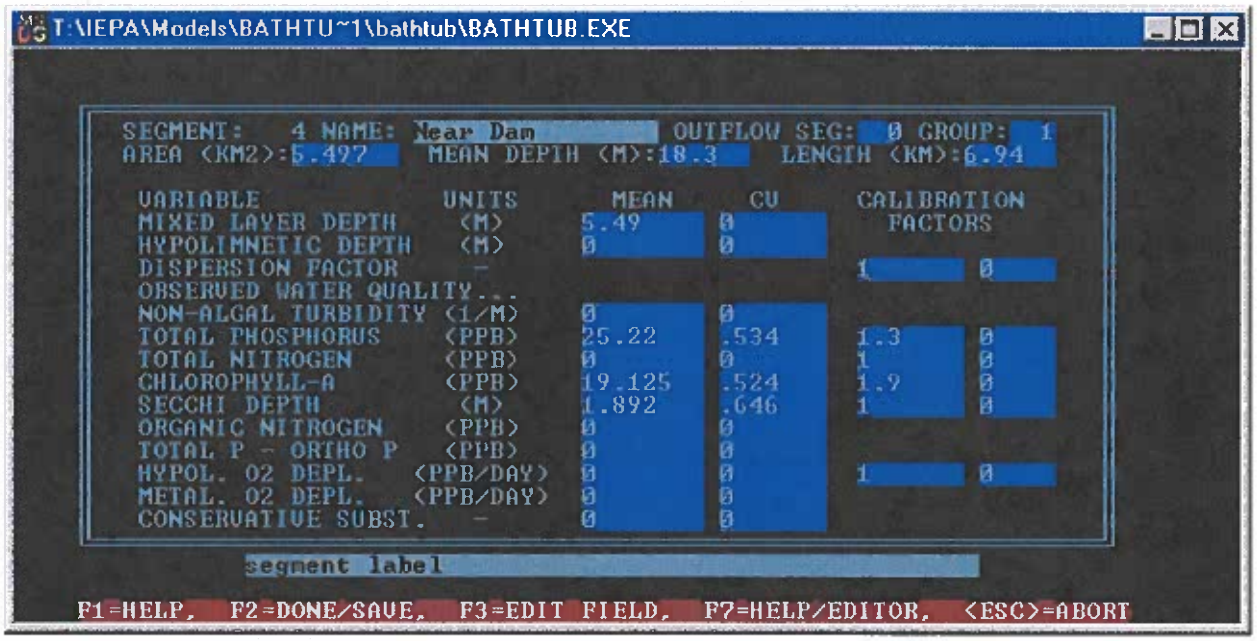


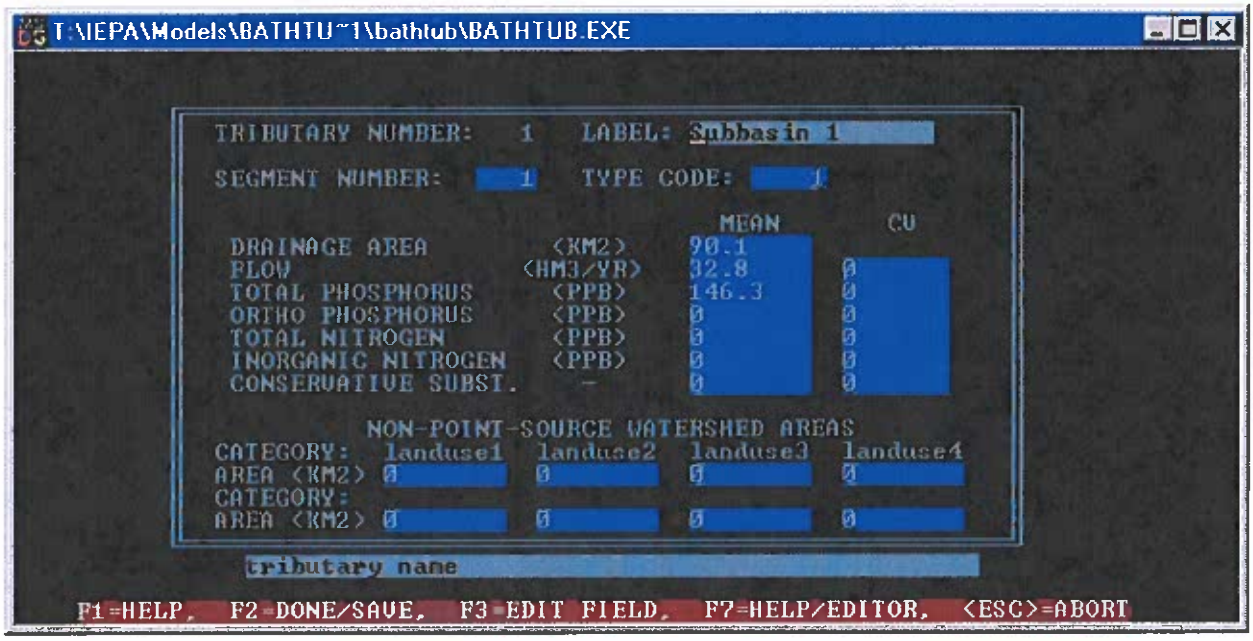


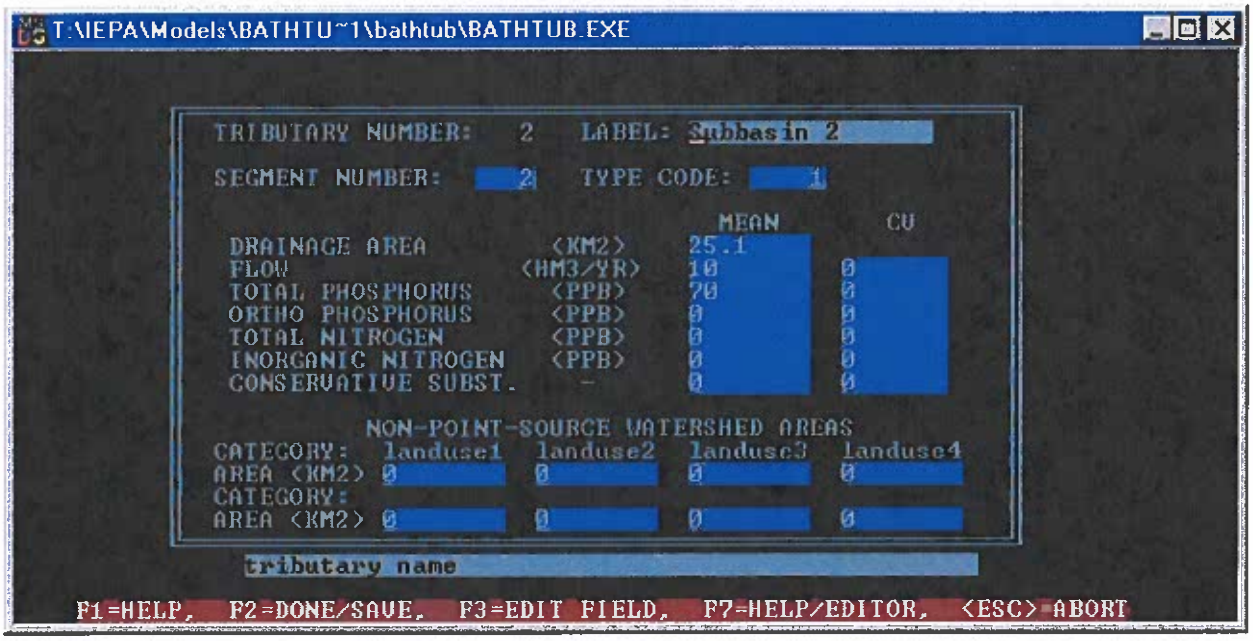

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2):.843 MEAN DEPTH (M):1.21 LENGTH (KM):4.06
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 1.21 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 135.4 .293 1.3 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 52.103 .558 .7 0
SECCHI DEPTH (M) .449 .717 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

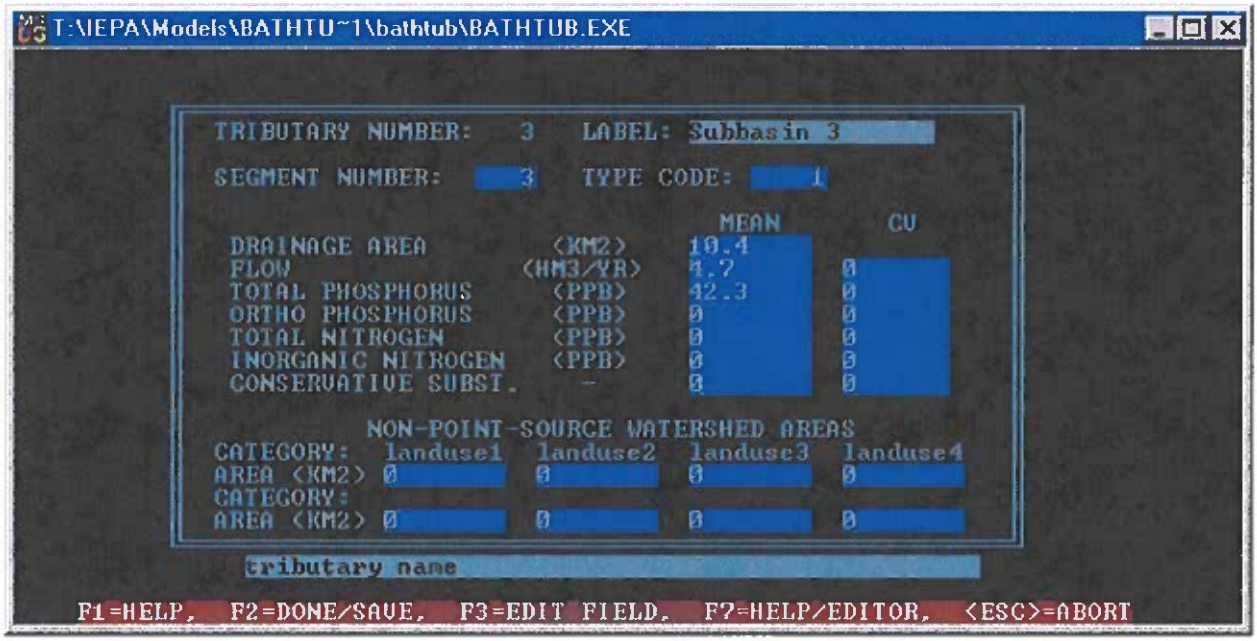

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 2 NAME: Middle Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2):1.743 MEAN DEPTH (M):7.53 LENGTH (KM):4.62
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.49 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 36.8 .734 .7 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 24.303 .442 1.5 0
SECCHI DEPTH (M) 1.321 .666 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

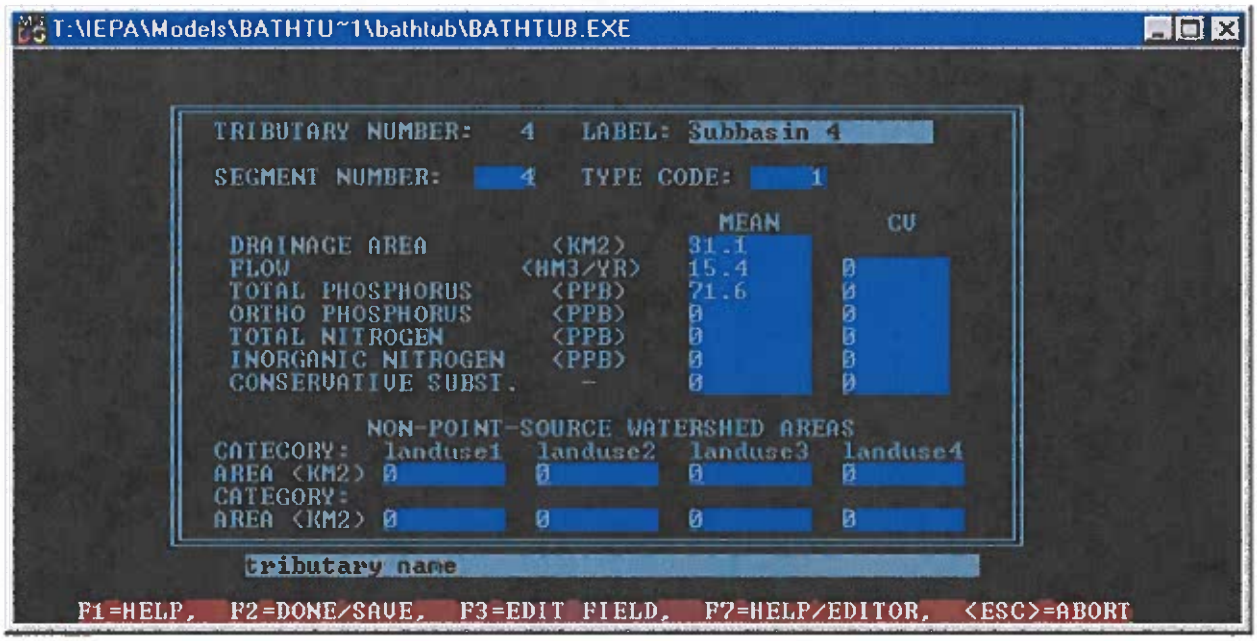

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 3 NAME: Lower Pool OUTFLOW SEG: 4 GROUP: 1
AREA (KM2):1.426 MEAN DEPTH (M):10.88 LENGTH (KM):3.36
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.33 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 22.2 .456 .7 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 23.4 .442 2 0
SECCHI DEPTH (M) 1.577 .587 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 4 NAME: Near Dam OUTFLOW SEG: 0 GROUP: 1
AREA (KM2):5.497 MEAN DEPTH (M):18.3 LENGTH (KM):6.94
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.49 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 25.22 .534 1.3 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 19.125 .524 1.9 0
SECCHI DEPTH (M) 1.892 .646 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 1 LABEL: Subbasin 1
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 90.1
FLOW (HM3/YR) 32.8 0
TOTAL PHOSPHORUS (PPB) 146.3 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 2 LABEL: Subbasin 2
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 25.1
FLOW (HM3/YR) 10 0
TOTAL PHOSPHORUS (PPB) 70 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 3 LABEL: Subbasin 3
SEGMENT NUMBER: 3 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 10.4
FLOW (HM3/YR) 4.7 0
TOTAL PHOSPHORUS (PPB) 42.3 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 4 LABEL: Subbasin 4
SEGMENT NUMBER: 4 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 31.1
FLOW (HM3/YR) 15.4 0
TOTAL PHOSPHORUS (PPB) 21.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

BATHTUB Model Output for 1994 Simulation

CASE: Kinkaid 1994 - Calibrated
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	135.4	.29	137.6	.48	.98	-.06	-.06	-.03
CHL-A	MG/M3	52.1	.56	49.9	.53	1.04	.08	.12	.06
SECCHI	M	.4	.72	.5	.66	.98	-.03	-.09	-.03
ORGANIC N	MG/M3	.0	.00	1364.6	.41	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	106.7	.39	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.8	.73	39.3	.45	.94	-.09	-.25	-.08
CHL-A	MG/M3	24.3	.44	22.2	.67	1.09	.20	.26	.11
SECCHI	M	1.3	.67	1.4	.53	.93	-.11	-.25	-.08
ORGANIC N	MG/M3	.0	.00	675.5	.47	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	39.0	.49	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	22.2	.46	23.1	.45	.96	-.09	-.15	-.06
CHL-A	MG/M3	23.4	.44	20.2	.67	1.16	.33	.43	.18
SECCHI	M	1.6	.59	1.7	.60	.92	-.14	-.29	-.10
ORGANIC N	MG/M3	.0	.00	623.3	.48	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	33.7	.58	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	25.2	.53	23.3	.46	1.08	.15	.30	.12
CHL-A	MG/M3	19.1	.52	19.1	.66	1.00	.01	.01	.00
SECCHI	M	1.9	.65	1.8	.60	1.05	.08	.19	.06
ORGANIC N	MG/M3	.0	.00	597.8	.46	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	31.7	.58	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.7	.48	36.3	.45	1.01	.02	.03	.01
CHL-A	MG/M3	23.6	.50	22.6	.53	1.05	.09	.14	.06
SECCHI	M	1.6	.64	1.6	.50	1.01	.02	.04	.01
ORGANIC N	MG/M3	.0	.00	683.9	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.0	.50	.00	.00	.00	.00

CASE: Kinkaid 1994 - Calibrated
GROSS WATER BALANCE:

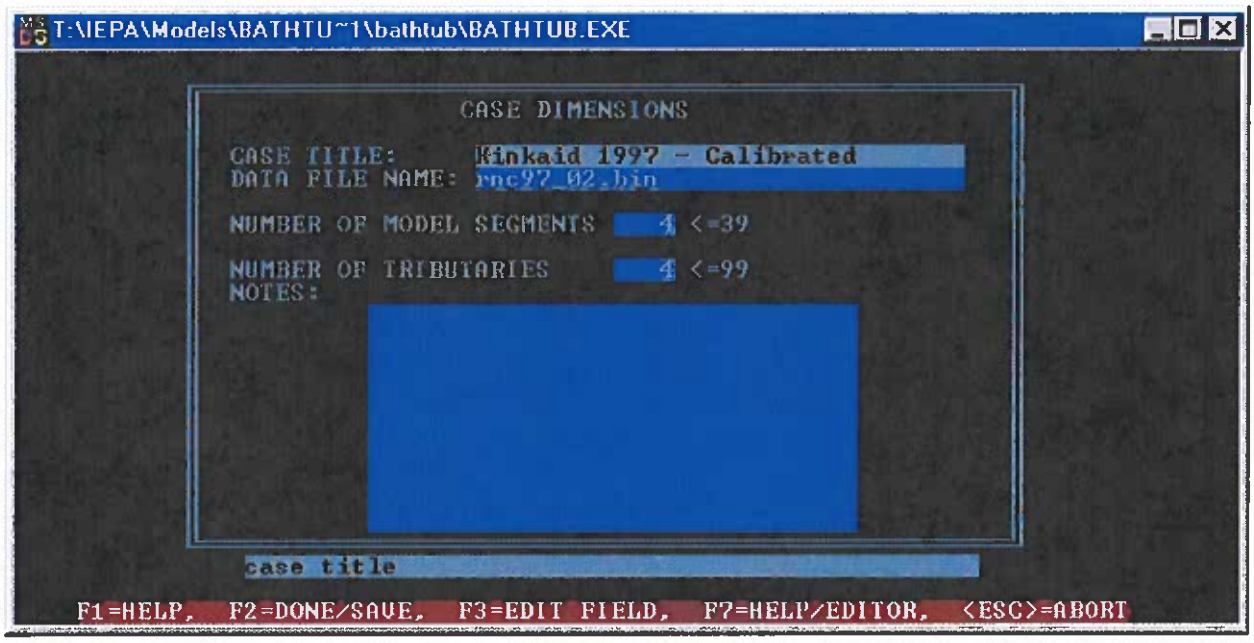
ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	32.800	.000E+00	.000	.364
2	1	Subbasin 2	25.100	10.000	.000E+00	.000	.398
3	1	Subbasin 3	10.400	4.700	.000E+00	.000	.452
4	1	Subbasin 4	31.100	15.400	.000E+00	.000	.495
PRECIPITATION			9.509	10.555	.446E+01	.200	1.110
TRIBUTARY INFLOW			156.700	62.900	.000E+00	.000	.401
***TOTAL INFLOW			166.209	73.455	.446E+01	.029	.442
ADVECTIVE OUTFLOW			166.209	65.448	.102E+02	.049	.394
***TOTAL OUTFLOW			166.209	65.448	.102E+02	.049	.394
***EVAPORATION			.000	8.007	.577E+01	.300	.000

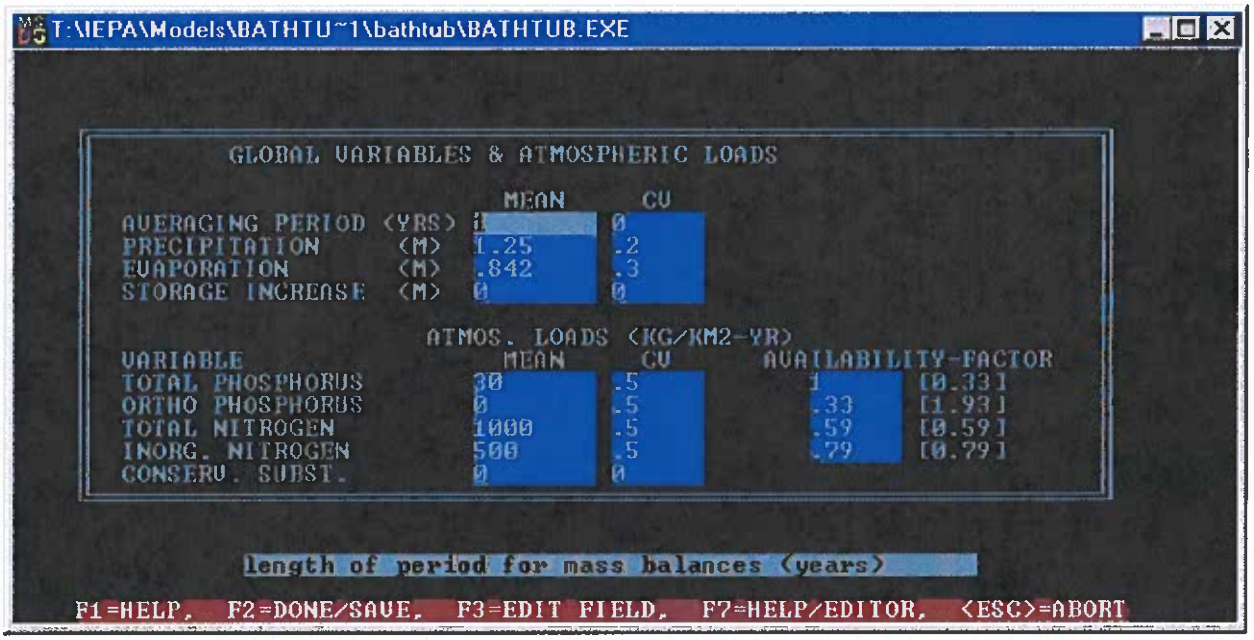
GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

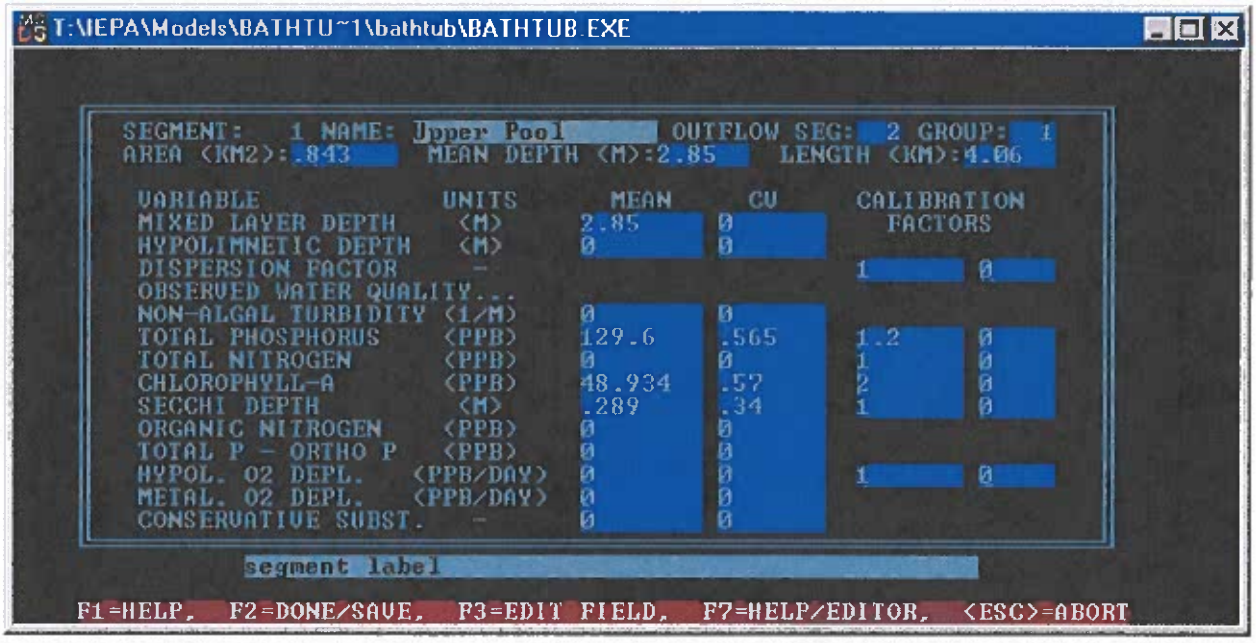
ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	4798.6	67.7	.000E+00	.0	.000	146.3	53.3
2	1	Subbasin 2	700.0	9.9	.000E+00	.0	.000	70.0	27.9
3	1	Subbasin 3	198.8	2.8	.000E+00	.0	.000	42.3	19.1
4	1	Subbasin 4	1102.6	15.6	.000E+00	.0	.000	71.6	35.5
PRECIPITATION			285.3	4.0	.203E+05	100.0	.500	27.0	30.0
TRIBUTARY INFLOW			6800.1	96.0	.000E+00	.0	.000	108.1	43.4
***TOTAL INFLOW			7085.4	100.0	.203E+05	100.0	.020	96.5	42.6
ADVECTIVE OUTFLOW			1521.9	21.5	.483E+06	2375.1	.457	23.3	9.2
***TOTAL OUTFLOW			1521.9	21.5	.483E+06	2375.1	.457	23.3	9.2
***RETENTION			5563.5	78.5	.495E+06	2432.9	.126	.0	.0

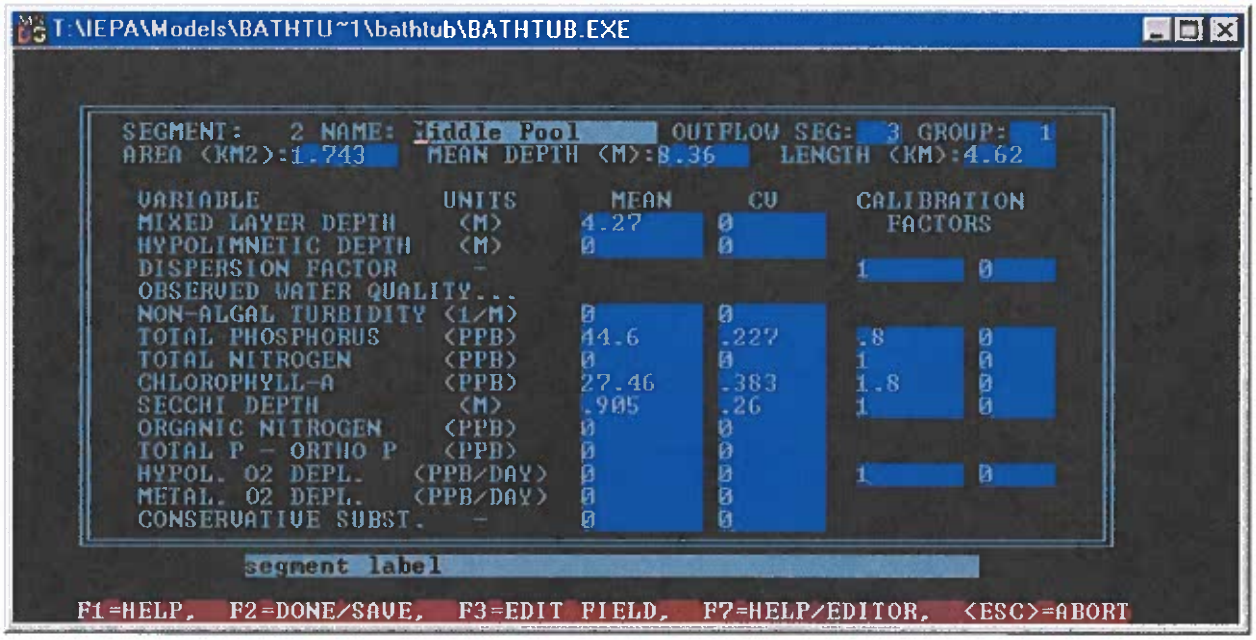
OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
6.88	1.9902	36.7	.6739	1.4839	.7852

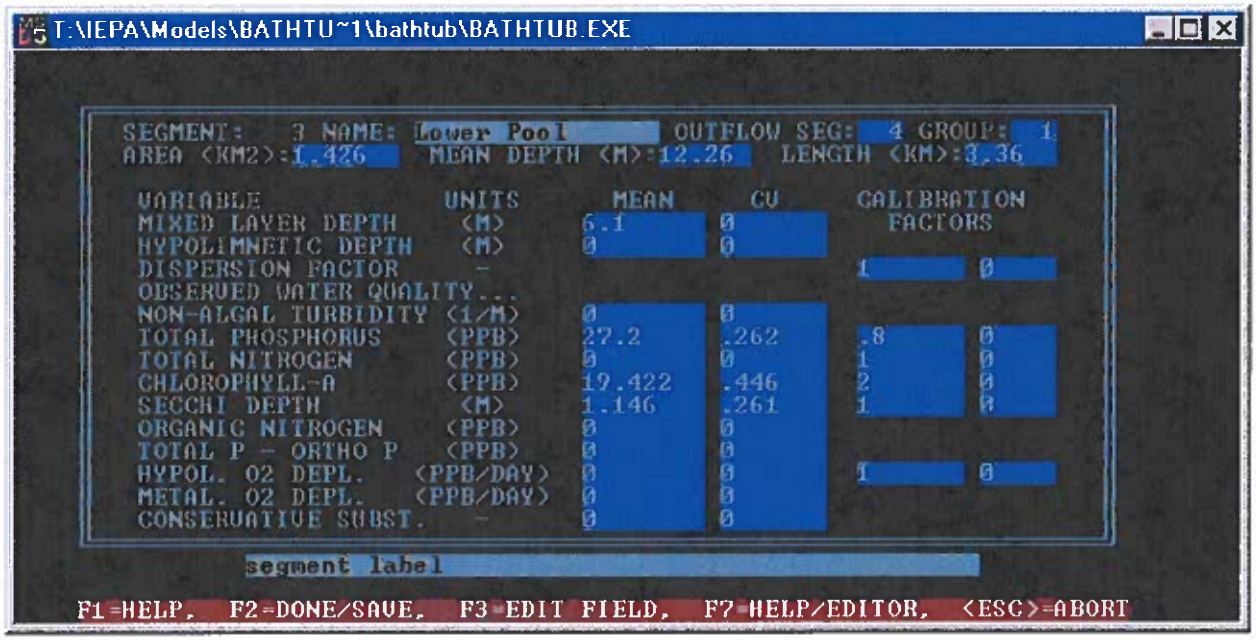
BATHTUB Model Input Screens for 1997 Simulation

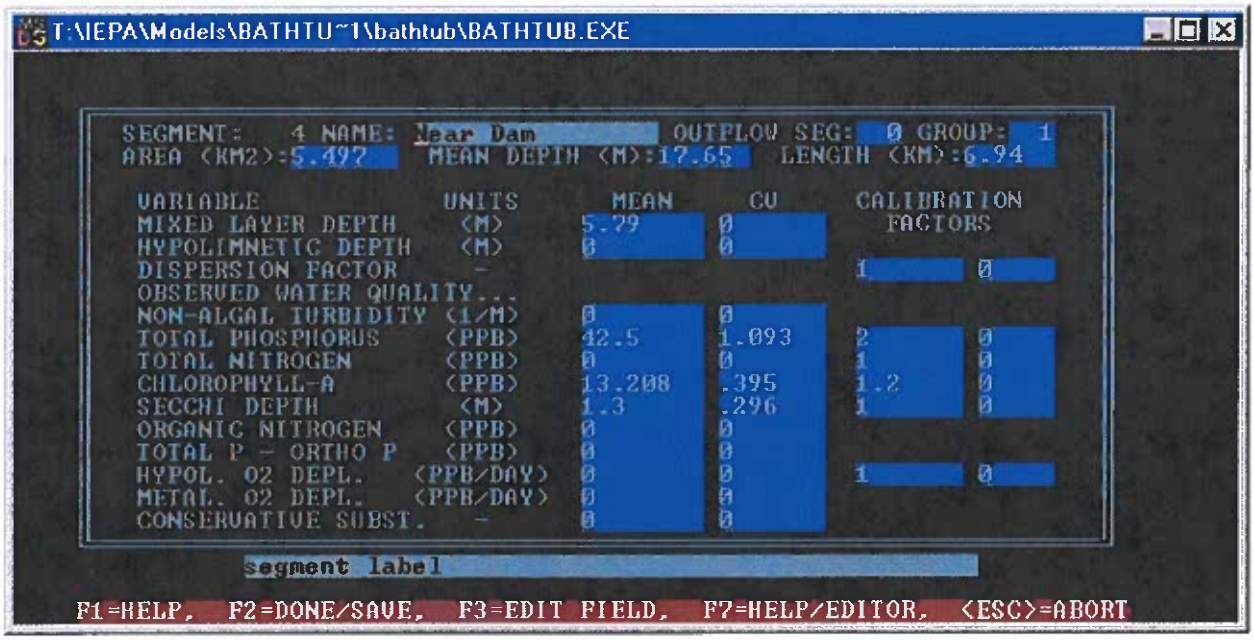


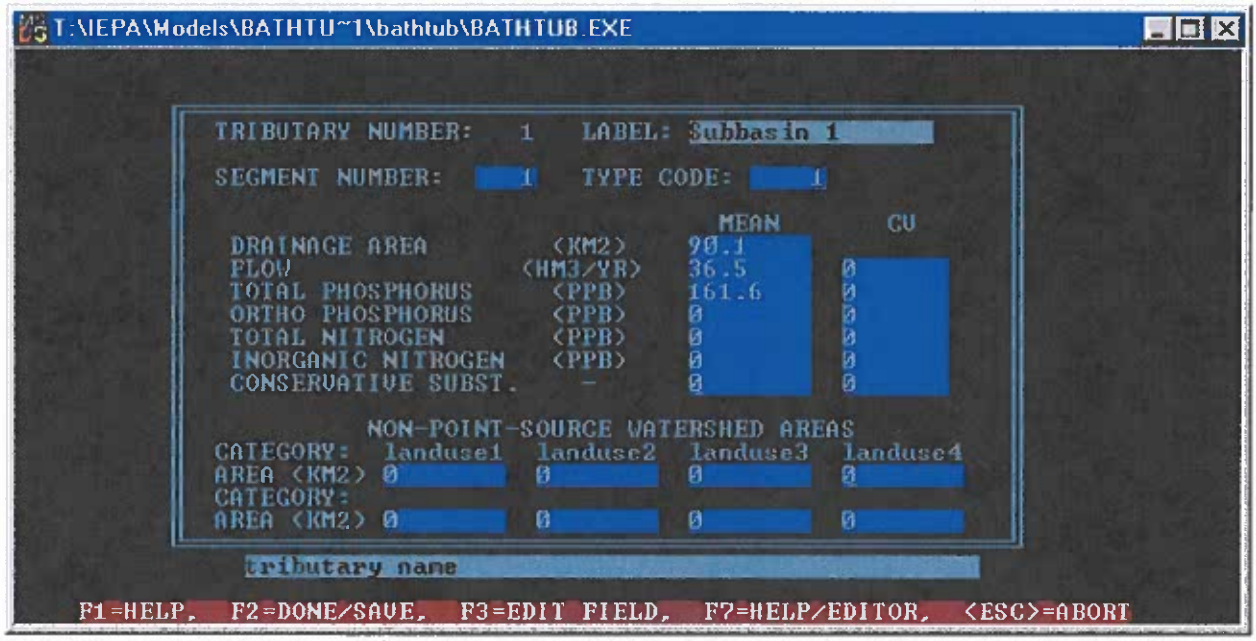


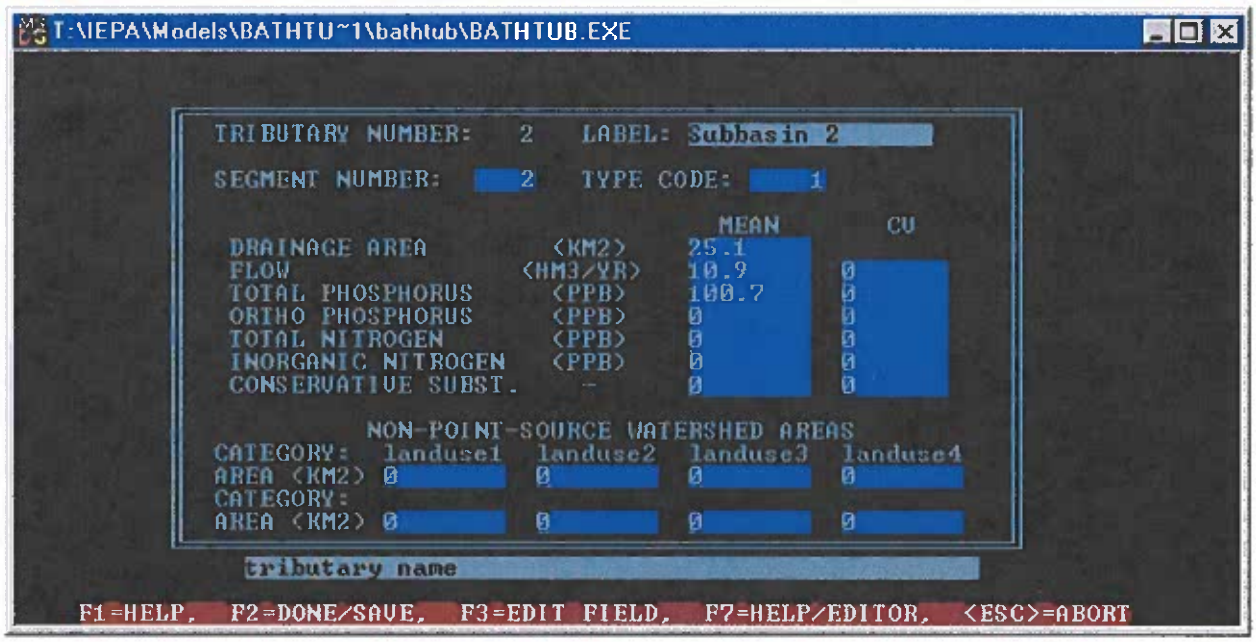

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2):.843 MEAN DEPTH (M):2.85 LENGTH (KM):4.06
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 2.85 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 129.6 .565 1.2 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 48.934 .57 2 0
SECCHI DEPTH (M) .289 .34 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

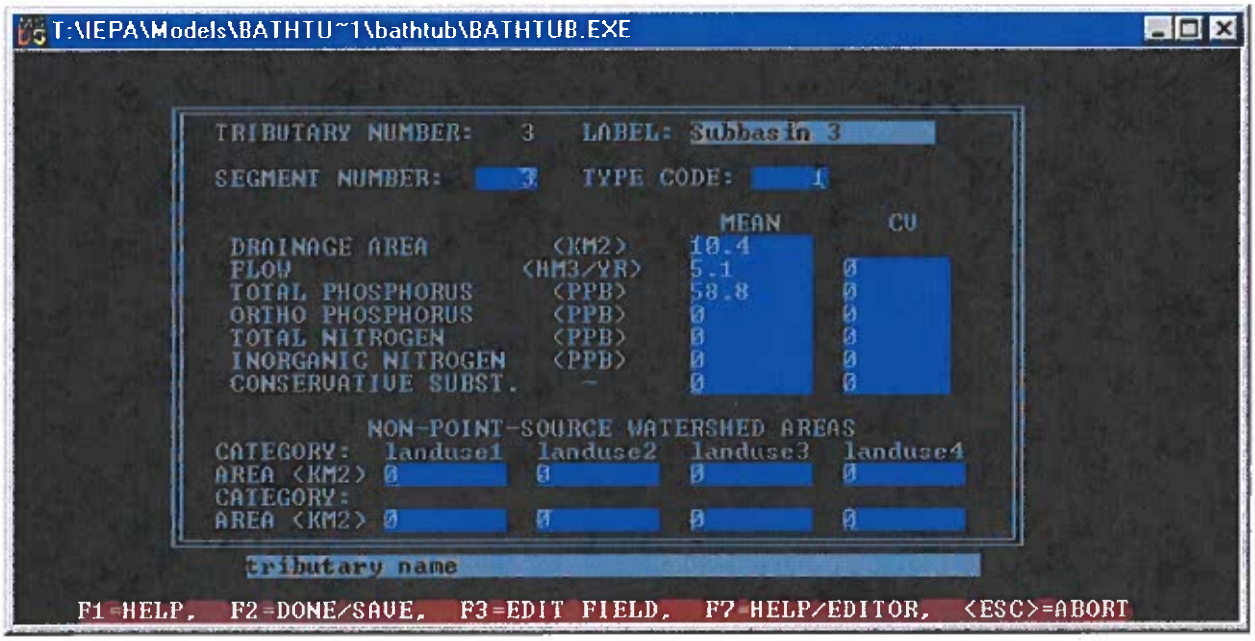

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 2 NAME: Middle Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2):1.743 MEAN DEPTH (M):8.36 LENGTH (KM):4.62
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 4.27 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 44.6 .227 .8 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 27.46 .383 1.8 0
SECCHI DEPTH (M) .905 .26 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

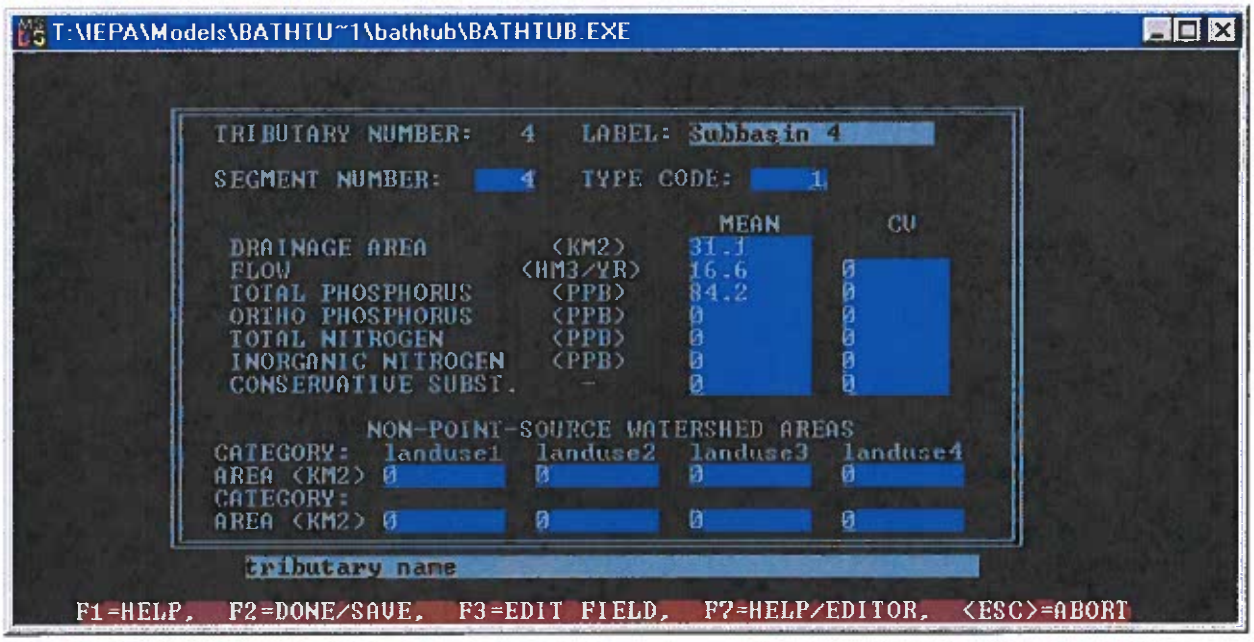

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 3 NAME: Lower Pool OUTFLOW SEG: 4 GROUP: 1
AREA (KM2):1.426 MEAN DEPTH (M):12.26 LENGTH (KM):3.36
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 6.1 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 27.2 .262 .8 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 19.422 .446 2 0
SECCHI DEPTH (M) 1.146 .261 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 4 NAME: Near Dam OUTFLOW SEG: 0 GROUP: 1
AREA (KM2):5.497 MEAN DEPTH (M):17.65 LENGTH (KM):6.94
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.29 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 42.5 1.093 2 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 13.208 .395 1.2 0
SECCHI DEPTH (M) 1.3 .296 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 1 LABEL: Subbasin 1
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 90.1
FLOW (HM3/YR) 36.5 0
TOTAL PHOSPHORUS (PPB) 161.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 2 LABEL: Subbasin 2
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 25.1
FLOW (HM3/YR) 10.9 0
TOTAL PHOSPHORUS (PPB) 100.7 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 3 LABEL: Subbasin 3
SEGMENT NUMBER: 3 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 10.4
FLOW (HM3/YR) 5.1 0
TOTAL PHOSPHORUS (PPB) 58.8 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 4 LABEL: Subbasin 4
SEGMENT NUMBER: 4 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 31.1
FLOW (HM3/YR) 16.6 0
TOTAL PHOSPHORUS (PPB) 84.2 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

BATHTUB Model Output for 1997 Simulation

CASE: Kinkaid 1997 - Calibrated
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	129.6	.56	133.1	.45	.97	-.05	-.10	-.04
CHL-A	MG/M3	48.9	.57	45.6	.46	1.07	.12	.20	.10
SECCHI	M	.3	.34	.3	.32	.98	-.07	-.09	-.05
ORGANIC N	MG/M3	.0	.00	1364.9	.32	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	130.1	.25	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	44.6	.23	43.0	.45	1.04	.16	.14	.07
CHL-A	MG/M3	27.5	.38	27.5	.50	1.00	.00	.00	.00
SECCHI	M	.9	.26	.9	.35	1.00	.00	.00	.00
ORGANIC N	MG/M3	.0	.00	814.6	.39	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	54.7	.42	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.2	.26	25.6	.45	1.06	.23	.22	.11
CHL-A	MG/M3	19.4	.45	15.9	.54	1.22	.45	.58	.29
SECCHI	M	1.1	.26	1.3	.38	.90	-.41	-.38	-.23
ORGANIC N	MG/M3	.0	.00	548.0	.36	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	33.3	.43	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	42.5	1.09	37.0	.45	1.15	.13	.52	.12
CHL-A	MG/M3	13.2	.40	12.9	.47	1.03	.06	.07	.04
SECCHI	M	1.3	.30	1.3	.33	.99	-.04	-.04	-.02
ORGANIC N	MG/M3	.0	.00	483.8	.30	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	29.2	.37	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	48.3	.75	44.9	.45	1.08	.10	.27	.08
CHL-A	MG/M3	19.9	.44	18.9	.43	1.05	.12	.15	.09
SECCHI	M	1.1	.29	1.1	.29	.98	-.09	-.09	-.06
ORGANIC N	MG/M3	.0	.00	632.2	.31	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	43.5	.35	.00	.00	.00	.00

CASE: Kinkaid 1997 - Calibrated
GROSS WATER BALANCE:

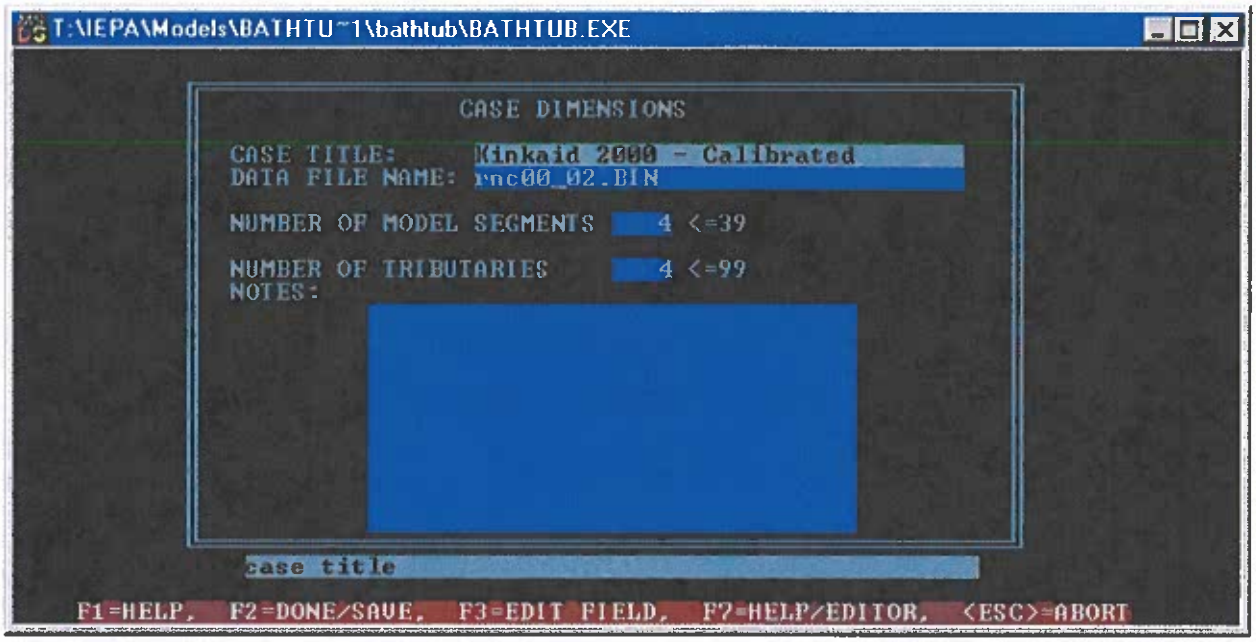
ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	36.500	.000E+00	.000	.405
2	1	Subbasin 2	25.100	10.900	.000E+00	.000	.434
3	1	Subbasin 3	10.400	5.100	.000E+00	.000	.490
4	1	Subbasin 4	31.100	16.600	.000E+00	.000	.534
PRECIPITATION			9.509	11.886	.565E+01	.200	1.250
TRIBUTARY INFLOW			156.700	69.100	.000E+00	.000	.441
***TOTAL INFLOW			166.209	80.986	.565E+01	.029	.487
ADVECTIVE OUTFLOW			166.209	72.980	.114E+02	.046	.439
***TOTAL OUTFLOW			166.209	72.980	.114E+02	.046	.439
***EVAPORATION			.000	8.007	.577E+01	.300	.000

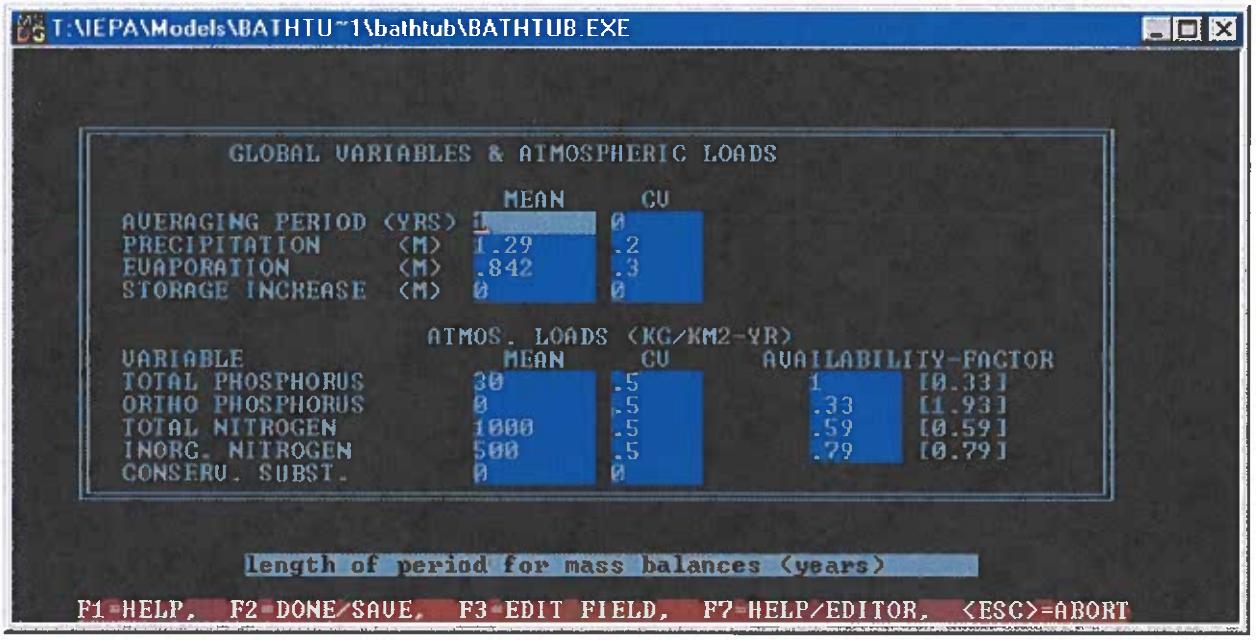
GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

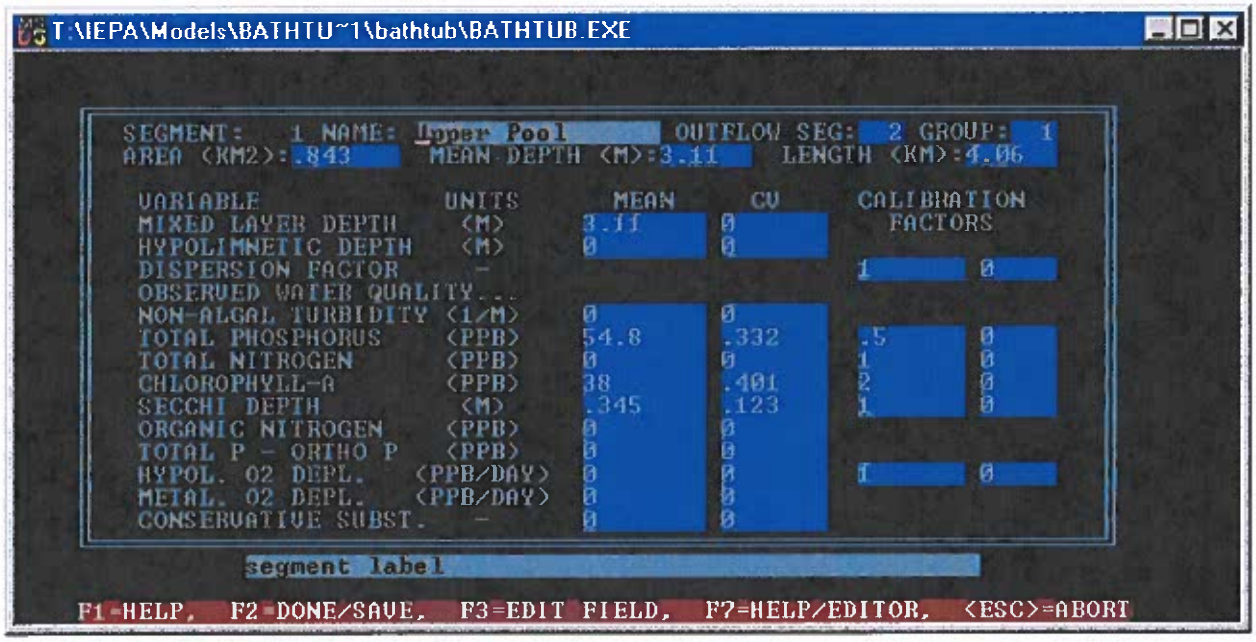
ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	5898.4	65.7	.000E+00	.0	.000	161.6	65.5
2	1	Subbasin 2	1097.6	12.2	.000E+00	.0	.000	100.7	43.7
3	1	Subbasin 3	299.9	3.3	.000E+00	.0	.000	58.8	28.8
4	1	Subbasin 4	1397.7	15.6	.000E+00	.0	.000	84.2	44.9
PRECIPITATION			285.3	3.2	.203E+05	100.0	.500	24.0	30.0
TRIBUTARY INFLOW			8693.6	96.8	.000E+00	.0	.000	125.8	55.5
***TOTAL INFLOW			8978.9	100.0	.203E+05	100.0	.016	110.9	54.0
ADVECTIVE OUTFLOW			2697.3	30.0	.150E+07	7379.0	.454	37.0	16.2
***TOTAL OUTFLOW			2697.3	30.0	.150E+07	7379.0	.454	37.0	16.2
***RETENTION			6281.6	70.0	.151E+07	7412.4	.195	.0	.0

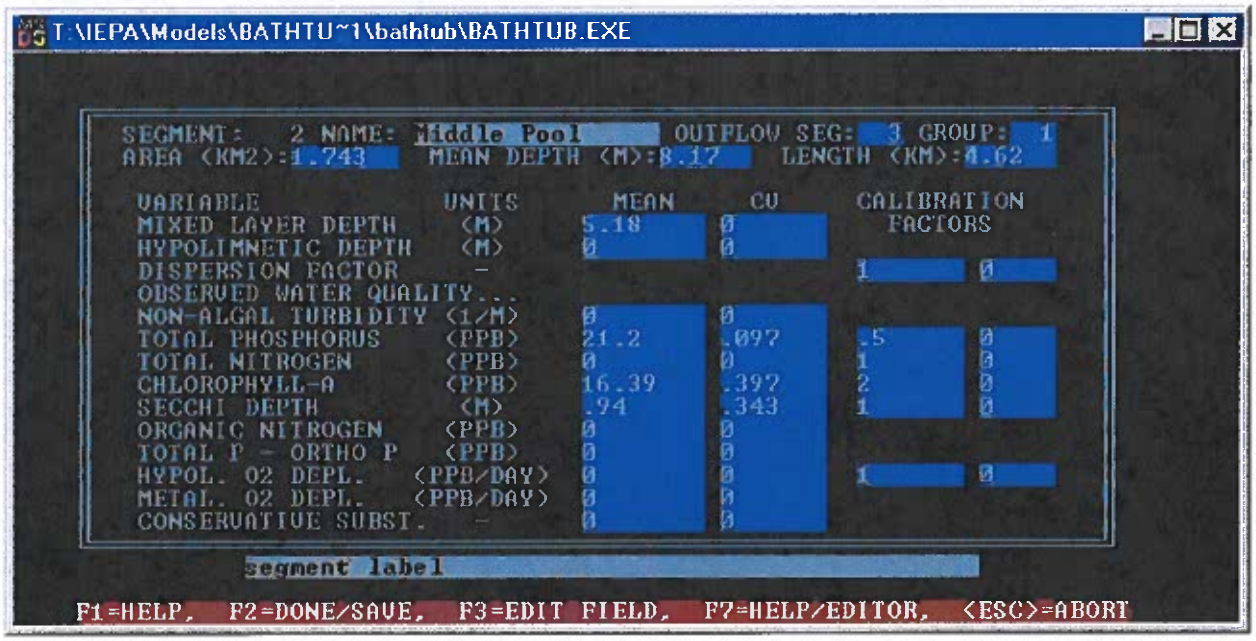
OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.67	1.8016	48.3	.7074	1.4135	.6996

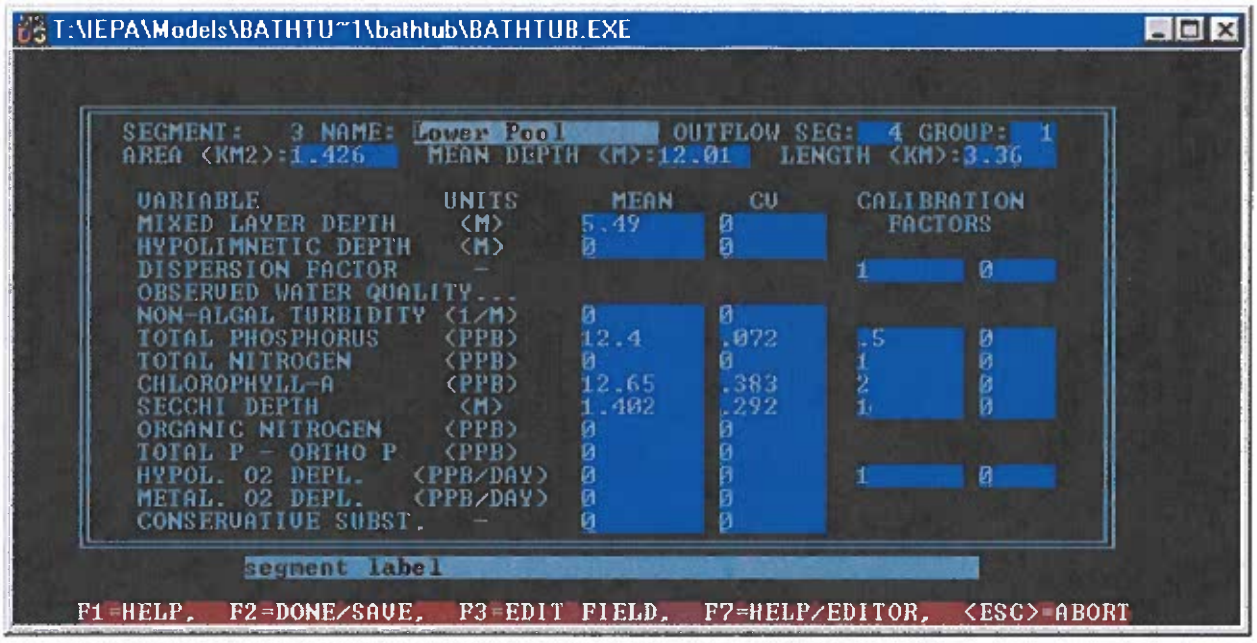
BATHTUB Model Input Screens for 2000 Simulation

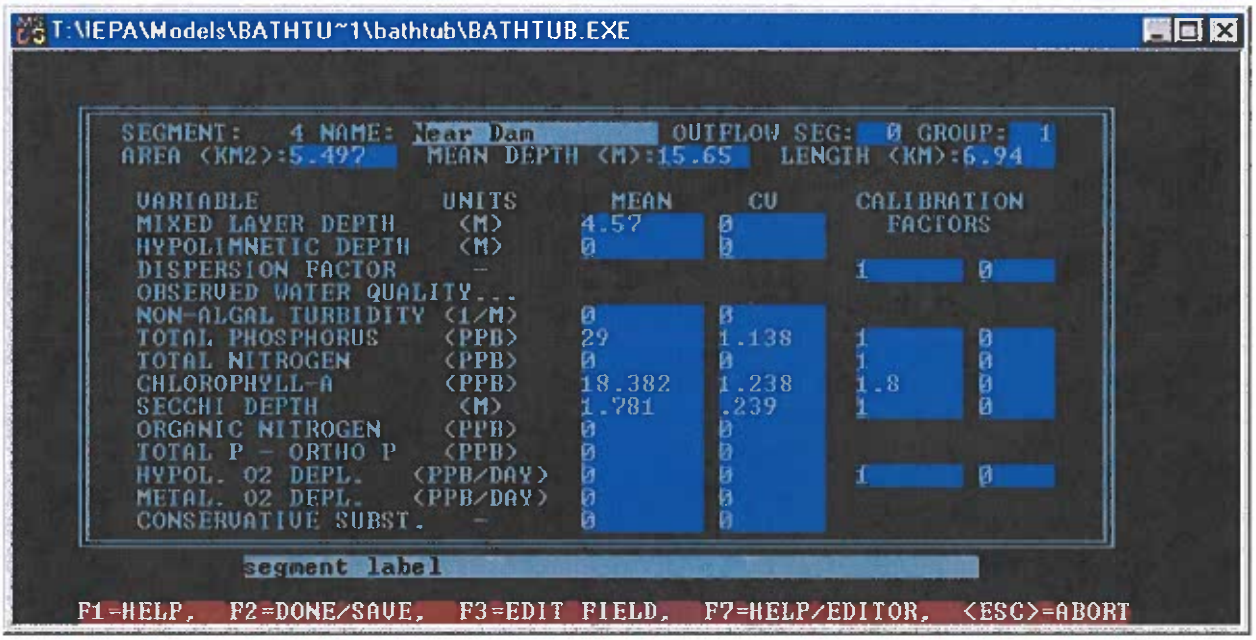


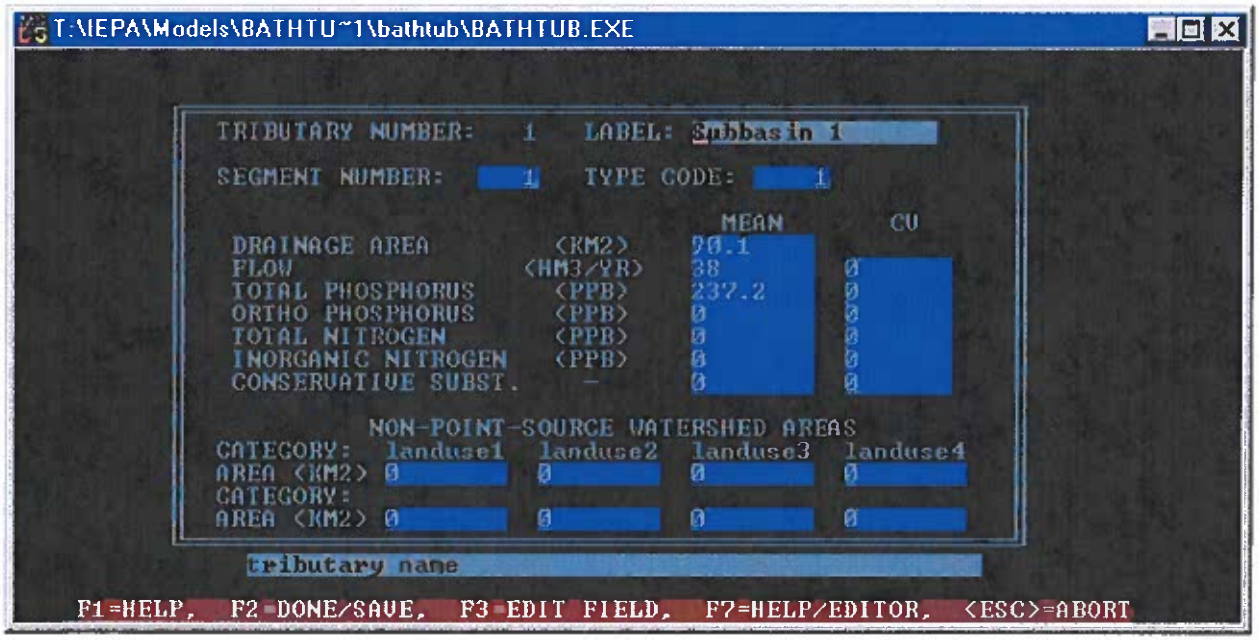


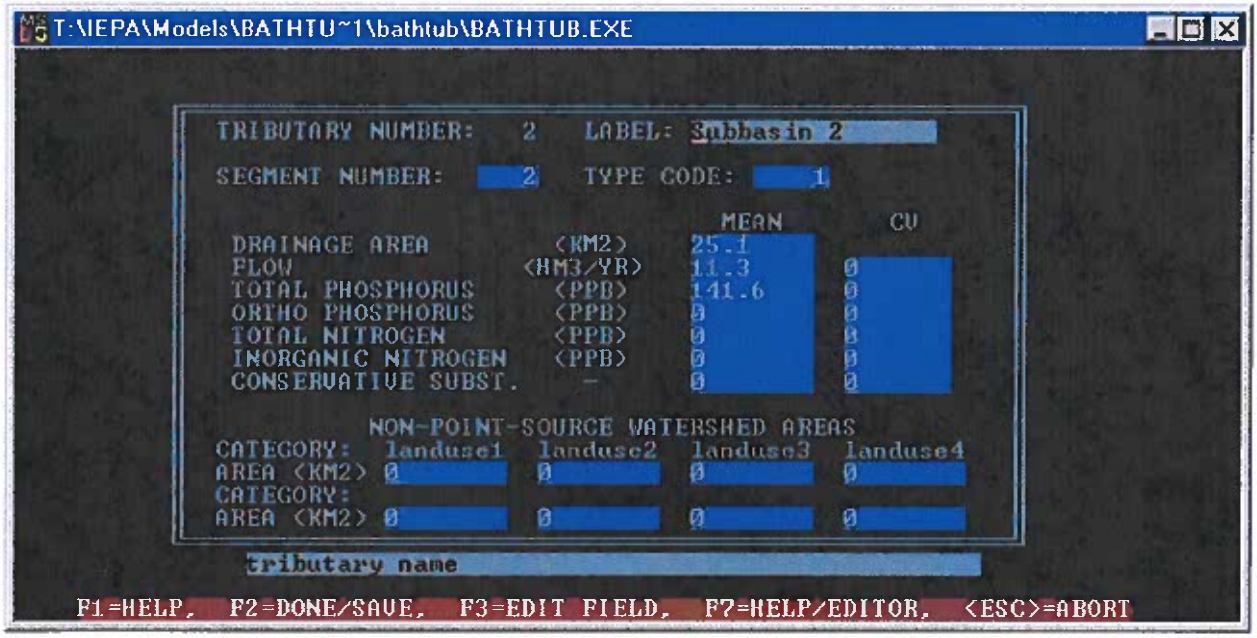

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2):.843 MEAN DEPTH (M):3.11 LENGTH (KM):4.06
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 3.11 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 54.8 .332 .5 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 38 .401 2 0
SECCHI DEPTH (M) .345 .123 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

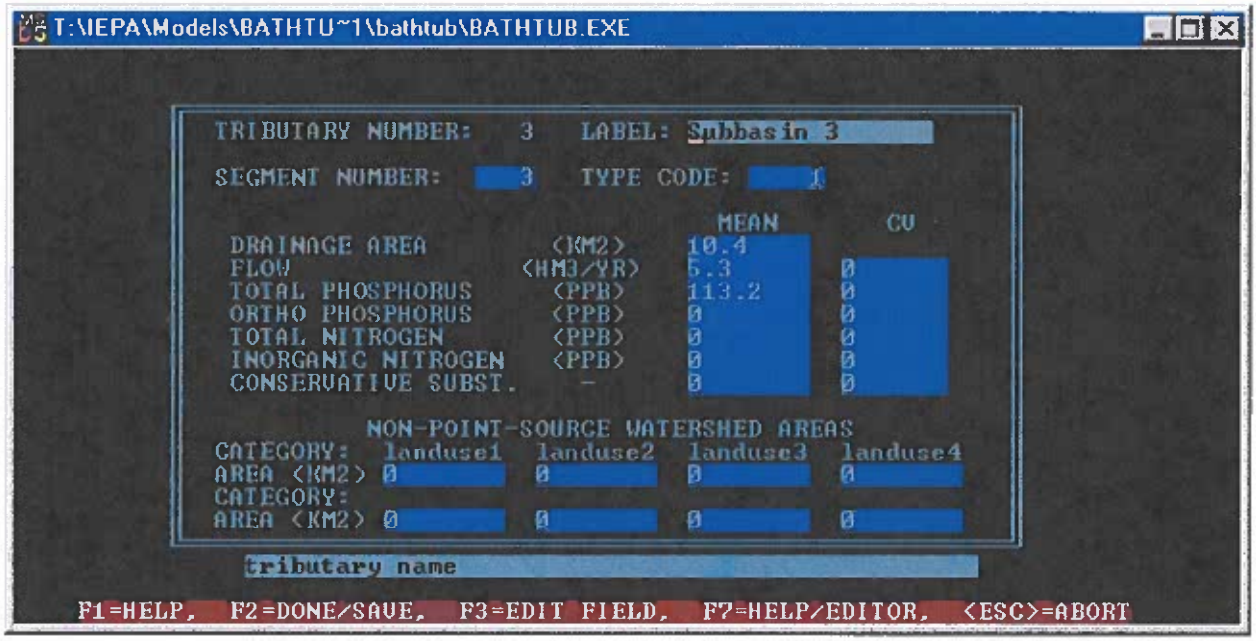

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 2 NAME: Middle Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2):1.743 MEAN DEPTH (M):3.17 LENGTH (KM):4.62
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.18 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 21.2 .097 .5 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 16.39 .397 2 0
SECCHI DEPTH (M) .94 .343 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

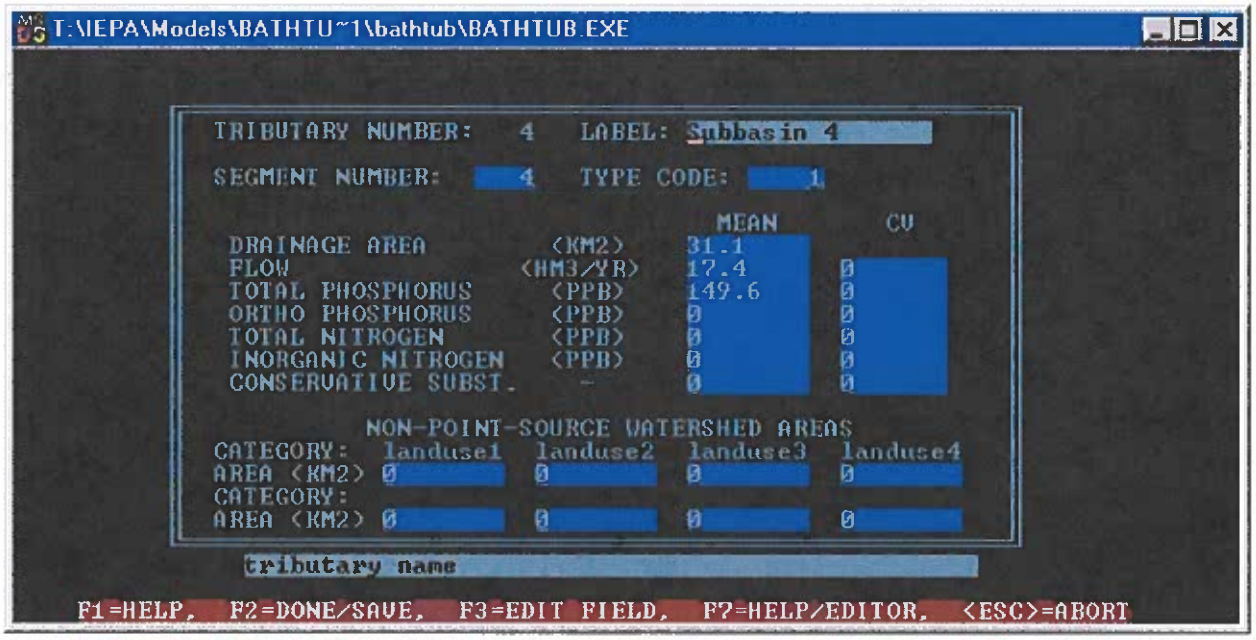

T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 3 NAME: Lower Pool OUTFLOW SEG: 4 GROUP: 1
AREA (KM2):1.426 MEAN DEPTH (M):12.01 LENGTH (KM):3.36
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.49 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 12.4 .072 .5 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 12.65 .383 2 0
SECCHI DEPTH (M) 1.402 .292 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 4 NAME: Near Dam OUTFLOW SEG: 0 GROUP: 1
AREA (KM2):5.492 MEAN DEPTH (M):15.65 LENGTH (KM):6.94
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 4.57 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 29 1.138 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 18.382 1.238 1.8 0
SECCHI DEPTH (M) 1.781 .239 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 1 LABEL: Subbasin 1
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 90.1
FLOW (HM3/YR) 38 0
TOTAL PHOSPHORUS (PPB) 237.2 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 2 LABEL: Subbasin 2
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 25.1
FLOW (HM3/YR) 11.3 0
TOTAL PHOSPHORUS (PPB) 141.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 3 LABEL: Subbasin 3
SEGMENT NUMBER: 3 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 10.4
FLOW (HM3/YR) 5.3 0
TOTAL PHOSPHORUS (PPB) 113.2 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 4 LABEL: Subbasin 4
SEGMENT NUMBER: 4 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 31.1
FLOW (HM3/YR) 17.4 0
TOTAL PHOSPHORUS (PPB) 149.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

BATHTUB Model Output for 2000 Simulation

CASE: Kinkaid 2000 - Calibrated
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	CV	ESTIMATED MEAN	CV	RATIO	T STATISTICS 1	2	3
TOTAL P	MG/M3	54.8	.33	72.2	.45	.76	-.83	-1.03	-.49
CHL-A	MG/M3	38.0	.40	32.0	.42	1.19	.43	.50	.30
SECCHI	M	.3	.12	.4	.21	.95	-.43	-.19	-.22
ORGANIC N	MG/M3	.0	.00	1032.9	.31	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	99.0	.27	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

VARIABLE		OBSERVED MEAN	CV	ESTIMATED MEAN	CV	RATIO	T STATISTICS 1	2	3
TOTAL P	MG/M3	21.2	.10	32.6	.45	.65	-4.43	-1.60	-.93
CHL-A	MG/M3	16.4	.40	18.3	.52	.90	-.27	-.31	-.17
SECCHI	M	.9	.34	.9	.33	1.04	.13	.15	.09
ORGANIC N	MG/M3	.0	.00	623.0	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	43.9	.38	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

VARIABLE		OBSERVED MEAN	CV	ESTIMATED MEAN	CV	RATIO	T STATISTICS 1	2	3
TOTAL P	MG/M3	12.4	.07	19.4	.45	.64	-6.21	-1.66	-.98
CHL-A	MG/M3	12.6	.38	12.7	.56	.99	-.02	-.02	-.01
SECCHI	M	1.4	.29	1.4	.36	1.00	.01	.01	.01
ORGANIC N	MG/M3	.0	.00	477.6	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	28.0	.46	.00	.00	.00	.00

SEGMENT: 4 Near Dam

VARIABLE		OBSERVED MEAN	CV	ESTIMATED MEAN	CV	RATIO	T STATISTICS 1	2	3
TOTAL P	MG/M3	29.0	1.14	24.3	.45	1.20	.16	.66	.15
CHL-A	MG/M3	18.4	1.24	19.7	.70	.93	-.06	-.20	-.05
SECCHI	M	1.8	.24	1.7	.73	1.06	.24	.20	.07
ORGANIC N	MG/M3	.0	.00	614.0	.49	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	33.4	.58	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	CV	ESTIMATED MEAN	CV	RATIO	T STATISTICS 1	2	3
TOTAL P	MG/M3	27.4	.77	29.3	.45	.93	-.09	-.25	-.08
CHL-A	MG/M3	18.9	.87	19.5	.57	.97	-.04	-.09	-.03
SECCHI	M	1.4	.26	1.4	.56	1.05	.18	.16	.07
ORGANIC N	MG/M3	.0	.00	632.3	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.3	.45	.00	.00	.00	.00

CASE: Kinkaid 2000 - Calibrated
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	38.000	.000E+00	.000	.422
2	1	Subbasin 2	25.100	11.300	.000E+00	.000	.450
3	1	Subbasin 3	10.400	5.300	.000E+00	.000	.510
4	1	Subbasin 4	31.100	17.400	.000E+00	.000	.559
PRECIPITATION			9.509	12.267	.602E+01	.200	1.290
TRIBUTARY INFLOW			156.700	72.000	.000E+00	.000	.459
***TOTAL INFLOW			166.209	84.267	.602E+01	.029	.507
ADVECTIVE OUTFLOW			166.209	76.260	.118E+02	.045	.459
***TOTAL OUTFLOW			166.209	76.260	.118E+02	.045	.459
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	9013.6	63.9	.000E+00	.0	.000	237.2	100.0
2	1	Subbasin 2	1600.1	11.3	.000E+00	.0	.000	141.6	63.7
3	1	Subbasin 3	600.0	4.3	.000E+00	.0	.000	113.2	57.7
4	1	Subbasin 4	2603.0	18.5	.000E+00	.0	.000	149.6	83.7
PRECIPITATION			285.3	2.0	.203E+05	100.0	.500	23.3	30.0
TRIBUTARY INFLOW			13816.7	98.0	.000E+00	.0	.000	191.9	88.2
***TOTAL INFLOW			14101.9	100.0	.203E+05	100.0	.010	167.3	84.8
ADVECTIVE OUTFLOW			1850.4	13.1	.702E+06	3452.5	.453	24.3	11.1
***TOTAL OUTFLOW			1850.4	13.1	.702E+06	3452.5	.453	24.3	11.1
***RETENTION			12251.5	86.9	.717E+06	3523.1	.069	.0	.0

HYDRAULIC		TOTAL P			
OVERFLOW RATE M/YR	RESIDENCE TIME YRS	POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
8.02	1.5738	27.4	.2329	4.2933	.8688

Appendix D
GWLF Manual

G W L F

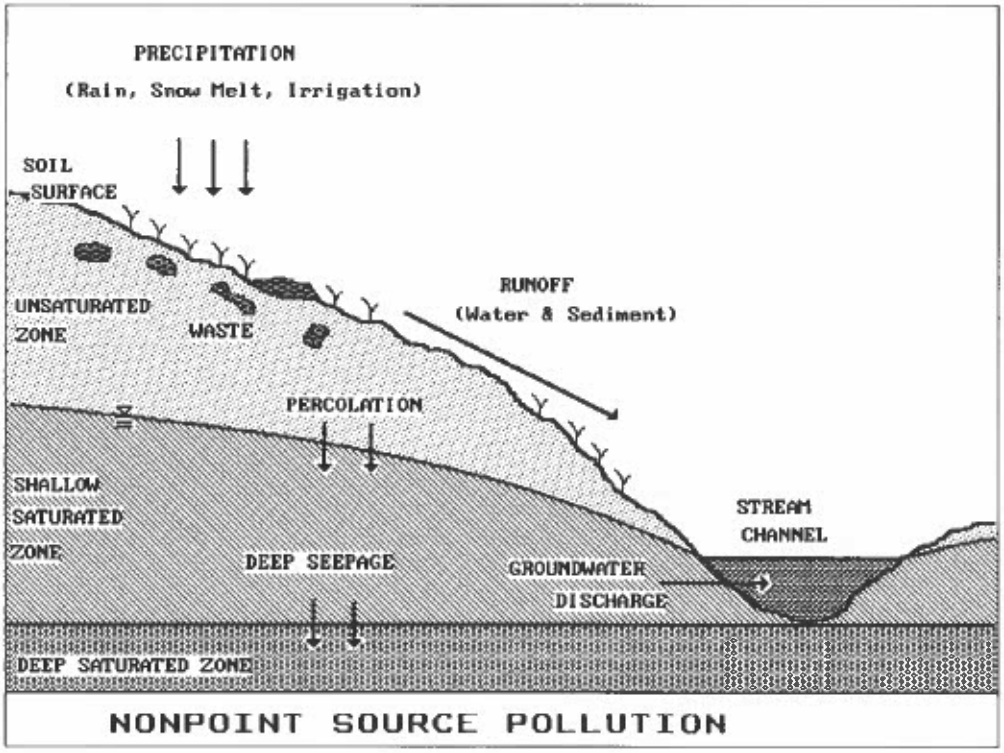
GENERALIZED WATERSHED LOADING FUNCTIONS

VERSION 2.0

USER'S MANUAL

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INTRODUCTION

Mathematical models for estimating nonpoint sources of nitrogen and phosphorus in streamflow include export coefficients, loading functions and chemical simulation models. Export coefficients are average annual unit area nutrient loads associated with watershed land uses. Coefficients provide gross estimates of nutrient loads, but are of limited value for determining seasonal loads or evaluating water pollution control measures. Chemical simulation models are mechanistic (mass balance) descriptions of nutrient availability, wash off, transport and losses. Chemical simulation models provide the most complete descriptions of nutrient loads, but they are too data intensive for use in many water quality studies.

Loading functions are engineering compromises between the empiricism of export coefficients and the complexity of chemical simulation models. Mechanistic modeling is limited to water and/or sediment movement. Chemical behavior of nutrients is either ignored or described by simple empirical relationships. Loading functions provide useful means of estimating nutrient loads when chemical simulation models are impractical.

The Generalized Watershed Loading Functions (GWLF) model described in this manual estimates dissolved and total monthly nitrogen and phosphorus loads in streamflow from complex watersheds. Both surface runoff and groundwater sources are included, as well as nutrient loads from point sources and on-site wastewater disposal (septic) systems. In addition, the model provides monthly streamflow, soil erosion and sediment yield values. The model does not require water quality data for calibration, and has been validated for an 85,000 ha watershed in upstate New York.

The model described in this manual is a based on the original GWLF model as described by Haith & Shoemaker (1987). However, the current version (Version 2.0) contains several enhancements. Nutrient loads from septic systems are now included and the urban runoff model has been modified to more closely approximate procedures used in the Soil Conservation Service's Technical Release 55 (Soil Conservation Service, 1986) and models such as SWMM (Huber & Dickinson, 1988) and STORM (Hydrologic Engineering Center, 1977). The groundwater model has been given a somewhat stronger conceptual basis by limiting the unsaturated zone moisture storage capacity. The graphics outputs have been converted to VGA and color has been used more extensively.

The most significant changes in the manual are an expanded mathematical description of the model (Appendix A) and much more detailed guidance on parameter estimation (Appendix B). Both changes are in response to suggestions by many users. The extra mathematical details are for the benefit of researchers who wish to modify (and improve) GWLF for their own purposes. The new sections on parameter estimation (and the many new tables) are for users who may not be familiar with curve numbers, erosivity coefficients, etc., or who do not have access to some of the primary sources. The general intent has been to make the manual self-contained.

This manual describes the computer software package which can be used to implement GWLF. The associated programs are written in QuickBASIC 4.5 for personal computers using the MS-DOS operating system and VGA graphics. The manual and associated programs (on floppy disk) are available without charge from the senior author. The programs are distributed in both executable (.EXE) and source code form (.BAS). Associated example data files and outputs for Example 1 and a 30-yr weather set for Walton NY used in Example 3 are also included on the disk.

The main body of this manual describes the program structures and input and output files and options. Three examples are also presented. Four appendices present the mathematical structure of GWLF, methods for estimation of model parameters, results of a validation study, and sample listings of input and output files.

In this manual, the program name, options in the menu page, and input by the user are written in **bold**, underline and *italic*, respectively.

MODEL DESCRIPTION

Model Structure

The GWLF model includes dissolved and solid-phase nitrogen and phosphorus in streamflow from the sources shown in Figure 1. Rural nutrient loads are transported in runoff water and eroded soil from numerous source areas, each of which is considered uniform with respect to soil and cover. Dissolved loads from each source area are obtained by multiplying runoff by dissolved concentrations. Runoff is computed by using the Soil Conservation Service Curve Number Equation. Solid-phase rural nutrient loads are given by the product of monthly sediment yield and average sediment nutrient concentrations. Erosion is computed using the Universal Soil Loss Equation and the sediment yield is the product of erosion and sediment delivery ratio. The yield in any month is proportional to the total transport capacity of daily runoff during the month. Urban nutrient loads, assumed to be entirely solid-phase, are modeled by exponential accumulation and washoff functions. Septic systems are classified according to four types: normal systems, ponding systems, short-circuiting systems, and direct discharge systems. Nutrient loads from septic systems are calculated by estimating the per capita daily load from each type of system and the number of people in the watershed served by each type. Daily evapotranspiration is given by the product of a cover factor and potential evapotranspiration. The latter is estimated as a function of daylight hours, saturated water vapor pressure and daily temperature.

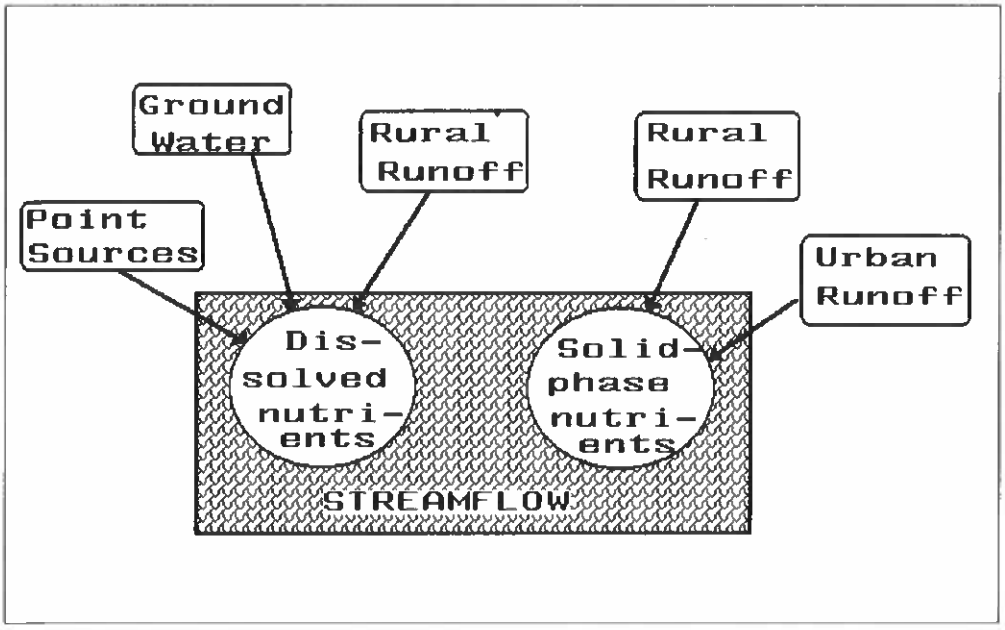


Figure 1. Nutrient Sources in GWLF.

Streamflow consists of runoff and discharge from groundwater. The latter is obtained from a lumped parameter watershed water balance. Daily water balances are calculated for unsaturated and shallow saturated zones. Infiltration to the unsaturated and shallow saturated zones equals the excess, if any, of rainfall and snowmelt less runoff and evapotranspiration. Percolation occurs when unsaturated zone water exceeds field capacity. The shallow saturated zone is modeled as a linear groundwater reservoir.

Model structure, including mathematics, is discussed in more detail in Appendix A.

Input Data

The GWLF model requires daily precipitation and temperature data, runoff sources and transport and chemical parameters. Transport parameters include areas, runoff curve numbers for antecedent moisture condition II and the erosion product KLSCP for each runoff source. Required watershed transport parameters are groundwater recession and seepage coefficients, the available water capacity of the unsaturated zone, the

sediment delivery ratio and monthly values for evapotranspiration cover factors, average daylight hours, growing season indicators and rainfall erosivity coefficients. Initial values must also be specified for unsaturated and shallow saturated zones, snow cover and 5-day antecedent rain fall plus snowmelt.

Input nutrient data for rural source areas are dissolved nitrogen and phosphorus concentrations in runoff and solid-phase nutrient concentrations in sediment. If manure is spread during winter months on any rural area, dissolved concentrations in runoff are also specified for each manured area. Daily nutrient accumulation rates are required for each urban land use. Septic systems need estimates of the per capita nutrient load in septic system effluent and per capita nutrient losses due to plant uptake, as well as the number of people served by each type of system. Point sources of nitrogen and phosphorus are assumed to be in dissolved form and must be specified for each month. The remaining nutrient data are dissolved nitrogen and phosphorus concentrations in groundwater.

Procedures for estimating transport and nutrient parameters are described in Appendix B. Examples are given in Appendix C and in subsequent sections of this manual.

Model Output

The GWLF program provides its simulation results in tables as well as in graphs. The following principal variables are given:

Monthly Streamflow
Monthly Watershed Erosion and Sediment Yield
Monthly Total Nitrogen and Phosphorus Loads in Streamflow
Annual Erosion from Each Land Use
Annual Nitrogen and Phosphorus Loads from Each Land Use

The program also provides

Monthly Precipitation and Evapotranspiration
Monthly Ground Water Discharge to Streamflow
Monthly Watershed Runoff
Monthly Dissolved Nitrogen and Phosphorus Loads in Streamflow
Annual Dissolved Nitrogen and Phosphorus Loads from Each Land Use
Annual Dissolved Nitrogen and Phosphorus Loads from Septic Systems

GWLF PROGRAM

Required Files

Simulations by GWLF require four program modules and three data files on the default drive. The three necessary data files are **WEATHER.DAT**, **TRANSPRT.DAT** and **NUTRIENT.DAT**. The four compiled modules, **GWLF20.EXE**, **TRAN20.EXE**, **NUTR20.EXE**, and **OUTP20.EXE** are run by typing *GWLF20*.

Two daily weather files for Walton, NY are included on the disks. **WALT478.382** is the four year (4/78-3/92) record used for model validation and in Examples 1 and 2. **WALT462.392** is the 30 year (4/62- 3/92) record used in Example 3. Prior to running the programs, the appropriate weather record should be copied to **WEATHER.DAT**.

The final two data files on the disks (**RESULTS.DAT**, and **SUMMARY.DAT**) are output files from Example 1. **GWLF20.BAS**, **TRAN20.BAS**, **NUTR20.BAS**, and **OUTP20.BAS** are the uncompiled, Quick-BASIC files for the modules, and can be used to modify the existing program.

Program Structure

The structure of GWLF is illustrated in Figure 2. Once the program has been activated, the main control page appears on the screen, as shown in DISPLAY 1.This page is the main menu page that leads to the four major options of the program. The selection of a program option provides access to another set of menu pages within the chosen option. After completing an option, the program returns the user to the main menu page for further actions.

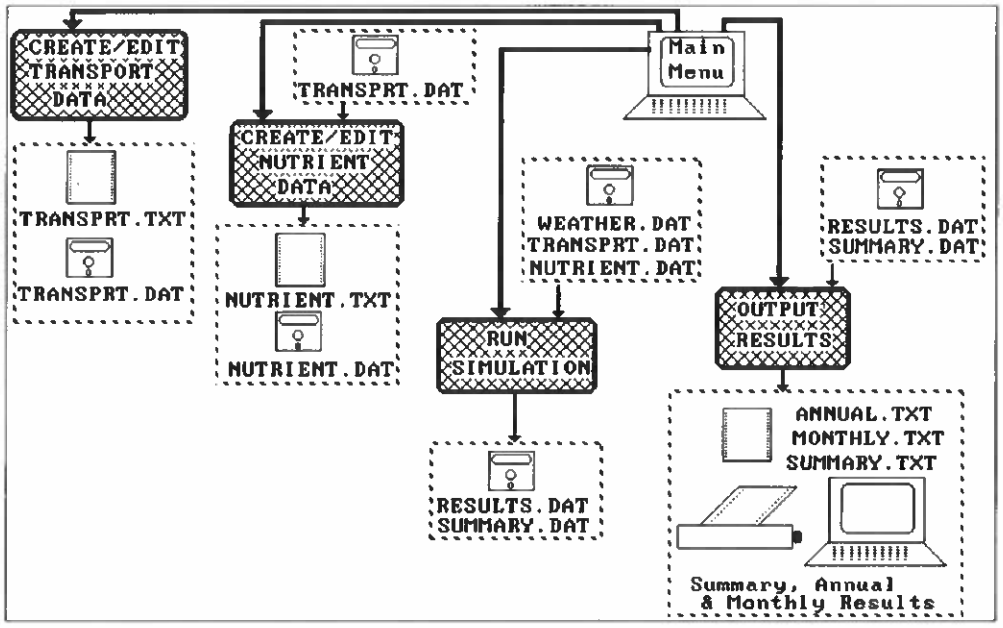


Figure 2. Structure of the GWLF Program.

The selection of the menu options is done by typing the number indicating a choice and then *Enter*. For example, selection of Run simulation is done by typing *3* and *Enter*.

```
Select one of the following :
      1      Create or print TRANSPRT.DAT (Transport parameters)
      2      Create or print NUTRIENT.DAT (nutrient parameters)
               (TRANSPRT.DAT must be created before NUTRIENT.DAT)
      3      Run simulation
      4      Obtain output
      5      Stop (End)
?
```

DISPLAY 1. The Main Menu Page of the GWLF Program.

Transport Data Manipulation

The first step in using the program is to define transport parameters either by creating a new transport data file or modifying an existing one. Options are shown in DISPLAY 2. If the user wishes to create a new transport data file, selection of Create new TRANSPRT.DAT file leads to the input mode. On the other hand, if the user wishes to modify an existing transport data file, selection of Modify existing TRANSPRT.DAT file leads to the modification mode. After input/modification, the user can obtain a hard copy of the transport data by selecting Print TRANSPORT data.

```
Select :
      1       Create new TRANSPRT.DAT file
      2       Modify existing TRANSPRT.DAT file
      3       Print TRANSPORT data
  otherwise   Return
?
```

DISPLAY 2. The Menu Page for Manipulation of Transport Parameters.

Create a New TRANSPRT.DAT File. New values of transport parameters are input one by one in this mode. Values are separated by *Enter* keys. After the number of land uses are input, a table is displayed in the screen to help the user to input data. The line in the bottom of the screen provides on-line help which indicates the expected input data type.

In cases when a serious error has been made, the user can always restart this process by hitting *F1*, then *Enter*. Alternatively, the user may save current input and modify the data in the modification mode.

After all input is complete, the user is asked whether to save or abort the changes. An input of *Y* will overwrite the existing, if any, transport data file.

Modify an Existing TRANSPRT.DAT File. An existing transport data file can be modified in this mode. This is convenient when only minor modification of transport data is needed, e.g., in the case of studying impacts of changes of land use on a watershed.

In this mode, the user is expected to hit *Enter* if no change would be made and *Space bar* if a new value would be issued. The two lines at the bottom of screen provide on-line help.

Print TRANSPORT Data. The user can choose one or more of the three types of print out of transport parameters, namely, to display to screen, print a hard copy, or create a ASCII text file named **TRANSPRT.TXT**. The text file can later be imported to a word processor to generate reports.

Nutrient Data Manipulation

0When nutrient loads are of concern, the nutrient data file (**NUTRIENT.DAT**) must be available before a simulation can be run. This is done by either creating a new nutrient data file or modifying an existing one. Options are shown in DISPLAY 3. Procedures for creating, modifying or printing nutrient data are similar to those described for the transport data. The ASCII text file is **NUTRIENT.TXT**.

```
Select :
      1       Create new NUTRIENT.DAT file
      2       Modify existing NUTRIENT.DAT file
      3       Print NUTRIENT data
      4       Return
?
```

DISPLAY 3. The Menu Page for Manipulation of Nutrient Parameters.

Simulation

Four categories of simulation can be performed, as shown in DISPLAY 4. To simulate streamflow or sediment yield, two data files, **WEATHER.DAT** and **TRANSPRT.DAT** must be in the default directory. An additional data file, **NUTRIENT.DAT**, is required when nutrient loads are simulated.

```
Select program options:
      1     Streamflow simulation only
      2     Streamflow and sediment yield only
      3     Streamflow, sediment yield, and nutrient loads
      4     Streamflow, sediment yield, nutrient loads, and septic systems
  otherwise  Return
?
```

DISPLAY 4. The Menu Page for Simulation Options.

After choosing the type of simulation, the user inputs the title of this specific simulation. This title can be a word, a sentence, or a group of words. The user then decides the length, in years, of the simulation run (not to exceed the number of years of weather data in **WEATHER.DAT**).

Results Output

Simulation output can be reported in three categories, namely, overall means, annual values, and monthly values. Either tables or graphs can be generated, as shown in DISPLAY 5. In producing tables, i.e., when one of the first three options is selected, the user can choose to display it on screen, print it on a printer, or save it as an ASCII text file. When one of the graph options is selected, the user is able to see the graph on the screen. If the computer has suitable printer driver, a hard copy of the graph can be obtained by pressing *Shift-PrtSc* keys together.

```
Select :
      1      Print summary
      2      Print annual results
      3      Print monthly results
      4      Graph summary (average)
      5      Graph annual results
      6      Graph monthly results
             (PrtSc for hard copy, carriage return to continue)
  otherwise  Return
?
```

DISPLAY 5. The Menu Page for Output Generation.

EXAMPLE 1: 4-YEAR STUDY IN WEST BRANCH DELAWARE BASIN

This example is designed to allow the user to become familiar with the operation of the program and the way results are presented. The data set and results are those described in Appendix C for the GWLF validation for the West Branch Delaware River Watershed in New York.

The programs **GWLF20.EXE, TRAN20.EXE, NUTR20.EXE,** and **OUTP20.EXE**, and the data files **WEATHER.DAT, TRANSPRT.DAT,** and **NUTRIENT.DAT** must be on the default drive. The weather file can be obtained by copying **WALT478.382** to **WEATHER.DAT**.

Simulation

To start the program, type *GWLF20* then *Enter*. The first screen is the main menu (see DISPLAY 1). To select Run simulation, type *3* and *Enter*. This will lead to the simulation option menu (see DISPLAY 4). Since nutrient fluxes and septic system loads are of interest, type *4* and *Enter*. This will start the simulation.

The user is then asked to input the title of this simulation. Type *Example 1* and *Enter*. Finally the user is expected to specify the length of the simulation. Type *4*, then *Enter*. This concludes the information required for a simulation run. The input section described above is shown in DISPLAY 6.

```
Select one of the following :
      1     Create or print TRANSPRT.DAT (Transport parameters)
      2     Create or print NUTRIENT.DAT (nutrient parameters)
              (TRANSPRT.DAT must be created before NUTRIENT.DAT)
      3     Run simulation
      4     Obtain output
      5     Stop (End)
? 3

Select program options:
      1     Streamflow simulation only
      2     Streamflow and sediment yield only
      3     Streamflow, sediment yield, and nutrient loads
      4     Streamflow, sediment yield, nutrient loads, and septic systems
  otherwise Return
? 3

TITLE OF SIMULATION? Example 1
LENGTH OF RUN IN YEARS? 4
```

DISPLAY 6. Input Section in Example 1. User Input is Indicated by Italics.

The screen is now switched to graphic mode. During the computation, part of the result will be displayed. This is to provide a sample of the result and to monitor the progress of the simulation. As shown in Figure 3, the line on the top of the screen reports the length of simulation and the current simulated month/year.

The main menu is displayed at the end of the simulation. From here, the user can generate several types of results.

Results Generation

Type *4*, then *Enter* to generate results. For printing out monthly streamflows, sediment yields, and nutrient loads, type *3*, then *Enter*. The user is asked whether to specify the range of the period to be reported. Type *N*, then *Enter* to select the default full period.

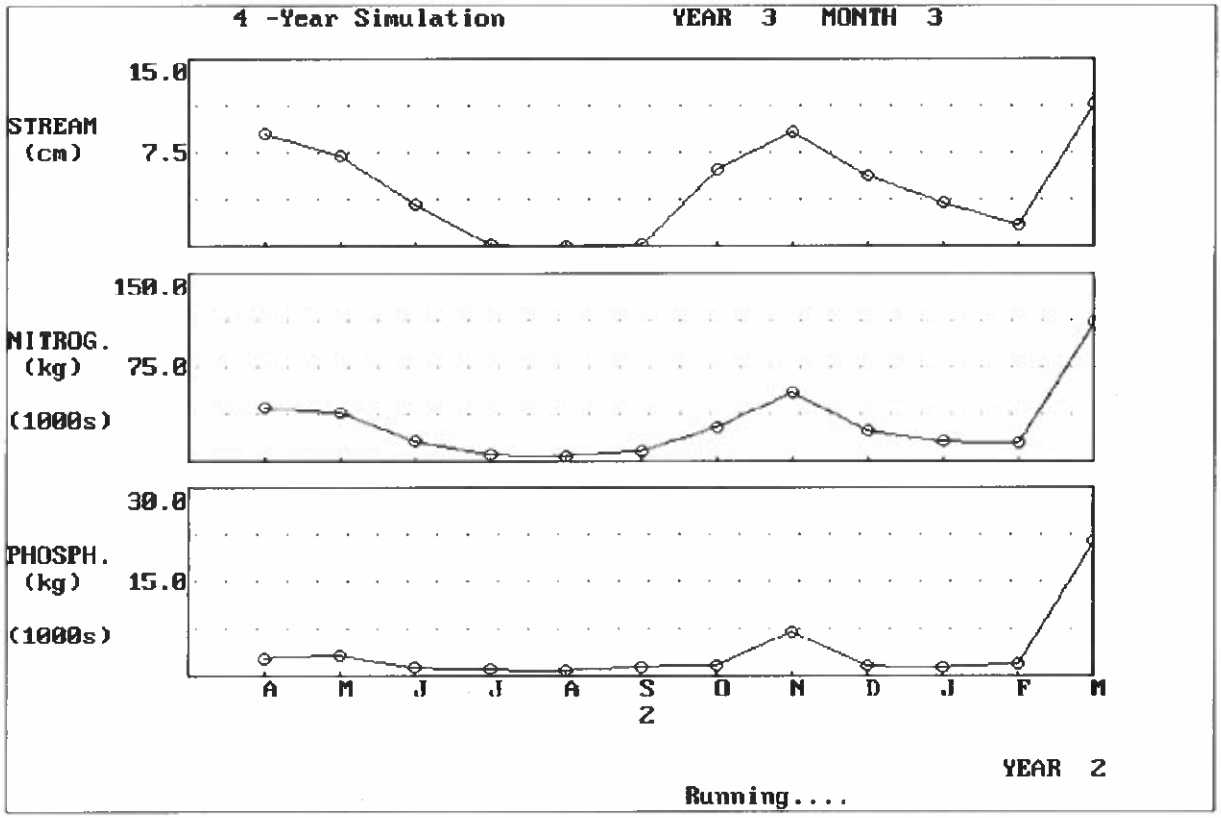


Figure 3. Screen Display during Simulation.

The user decides on the type of output. Type *1*, then *Enter* to print to the screen. The result is displayed in nine screens. After reading a screen, press *Enter* to bring up the next screen. To generate a hard copy, turn on the printer, type *2* and *Enter*. Alternatively, the user can save the result in a text file, **MONTHLY.TXT**. The user can go back to the previous page menu to select another option of results generation by pressing *Enter*. Part of the process described above is shown in DISPLAY 7. To generate graphs of the monthly results, type *6* and *Enter*. This produces graphs such as Figure 4 and Figure 5. The user can call up the main menu again by pressing *Enter* keys. The data input files **TRANSPRT.DAT**, **NUTRIENT.DAT** and **WEATHER.DAT** for this example are listed in Appendix E with the various **.TXT** files that may be generated.

EXAMPLE 2: EFFECTS OF ELIMINATION OF WINTER MANURE SPREADING

In this example, nutrient parameters are modified to investigate effects of winter manure applications. The example involves manipulation of the data file **NUTRIENT.DAT**. If the user wishes to save the original file, it should first be copied to a new file, say **NUTRIENT.EX1**.

Nutrient Parameters Modification

From the main menu, type *2*, *Enter*. This leads to the nutrient data manipulation option. Type *2*, *Enter* to modify **NUTRIENT.DAT** (see DISPLAY 8).

Type *Enter* to accept the original dissolved nutrient concentrations. Repeat this procedure until the cursor is in the line, Number of Land Uses on Which Manure is Spread (see DISPLAY 9), hit *Space-bar*, type *0*, and hit *Enter*.

Accept all the rest of original data by hitting *Enter* key until the end of the file. Type *Y* to save the

changes. This concludes the modification of **NUTRIENT.DAT**.

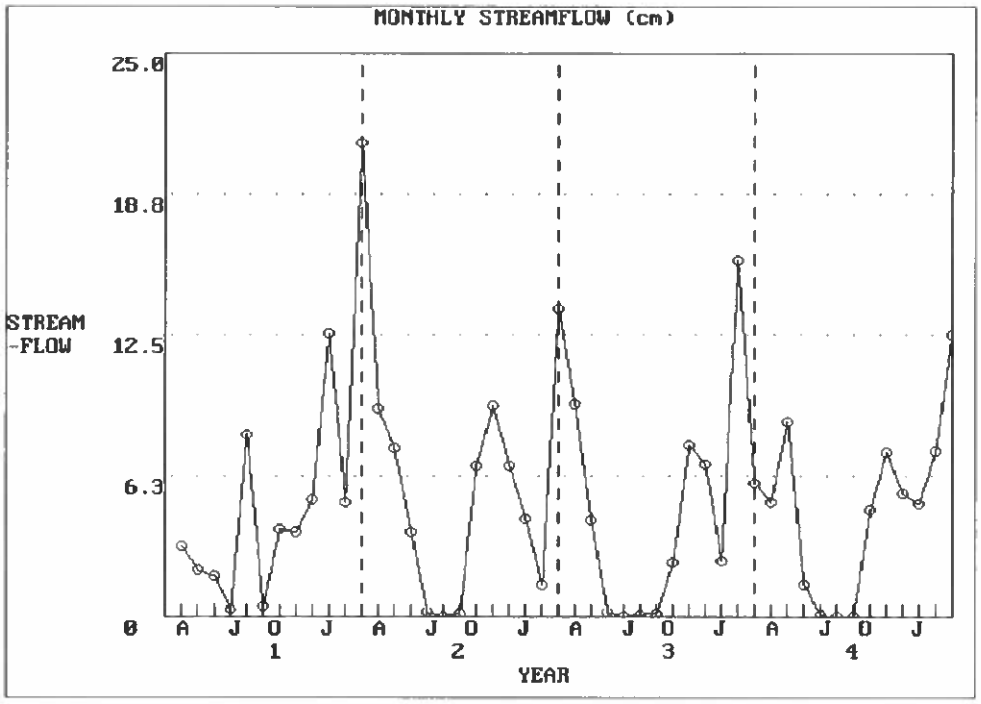


Figure 4. Monthly Streamflows for Example 1.

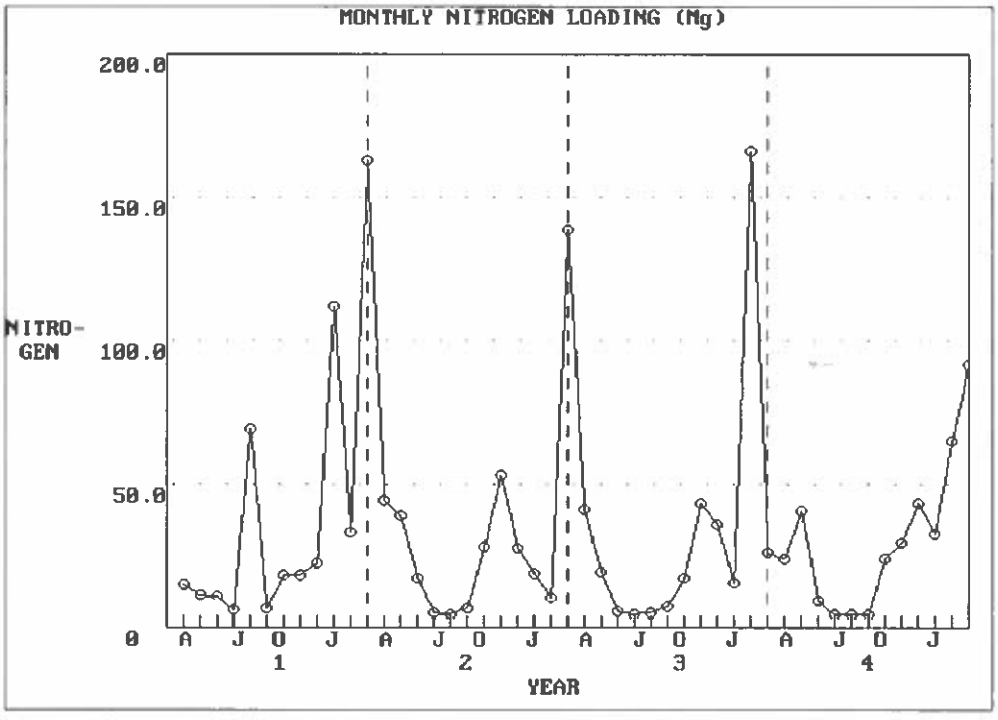


Figure 5. Monthly Nitrogen Loads for Example 1.

The user may print out nutrient data to make sure these changes have been made. To do so, the user selects Print NUTRIENT data in the nutrient data manipulation page (see DISPLAY 3). Then select Print to screen to display the current nutrient parameters.

```
  Select one of the following :
        1       Create or print TRANSPRT.DAT (Transport parameters)
        2       Create or print NUTRIENT.DAT (nutrient parameters)
                  (TRANSPRT.DAT must be created before NUTRIENT.DAT)
        3       Run simulation
        4       Obtain output
        5       Stop (End)
  ? 4

  Select :
        1       Print summary
        2       Print annual results
        3       Print monthly results
        4       Graph summary (average)
        5       Graph annual results
        6       Graph monthly results
                (PrtSc for hard copy, carriage return to continue)
    otherwise   Return
  ? 3
       Want to specify the range of years in output?   ( Type  Y  or  N )
  ? N

  Select : (For printing MONTHLY data)
        1       Print to screen (carriage return to continue)
        2       Print a hard copy (turn on printer first)
        3       Print to a file named MONTHLY.TXT
    otherwise   Return
  ? 1
```

DISPLAY 7. Result Generating Menu in Example 1.

```
  Select one of the following :
        1       Create or print TRANSPRT.DAT (Transport parameters)
        2       Create or print NUTRIENT.DAT (nutrient parameters)
                  (TRANSPRT.DAT must be created before NUTRIENT.DAT)
        3       Run simulation
        4       Obtain output
        5       Stop (End)
  ? 2

  Select :
        1       Create new NUTRIENT.DAT file
        2       Modify existing NUTRIENT.DAT file
        3       Print NUTRIENT data
    otherwise   Return
  ? 2
```

DISPLAY 8. Modification of Nutrient Parameters.

Simulation and Results Generation

Following the procedures described in Example 1, the results of a 3-year simulation are shown in Figure 6.

```
Number of Land Uses on Which Manure is Spread: -1

                                To redo from start, Hit <F1> then <ENTER> key
Hint: Press Space-Bar to Input Value or Enter-Key to Accept Current Value
```

DISPLAY 9. The First Screen for Modifying Nutrient Parameters. The Original Number is 1. Hit the *Space Bar*, Type *0*, and then Hit *Enter* Key to Change this Number to 0.

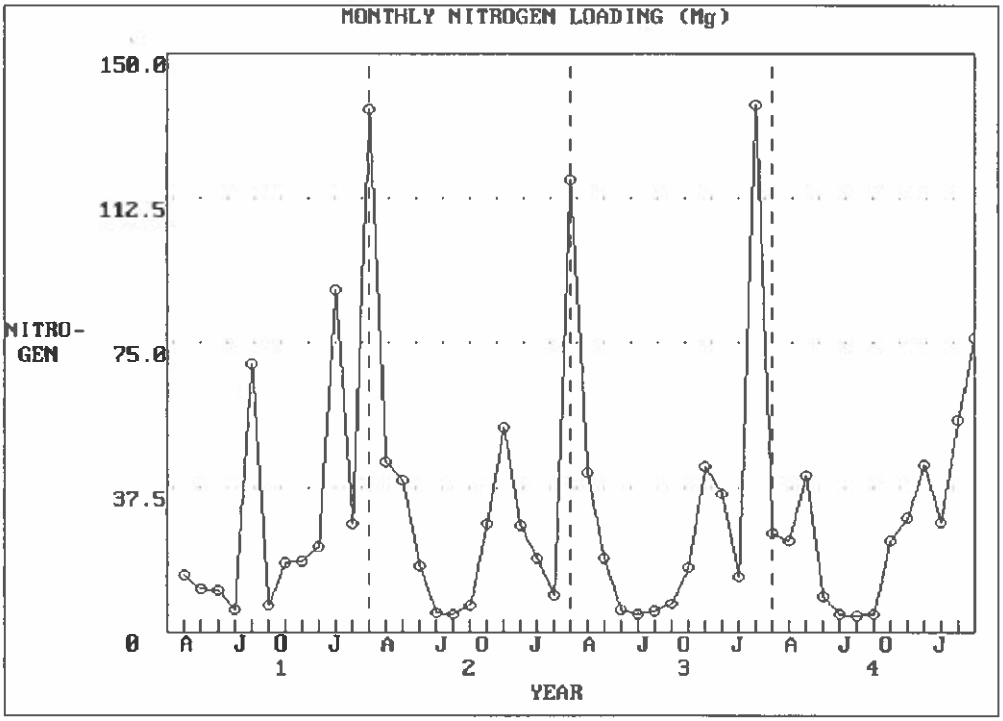


Figure 6. Monthly Nitrogen Loads with no Manure Spreading .

EXAMPLE 3: A 30-YEAR SIMULATION STUDY

In Example 3, a simulation of the West Branch Delaware River Basin is based on a 30-yr (4/62-3/92) weather record given in the file **WALT462.392**.

Simulation and Results Generation

The simulation is run by following procedures as in Example 1 (see DISPLAY 6). Answer LENGTH OF RUN IN YEARS by typing *30* and then *Enter*.

At the end of the computation, the main menu is displayed. From here, the user can generate several types of results by typing *4*, then *Enter*. For a summary of the results, type *1* and *Enter*. To display the summary in screen, type *1* and *Enter*. The summary is displayed in three screens. After reading a screen, press *Enter* to bring up next screen. To generate a hard copy from the printer, turn on the printer, select Print a hard copy. Hit *Enter* to obtain the output option menu.

From the output generation menu (see DISPLAY 5), to obtain a graphical description of the summary, type *4* and then *Enter*. This brings up a screen of options (see DISPLAY 10). Eighteen types of graphs can be generated. For example, to investigate the relative magnitudes of average monthly streamflow, type *5* and *Enter*. This produces the bar chart shown in Figure 7. Similarly, to investigate the nitrogen loads from each source, type *15* and then *Enter*. This generates another bar chart as shown in Figure 8.

```
Select :
    1     Mean Monthly Precipitation
    2     Mean Monthly Evapotranspiration
    3     Mean Monthly Groundwater Flow
    4     Mean Monthly Runoff
    5     Mean Monthly Streamflow
    6     Mean Monthly Erosion
    7     Mean Monthly Sediment
    8     Mean Monthly Dissolved Nitrogen
    9     Mean Monthly Total Nitrogen
   10     Mean Monthly Dissolved Phosphorus
   11     Mean Monthly Total Phosphorus
   12     Mean Annual Runoff from Sources
   13     Mean Annual Erosion from Sources
   14     Mean Annual Dissolved Nitrogen Loads from Sources
   15     Mean Annual Total Nitrogen Loads from Sources
   16     Mean Annual Dissolved Phosphorus Loads from Sources
   17     Mean Annual Total Phosphorus Loads from Sources
   18     Areas of Sources
otherwise Return
?
```

DISPLAY 10. The Options for Plotting Summary

For plotting annual streamflows, sediment yields and nutrient loads, type *5*, then *Enter*. The graphs will be displayed on several screens. For example, Figure 9 shows the predicted annual streamflows.

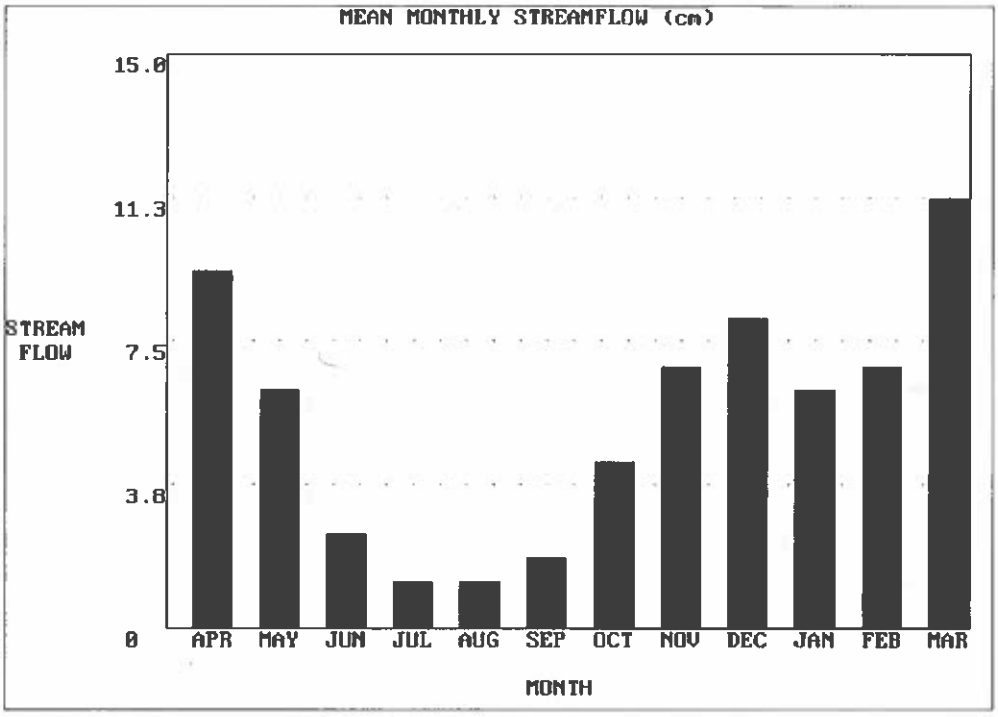


Figure 7. Mean Monthly Streamflows for 30-yr Simulation.

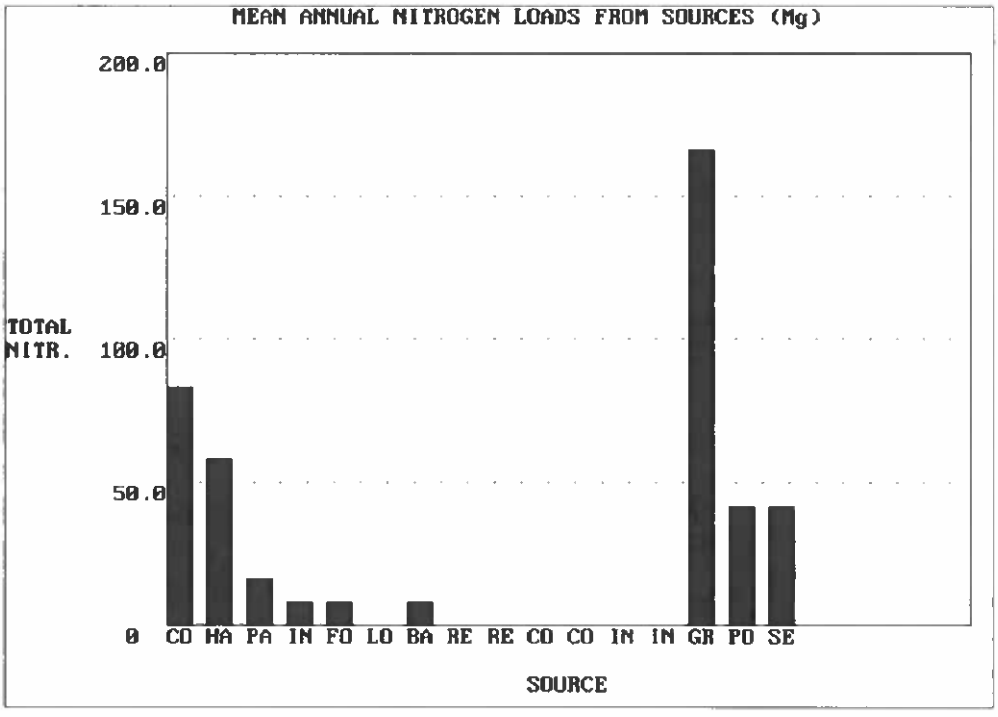


Figure 8. Mean Annual Nitrogen Load from Sources for 30-yr Simulation.

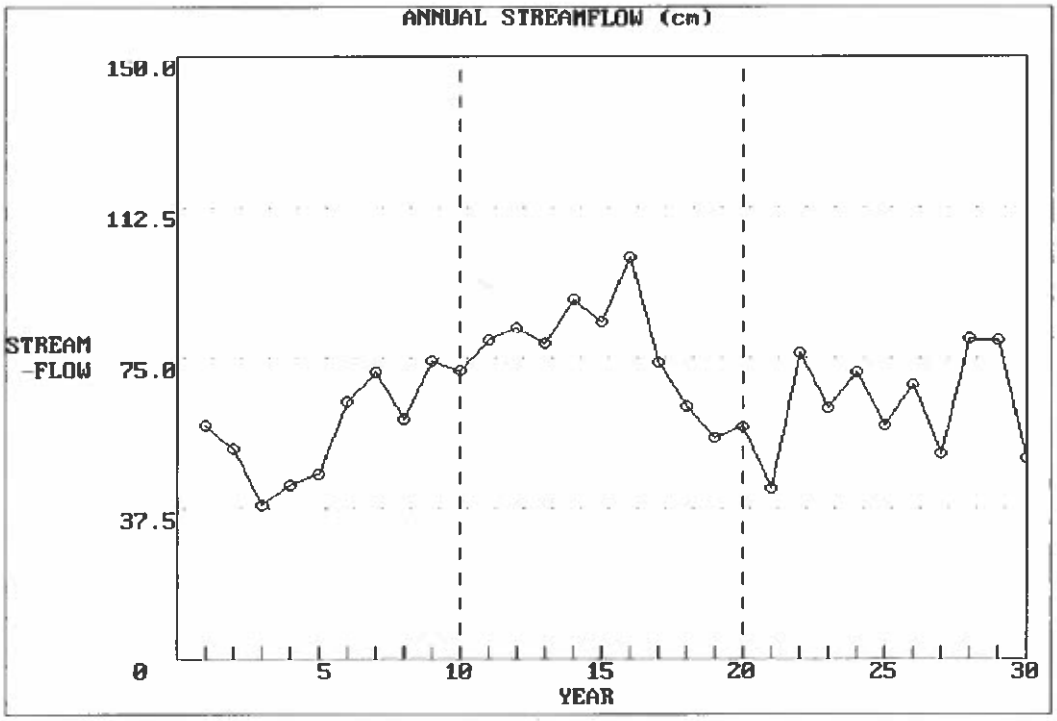


Figure 9. Annual Streamflows for 30-yr Simulation.

APPENDIX A: MATHEMATICAL DESCRIPTION OF GWLF

General Structure

Streamflow nutrient flux contains dissolved and solid phases. Dissolved nutrients are associated with runoff, point sources and groundwater discharges to the stream. Solid-phase nutrients are due to point sources, rural soil erosion or wash off of material from urban surfaces. The GWLF model describes nonpoint sources with a distributed model for runoff, erosion and urban wash off, and a lumped parameter linear reservoir groundwater model. Point sources are added as constant mass loads which are assumed known. Water balances are computed from daily weather data but flow routing is not considered. Hence, daily values are summed to provide monthly estimates of streamflow, sediment and nutrient fluxes (It is assumed that streamflow travel times are much less than one month).

Monthly loads of nitrogen or phosphorus in streamflow in any year are

$$LD_m = DP_m + DR_m + DG_m + DS_m \quad \text{(A-1)}$$

$$LS_m = SP_m + SR_m + SU_m \quad \text{(A-2)}$$

In these equations, LD_m is dissolved nutrient load, LS_m is solid-phase nutrient load, DP_m, DR_m, DG_m and DS_m are point source, rural runoff, groundwater and septic system dissolved nutrient loads, respectively, and SP_m, SR_m and SU_m and are solid-phase point source, rural runoff and urban runoff nutrient loads (kg), respectively, in month m (m = 1,2,...12). Note that the equations assume (i) point source, groundwater and septic system loads are entirely dissolved; and (ii) urban nutrient loads are entirely solid.

Rural Runoff Loads

Rural nutrient loads are transported in runoff water and eroded soil from numerous source areas, each of which is considered uniform with respect to soil and cover.

Dissolved Loads. Dissolved loads from each source area are obtained by multiplying runoff by dissolved concentrations. Monthly loads for the watershed are obtained by summing daily loads over all source areas:

$$LD_m = 0.1 \sum_{k} \sum_{t=1}^{d_m} Cd_k \, Q_{kt} \, AR_k \quad \text{(A-3)}$$

where Cd_k = nutrient concentration in runoff from source area k (mg/l), Q_{kt} = runoff from source area k on day t (cm) and AR_k = area of source area k (ha) and d_m = number of days in month m.

Runoff is computed from daily weather data by the U.S. Soil Conservation Service's Curve Number Equation (Ogrosky & Mockus, 1964):

$$Q_{kt} = \frac{(R_t + M_t - 0.2\, DS_{kt})^2}{R_t + M_t + 0.8\, DS_{kt}} \quad \text{(A-4)}$$

Rainfall R_t (cm) and snowmelt M_t (cm of water) on day t are estimated from daily precipitation and temperature data. Precipitation is assumed to be rain when daily mean air temperature T_t (°C) is above 0 and snow fall otherwise. Snowmelt water is computed by a degree-day equation (Haith, 1985):

$$M_t = 0.45\, T_t, \text{ for } T_t > 0 \quad \text{(A-5)}$$

The detention parameter DS_{kt} (cm) is determined from a curve number CN_{kt} as

$$DS_{kt} = \frac{2540}{CN_{kt}} - 25.4 \qquad \text{(A-6)}$$

Curve numbers are selected as functions of antecedent moisture as described in Haith (1985), and shown in Figure A-1. Curve numbers for antecedent moisture conditions 1 (driest), 2 (average) and 3 (wettest) are $CN1_k$, $CN2_k$ and $CN3_k$ respectively. The actual curve number for day t, CN_{kt}, is selected as a linear function of A_t, 5-day antecedent precipitation (cm):

$$A_t = \sum_{n=t-5}^{t-1} (R_n + M_n) \qquad \text{(A-7)}$$

Recommended values (Ogrosky & Mockus, 1964) for the break points in Figure A-1 are AM1 = 1.3, 3.6 cm, and AM2 = 2.8, 5.3 cm, for dormant and growing seasons, respectively. For snowmelt conditions, it is assumed that the wettest antecedent moisture conditions prevail and hence regardless of A_t, $CN_{kt} = CN3_k$ when $M_t > 0$.

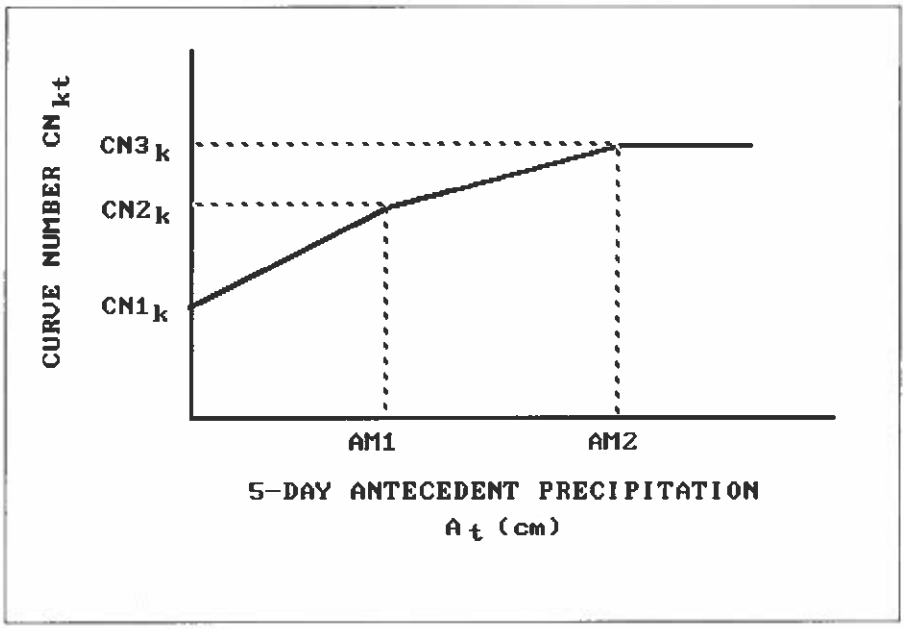


Figure A-1. Curve Number as Function of Antecedent Moisture.

The model requires specification of $CN2_k$. Values for $CN1_k$ and $CN3_k$ are computed from Hawkins (1978) approximations:

$$CN1_k = \frac{CN2_k}{2.334 - 0.01334\ CN2_k} \qquad \text{(A-8)}$$

$$CN3_k = \frac{CN2_k}{\qquad\qquad} \qquad \text{(A-9)}$$

$0.4036 + 0.0059\ CN2_k$

Solid-Phase Loads. Solid-phase rural nutrient loads (SR_m) are given by the product of monthly watershed sediment yields (Y_m, Mg) and average sediment nutrient concentrations (c_s, mg/kg):

$$SR_m = 0.001\ c_s\ Y_m \qquad \text{(A-10)}$$

Monthly sediment yields are determined from the model developed by Haith (1985). The model is based on three principal assumptions: (i) sediment originates from sheet and rill erosion (gully and stream bank erosion are neglected); (ii) sediment transport capacity is proportional to runoff to the 5/3 power (Meyer & Wischmeier, 1969); and (iii) sediment yields are produced from soil which erodes in the current year (no carryover of sediment supply from one year to the next).

Erosion from source area k on day t (Mg) is given by

$$X_{kt} = 0.132\ RE_t\ K_k\ (LS)_k\ C_k\ P_k\ AR_k \qquad \text{(A-11)}$$

in which K_k, $(LS)_k$, C_k and P_k are the standard values for soil erodibility, topographic, cover and management and supporting practice factors as specified for the Universal Soil Loss Equation (Wischmeier & Smith, 1978). RE_t is the rainfall erosivity on day t (MJ-mm/ha-h). The constant 0.132 is a dimensional conversion factor associated with the SI units of rainfall erosivity. Erosivity can be estimated by the deterministic portion of the empirical equation developed by Richardson et al. (1983) and subsequently tested by Haith & Merrill (1987):

$$RE_t = 64.6\ a_t\ R_t^{1.81} \qquad \text{(A-12)}$$

where the coefficient a_t varies with season and geographical location.

The total watershed sediment supply generated in month j (Mg) is

$$SX_j = DR \sum_k \sum_{t=1}^{d_j} X_{kt} \qquad \text{(A-13)}$$

where DR is the watershed sediment delivery ratio. The transport of this sediment from the watershed is based on the transport capacity of runoff during that month. A transport factor TR_j is defined as

$$TR_j = \sum_{t=1}^{d_j} Q_t^{5/3} \qquad \text{(A-14)}$$

The sediment supply SX_j is allocated to months j, j + 1, ... , 12 in proportion to the transport capacity for each month. The total transport capacity for months j, j + 1, ... , 12 is proportional to B_j, where

$$B_j = \sum_{h=j}^{12} TR_h \qquad \text{(A-15)}$$

For each month m, the fraction of available sediment X_j which contributes to Y_m, the monthly sediment yield (Mg), is TR_m/B_j. The total monthly yield is the sum of all contributions from preceding months:

$$Y_m = TR_m \sum_{j=1}^{m} (X_j/B_j) \qquad \text{(A-16)}$$

Urban Runoff

The urban runoff model is based on general accumulation and wash off relationships proposed by Amy et al. (1974) and Sartor & Boyd (1972). The exponential accumulation function was subsequently used in SWMM (Huber & Dickinson, 1988) and the wash off function is used in both SWMM and STORM (Hydrologic Engineering Center, 1977). The mathematical development here follows that of Overton and Meadows (1976).

Nutrients accumulate on urban surfaces over time and are washed off by runoff events. Runoff volumes are computed by equations A-4 through A-7.

If $N_k(t)$ is the accumulated nutrient load on source area (land use) k on day t (kg/ha), then the rate of accumulation during dry periods is

$$\frac{dN_k}{dt} = n_k - \beta N_k \qquad \text{(A-17)}$$

where n_k is a constant accumulation rate (kg/ha-day) and β is a depletion rate constant (day^{-1}). Solving equation A-17, we obtain

$$N_k(t) = N_{k0}\, e^{-\beta t} + (n_k/\beta)(1 - e^{-\beta t}) \qquad \text{(A-18)}$$

in which $N_{k0} = N_k(t)$ at time $t = 0$.

Equation A-18 approaches an asymptotic value $N_{k,max}$:

$$N_{k,max} = \lim_{t \to \infty} N_k(t) = n_k/\beta \qquad \text{(A-19)}$$

Data given in Sartor & Boyd (1972) and shown in Figure A-2 indicates that $N_k(t)$ approaches its maximum value in approximately 12 days. If we conservatively assume that $N_k(t)$ reaches 90% of $N_{k,max}$ in 20 days, then for $N_{k0} = 0$,

$$0.90\,(n_k/\beta) = (n_k/\beta)(1 - e^{-20\beta}), \text{ or } \beta = 0.12$$

Equation A-18 can also be written for a time interval $\Delta t = t_2 - t_1$ as

$$N_k(t_2) = N_k(t_1)\, e^{-0.12\Delta t} + (n_k/0.12)(1 - e^{-0.12\Delta t}) \qquad \text{(A-20)}$$

or, for a time interval of one day,

$$N_{k,t+1} = N_{kt}\, e^{-0.12} + (n_k/0.12)(1 - e^{-0.12}) \qquad \text{(A-21)}$$

where N_{kt} is the nutrient accumulation at the beginning of day t (kg/ha).

Equation A-21 can be modified to include the effects of wash off:

$$N_{k,t+1} = N_{kt}\, e^{-0.12} + (n_k/0.12)(1 - e^{-0.12}) - W_{kt} \qquad \text{(A-22)}$$

in which W_{kt} = runoff nutrient load from land use k on day t(kg/ha).

The runoff load is

$$W_{kt} = w_{kt}\,[N_{kt}\, e^{-0.12} + (n_k/0.12)(1 - e^{-0.12})] \qquad \text{(A-23)}$$

where w_{kt} is the first-order wash off function suggested by Amy et al. (1974):

$$w_{kt} = 1 - e^{-1.81Q_{kt}} \qquad \text{(A-24)}$$

Equation A-24 is based on the assumption that 1.27 cm (0.5 in) of runoff will wash off 90% of accumulated pollutants. Monthly runoff loads of urban nutrients are thus given by

$$SU_m = \sum_k \sum_{t=1}^{d_m} W_{kt} AR_k \qquad \text{(A-25)}$$

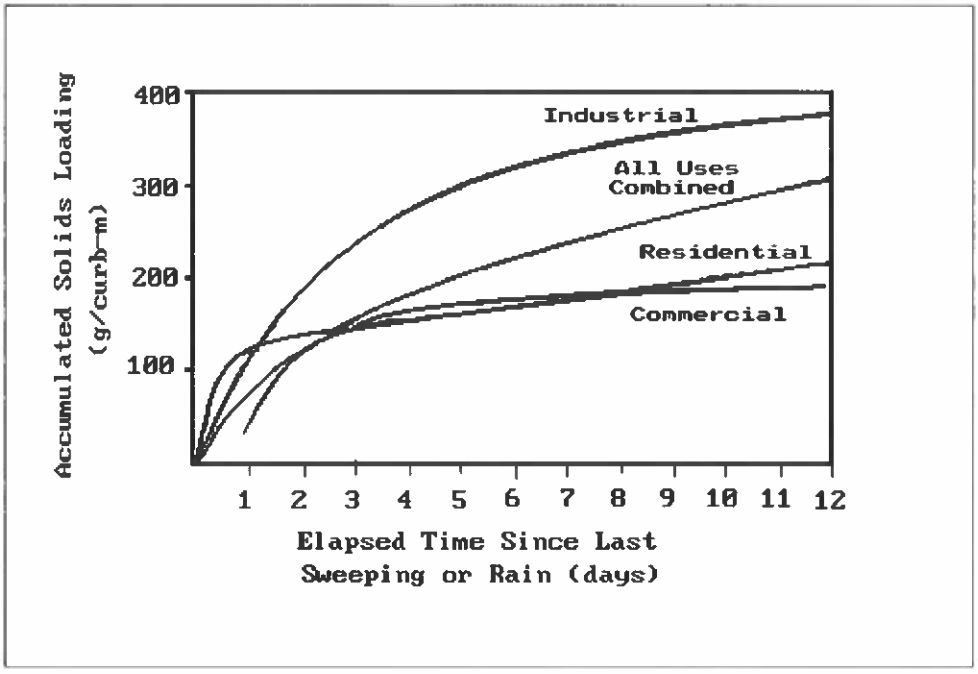


Figure A-2. Accumulation of Pollutants on Urban Surfaces (Sartor & Boyd, 1972; redrawn in Novotny & Chesters, 1981).

Groundwater Sources

The monthly groundwater nutrient load to the stream is

$$DG_m = 0.1\, C_g\, AT \sum_{t=1}^{d_m} G_t \qquad \text{(A-26)}$$

in which C_g = nutrient concentration in groundwater (mg/*l*), AT = watershed area (ha), and G_t = groundwater discharge to the stream on day t (cm).

Groundwater discharge is described by the lumped parameter model shown in Figure A-3. Streamflow consists of total watershed runoff from all source areas plus groundwater discharge from a shallow saturated zone. The division of soil moisture into unsaturated, shallow saturated and deep saturated zones is similar to that used by Haan (1972).

Daily water balances for the unsaturated and shallow saturated zones are

$$U_{t+1} = U_t + R_t + M_t - Q_t - E_t - PC_t \quad \text{(A-27)}$$

$$S_{t+1} = S_t + PC_t - G_t - D_t \quad \text{(A-28)}$$

In these equations, U_t and S_t are the unsaturated and shallow saturated zone soil moistures at the beginning of day t and Q_t, E_t, PC_t, G_t and D_t are watershed runoff, evapotranspiration, percolation into the shallow saturated zone, groundwater discharge to the stream and seepage flow to the deep saturated zone, respectively, on day t (cm).

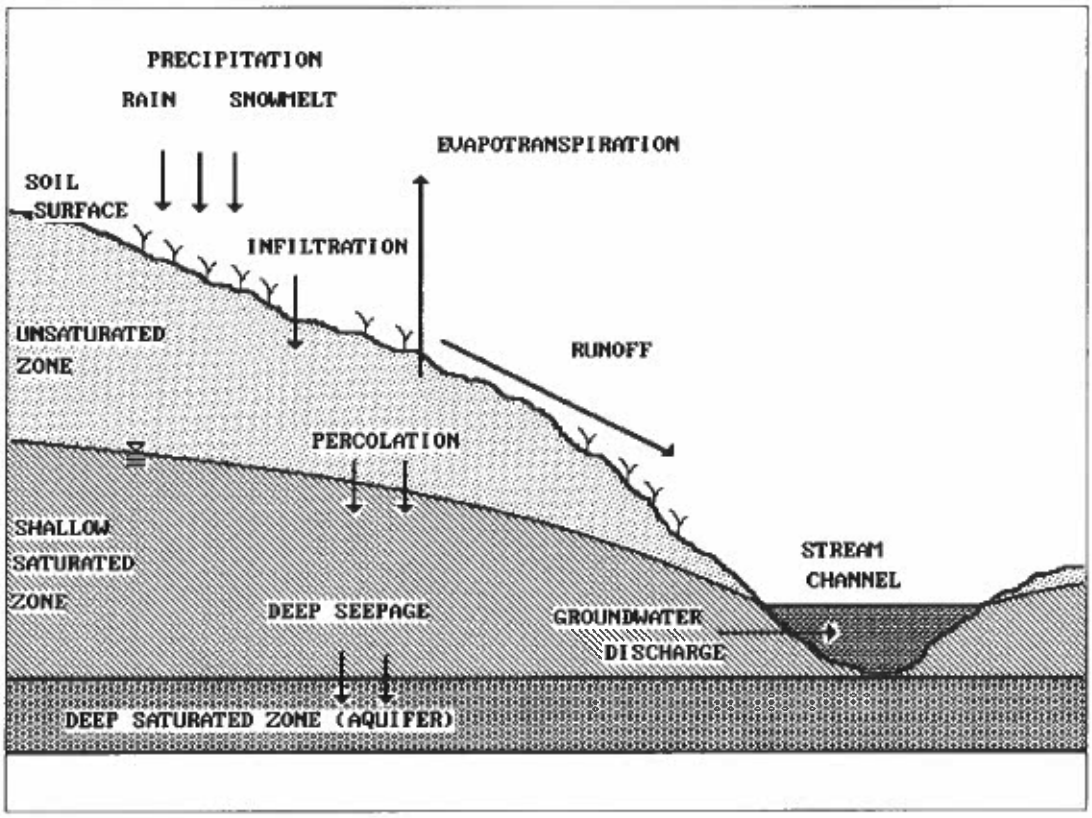


Figure A-3. Lumped Parameter Model for Groundwater Discharge.

Percolation occurs when unsaturated zone water exceeds available soil water capacity U^* (cm):

$$PC_t = \text{Max}\,(0;\ U_t + R_t + M_t - Q_t - E_t - U^*) \quad \text{(A-29)}$$

Evapotranspiration is limited by available moisture in the unsaturated zone:

$$E_t = \text{Min}\,(CV_t\ PE_t;\ U_t + R_t + M_t - Q_t) \quad \text{(A-30)}$$

for which CV_t is a cover coefficient and PE_t is potential evapotranspiration (cm) as given by Hamon (1961):

$$PE_t = \frac{0.021\ H_t^2\ e_t)}{T_t + 273} \quad \text{(A-31)}$$

In this equation, H_t is the number of daylight hours per day during the month containing day t, e_t is the saturated water vapor pressure in millibars on day t and T_t is the temperature on day t (°C). When $T_t \leq 0$, PE_t is set to zero. Saturated vapor pressure can be approximated as in (Bosen, 1960):

$$e_t = 33.8639\ [\ (0.00738\ T_t + 0.8072)^8 - 0.000019\ (1.8\ T_t + 48) + 0.001316\ ]\ ,\ T_t \geq 0 \qquad \text{(A-32)}$$

As in Haan (1972), the shallow unsaturated zone is modeled as a simple linear reservoir. Groundwater discharge and deep seepage are

$$G_t = r\ S_t \qquad \text{(A-33)}$$

and

$$D_t = s\ S_t \qquad \text{(A-34)}$$

where r and s are groundwater recession and seepage constants, respectively (day^{-1}).

Septic (On-site Wastewater Disposal) Systems

The septic system component of GWLF is based on the model developed by Mandel (1993). For purposes of assessing watershed water quality impacts, septic systems loads can be divided into four types:

$$DS_m = DS_{1m} + DS_{2m} + DS_{3m} + DS_{4m} \qquad \text{(A-35)}$$

where DS_{1m}, DS_{2m}, DS_{3m} and DS_{4m} are the dissolved nutrient load to streamflow from normal, short-circuited, ponded and direct discharge systems, respectively in month m (kg). These loads are computed from per capita daily effluent loads and monthly populations served a_{jm} for each system (j =1,2,3,4).

Normal Systems. A normal septic system is a system whose construction and operation conforms to recommended procedures such as those suggested by the EPA design manual for on-site wastewater disposal systems (U. S. Environmental Protection Agency, 1980). Effluents from such systems infiltrate into the soil and enter the shallow saturated zone. Effluent nitrogen is converted to nitrate, and except for removal by plant uptake, the nitrogen is transported to the stream by groundwater discharge. Conversely, phosphates in the effluent are adsorbed and retained by the soil and hence normal systems provide no phosphorus loads to streamflow. The nitrogen load to groundwater from normal systems in month m (kg) is

$$SL_{1m} = 0.001\ a_{1m}\ d_m\ (e - u_m) \qquad \text{(A-36)}$$

in which e = per capita daily nutrient load in septic tank effluent (g/day) and u_m = per capita daily nutrient uptake by plants in month m (g/day).

Normal systems are generally some distance from streams and their effluent mixes with other groundwater. Monthly nutrient loads are thus proportional to groundwater discharge to the stream. The portion of the annual load delivered in month m is equivalent to the portion of annual groundwater discharge which occurs in that month. Thus the load in month m of any year is

$$DS_{1m} = \frac{GR_m \sum_{m=1}^{12} SL_{1m}}{\sum_{m=1}^{12} GR_m} \qquad \text{(A-37)}$$

where GR_m = total groundwater discharge to streamflow in month m (cm), obtained by summing the daily values G_t for the month. Equation A-37 applies only for nitrogen. In the case of phosphorus, $DS_{1m} = 0$.

Short-Circuited Systems. These systems are located close enough to surface waters (< 15 m) so that negligible adsorption of phosphorus takes place. The only nutrient removal mechanism is plant uptake, and the watershed load for both nitrogen and phosphorus is

$$DS_{2m} = 0.001\ a_{2m}\ d_m\ (e - u_m) \qquad \text{(A-38)}$$

Ponded Systems. These systems exhibit hydraulic failure of the tank's absorption field and resulting surfacing of the effluent. Unless the surfaced effluent freezes, ponding systems deliver their nutrient loads to surface waters in the same month that they are generated through overland flow. If the temperature is below freezing, the surfacing effluent is assumed to freeze in a thin layer at the ground surface. The accumulated frozen effluent melts when the snowpack disappears and the temperature is above freezing. The monthly nutrient load is

$$DS_{3m} = 0.001 \sum_{t=1}^{d_m} PN_t \qquad \text{(A-39)}$$

where PN_t = watershed nutrient load in runoff from ponded systems on day t (g). Nutrient accumulation under freezing conditions is

$$FN_{t+1} = \begin{cases} FN_t + a_{3m}\ e\ , & SN_t > 0 \text{ or } T_t \le 0 \\ 0\ , & \text{otherwise} \end{cases} \qquad \text{(A-40)}$$

where FN_t = frozen nutrient accumulation in ponded systems at the beginning of day t (g). The runoff load is thus

$$PN_t = \begin{cases} a_{3m}\ e + FN_t - u_m\ , & SN_t = 0 \text{ and } T_t > 0 \\ 0\ , & \text{otherwise} \end{cases} \qquad \text{(A-41)}$$

Direct Discharge Systems. These illegal systems discharge septic tank effluent directly into surface waters. Thus,

$$DS_{4m} = 0.001\ a_{4m}\ d_m\ e \qquad \text{(A-42)}$$

APPENDIX B: DATA SOURCES & PARAMETER ESTIMATION

Four types of information must be assembled for GWLF model runs. Land use data consists of the areas of the various rural and urban runoff sources. Required weather data are daily temperature (°C) and precipitation (cm) records for the simulation period. Transport parameters are the necessary hydrologic, erosion and sediment data and nutrient parameters are the various nitrogen and phosphorus data required for loading calculations. This appendix discusses general procedures for estimation of these parameters. Examples of parameter estimation are provided in Appendix C.

Land Use Data

Runoff source areas are identified from land use maps, soil surveys and aerial or satellite photography (Haith & Tubbs, 1981; Delwiche & Haith, 1983). In principle, each combination of soil, surface cover and management must be designated. For example, each corn field in the watershed can be considered a source area, and its area determined and estimates made for runoff curve number and soil erodibility and topographic, cover and supporting practice factors. In practice, these fields can often be aggregated, as in Appendix C into one "corn" source area with area-weighted parameters. Each urban land use is broken down into impervious and pervious areas. The former are solid surfaces such as streets, driveways, parking lots and roofs.

Weather Data

Daily precipitation and temperature data are obtained from meteorological records and assembled in the data file **WEATHER.DAT**. An example of this file is given in Appendix D. Weather data must be organized in "weather years" which are consistent with model assumptions. Both the groundwater and sediment portions of GWLF require that simulated years begin at a time when soil moisture conditions are known and runoff events have "flushed" the watershed of the previous year's accumulated sediment. In the eastern U.S. this generally corresponds to early spring and hence in such locations an April - March weather year is appropriate.

Transport Parameters

A sample set of hydrologic, erosion and sediment parameters required for the data file **TRANSPRT.DAT** is given in Appendix D.

Runoff Curve Numbers. Runoff curve numbers for rural and urban land uses have been assembled in the U.S. Soil Conservation Service's Technical Release No. 55, 2nd edition (Soil Conservation Service, 1986). These curve numbers are based on the soil hydrologic groups given in Table B-1. Curve numbers for average antecedent moisture conditions ($CN2_k$) are listed in Tables B-2 through B-5. Barnyard curve numbers are given by Overcash & Phillips (1978) as $CN2_k$ = 90, 98 and 100 for earthen areas, concrete pads and roof areas draining into the barnyard, respectively.

Evapotranspiration Cover Coefficients. Estimation of evapotranspiration cover coefficients for watershed studies is problematic. Cover coefficients may be determined from published seasonal values such as those given in Tables B-6 and B-7. However, their use often requires estimates of crop development (planting dates, time to maturity, etc.) which may not be available. Moreover, a single set of consistent values is seldom available for all of a watershed's land uses.

Soil Hydrologic Group	Description
A	Low runoff potential and high infiltration rates even when thoroughly wetted. Chiefly deep, well to excessively drained sands or gravels. High rate of water transmission (> 0.75 cm/hr).
B	Moderate infiltration rates when thoroughly wetted. Chiefly moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. Moderate rate of water transmission (0.40-0.75 cm/hr).
C	Low infiltration rates when thoroughly wetted. Chiefly soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. Low rate of water transmission (0.15-0.40 cm/hr).
D	High runoff potential. Very low infiltration rates when thoroughly wetted. Chiefly clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, or shallow soils over nearly impervious material. Very low rate of water transmission (0-0.15 cm/hr).
Disturbed Soils (Major altering of soil profile by construction, development):	
A	Sand, loamy sand, sandy loam.
B	Silt loam, loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, clay.

Table B-1. Descriptions of Soil Hydrologic Groups (Soil Conservation Service, 1986)

A simplified procedure can be developed, however, based on a few general observations:

1. Cover coefficients should in principle vary between 0 and 1.

2. Cover coefficients will approach their maximum value when plants have developed full foliage.

3. Because evapotranspiration measures both transpiration and evaporation of soil water, the lower limit for cover coefficients will be greater than zero. This lower limit essentially represents a situation without any plant cover.

4. The protection of soil by impervious surfaces prevents evapotranspiration.

The cover coefficients given for annual crops in Table B-6 fall to approximately 0.3 before planting and after harvest. Similarly, cover coefficients for forests reach minimum values of 0.2 to 0.3 when leaf area indices approach zero. This suggests that monthly cover coefficients for can be given the value 0.3 when foliage is absent and 1.0 otherwise. Perennial crops, such as grass, hay, meadow, and pasture, crops grown in flooded soil, such as rice, and conifers can be given a cover coefficient of 1.0 year round.

Land Use/Cover		Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Fallow	Bare Soil	-		77	86	91	94
Crop residue cover (CR)		Poor[a/]	76	85	90	93	
		Good		74	83	88	90
Row Crops	Straight row (SR)	Poor		72	81	88	91
		Good		67	78	85	89
	SR + CR	Poor		71	80	87	90
		Good		64	75	82	85
	Contoured (C)	Poor		70	79	84	88
		Good		65	75	82	86
	C + CR	Poor		69	78	83	87
		Good		64	74	81	85
	Contoured & terraced (C&T)	Poor		66	74	80	82
		Good		62	71	78	81
	C&T + CR	Poor		65	73	79	81
		Good		61	70	77	80
Small Grains	SR	Poor		65	76	84	88
		Good		63	75	83	87
	SR + CR	Poor		64	75	83	86
		Good		60	72	80	84
	C	Poor		63	74	82	85
		Good		61	73	81	84
	C + CR	Poor		62	73	81	84
		Good		60	72	80	83
	C&T	Poor		61	72	79	82
		Good		59	70	78	81
	C&T + CR	Poor		60	71	78	81
		Good		58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor		66	77	85	89
		Good		58	72	81	85
	C	Poor		64	75	83	85
		Good		55	69	78	83
	C&T	Poor		63	73	80	83
		Good		51	67	76	80

[a/] Hydrologic condition is based on a combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good $ 20%), and (e) degree of surface roughness.

Table B-2. Runoff Curve Numbers (Antecedent Moisture Condition II) for Cultivated Agricultural Land (Soil Conservation Service, 1986).

Land Use/Cover	Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Pasture, grassland or range - continuous forage for grazing	Poor[a/]	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow - continuous grass, protected from grazing, generally mowed for hay	-	30	58	71	78
Brush - brush/weeds/grass mixture with brush the major element	Poor[b/]	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods/grass combination (orchard or tree farm)[c/]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor[/d]	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads - buildings, lanes, driveways and surrounding lots	-	59	74	82	86

[a/] Poor: < 50% ground cover or heavily grazed with no mulch; Fair: 50 to 75% ground cover and not heavily grazed; Good: > 75% ground cover and lightly or only occasionally grazed.

[b/] Poor: < 50% ground cover; Fair: 50 to 75% ground cover; Good: > 75% ground cover.

[c/] Estimated as 50% woods, 50% pasture.

[d/] Poor: forest litter, small trees and brush are destroyed by heavy grazing or regular burning; Fair: woods are grazed but not burned and some forest litter covers the soil; Good: Woods are protected from grazing and litter and brush adequately cover the soil.

Table B-3. Runoff Curve Numbers (Antecedent Moisture Condition II) for other Rural Land (Soil Conservation Service, 1986).

Land Use/Cover	Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Herbaceous - grass, weeds & low-growing brush; brush the minor component	Poor[a/]	-	80	87	93
	Fair	-	71	81	89
	Good	-	62	74	85
Oak/aspen - oak brush, aspen, mountain mahogany, bitter brush, maple and other brush	Poor	-	66	74	79
	Fair	-	48	57	63
	Good	-	30	41	48
Pinyon/juniper - pinyon, juniper or both; grass understory	Poor	-	75	85	89
	Fair	-	58	73	80
	Good	-	41	61	71
Sagebrush with grass understory	Poor	-	67	80	85
	Fair	-	51	63	70
	Good	-	35	47	55
Desert scrub - saltbush, greasewood, creosotebrush, blackbrush, bursage, palo verde, mesquite and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[a/] Poor: < 30% ground cover (litter, grass and brush overstory); Fair: 30 to 70% ground cover; Good: > 70% ground cover.

Table B-4. Runoff Curve Numbers (Antecedent Moisture Condition II) for Arid and Semiarid Rangelands (Soil Conservation Service, 1986).

Land Use	Soil Hydrologic Group A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.):				
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50-75%)	49	69	79	84
Good condition (grass cover > 75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc.)	98	98	98	98
Streets and roads:				
Paved with curbs & storm sewers	98	98	98	98
Paved with open ditches	83	89	92	93
Gravel	76	85	89	91
Dirt	72	82	87	89
Western desert urban areas:				
Natural desert landscaping (pervious areas, only)	63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1-2 in sand or gravel mulch and basin borders)	96	96	96	96

Table B-5. Runoff Curve Numbers (Antecedent Moisture Condition II) for Urban Areas (Soil Conservation Service, 1986).

Crop	% of Growing Season 0	10	20	30	40	50	60	70	80	90	100

Field corn	0.45	0.51	0.58	0.66	0.75	0.85	0.96	1.08	1.20	1.08	0.70
Grain sorghum	0.30	0.40	0.65	0.90	1.10	1.20	1.10	0.95	0.80	0.65	0.50
Winter wheat	1.08	1.19	1.29	1.35	1.40	1.38	1.36	1.23	1.10	0.75	0.40
Cotton	0.40	0.45	0.56	0.76	1.00	1.14	1.19	1.11	0.83	0.58	0.40
Sugar beets	0.30	0.35	0.41	0.56	0.73	0.90	1.08	1.26	1.44	1.30	1.10
Cantaloupe	0.30	0.30	0.32	0.35	0.46	0.70	1.05	1.22	1.13	0.82	0.44
Potatoes	0.30	0.40	0.62	0.87	1.06	1.24	1.40	1.50	1.50	1.40	1.26
Papago peas	0.30	0.40	0.66	0.89	1.04	1.16	1.26	1.25	0.63	0.28	0.16
Beans	0.30	0.35	0.58	1.05	1.07	0.94	0.80	0.66	0.53	0.43	0.36
Rice	1.00	1.06	1.13	1.24	1.38	1.55	1.58	1.57	1.47	1.27	1.00

Table B-6. Evapotranspiration Cover Coefficients for Annual Crops - Measured as Ratio of Evapotranspiration to Lake Evaporation (Davis & Sorensen, 1969; cited in Novotny & Chesters, 1981).

	Alfalfa	Pasture	Grapes	Citrus Orchards	Deciduous Orchards	Sugarcane
Jan	0.83	1.16	-	0.58	-	0.65
Feb	0.90	1.23	-	0.53	-	0.50
Mar	0.96	1.19	0.15	0.65	-	0.80
Apr	1.02	1.09	0.50	0.74	0.60	1.17
May	1.08	0.95	0.80	0.73	0.80	1.21
June	1.14	0.83	0.70	0.70	0.90	1.22
July	1.20	0.79	0.45	0.81	0.90	1.23
Aug	1.25	0.80	-	0.96	0.80	1.24
Sept	1.22	0.91	-	1.08	0.50	1.26
Oct	1.18	0.91	-	1.03	0.20	1.27
Nov	1.12	0.83	-	0.82	0.20	1.28
Dec	0.86	0.69	-	0.65	-	0.80

Table B-7. Evapotranspiration Cover Coefficients for Perennial Crops - Measured as Ratio of Evapotranspiration to Lake Evaporation (Davis & Sorensen, 1969; cited in Novotny & Chesters, 1981).

In urban areas, ground cover is a mixture of trees and grass. It follows that cover factors for pervious areas are weighted averages of the perennial crop, hardwood, and softwood cover factors. It may be difficult to determine the relative fractions of urban areas with these covers. Since these covers would have different values only during dormant seasons, it is reasonable to assume a constant month value of 1.0 for urban pervious surfaces and zero for impervious surfaces.

These approximate cover coefficients are given in Table B-8. Table B-9 list mean monthly values of daylight hours (H_l) for use in Equation A-31.

Cover	Dormant Season	Growing Season
Annual crops (foliage only in growing season)	0.3	1.0
Perennial crops (year-round foliage: grass, pasture, meadow, etc.)	1.0	1.0

Saturated crops (rice)	1.0	1.0
Hardwood (deciduous) forests & orchards	0.3	1.0
Softwood (conifer) forests & orchards	1.0	1.0
Disturbed areas & bare soil (barn yards, fallow, logging trails, construction and mining)	0.3	0.3
Urban areas (I = impervious fraction)	1 - I	1 - I

Table B-8. Approximate Values for Evapotranspiration Cover Coefficients.

	Latitude North (E)						
	48	46	44	42	40	38	36
	(---------- hr/day ----------)						
Jan	8.7	8.9	9.2	9.3	9.5	9.7	9.9
Feb	10.0	10.2	10.3	10.4	10.5	10.6	10.7
Mar	11.7	11.7	11.7	11.7	11.8	11.8	11.8
Apr	13.4	13.3	13.2	13.1	13.0	13.0	12.9
May	14.9	14.7	14.5	14.3	14.1	14.0	13.8
Jun	15.7	15.4	15.2	15.0	14.7	14.5	14.3
Jul	15.3	15.0	14.8	14.6	14.4	14.3	14.1
Aug	14.0	13.8	13.7	13.6	13.6	13.4	13.3
Sep	12.3	12.3	12.3	12.3	12.2	12.2	12.2
Oct	10.6	10.7	10.8	10.9	11.0	11.0	11.1
Nov	9.1	9.3	9.5	9.7	9.8	10.0	10.1
Dec	8.3	8.5	8.8	9.0	9.2	9.4	9.6
	34	32	30	28	26	24	
Jan	10.0	10.2	10.3	10.5	10.6	10.7	
Feb	10.8	10.9	11.0	11.1	11.1	11.2	
Mar	11.8	11.8	11.8	11.8	11.8	11.9	
Apr	12.8	12.8	12.7	12.7	12.6	12.6	
May	13.7	13.6	13.5	13.4	13.2	13.1	
Jun	14.2	14.0	13.9	13.7	13.6	13.4	
Jul	14.0	13.8	13.7	13.5	13.4	13.3	
Aug	13.2	13.3	13.0	13.0	12.9	12.8	
Sep	12.2	12.2	12.2	12.1	12.1	12.1	
Oct	11.2	11.2	11.3	11.3	11.4	11.4	
Nov	10.2	10.4	10.5	10.6	10.7	10.9	
Dec	9.8	10.0	10.1	10.3	10.4	10.6	

Table B-9. Mean Daylight Hours (Mills et al., 1985).

Groundwater. The groundwater portion of GWLF requires estimates of available unsaturated zone available soil moisture capacity U^*, recession constant r and seepage constant s.

In principle, U^* is equivalent to a mean watershed maximum rooting depth multiplied by a mean volumetric soil available water capacity. The latter also requires determination of a mean unsaturated zone depth, and this is probably impractical for most watershed studies. A default value of 10 cm can be assumed for pervious areas, corresponding to a 100 cm rooting depth and a 0.1 cm/cm volumetric available water

capacity. These values appear typical for a wide range of plants (Jensen et al., 1989; U.S. Forest Service, 1980) and soils (Rawls et al., 1982).

Estimates of the recession constant r can be estimated from streamflow records by standard hydrograph separation techniques (Chow, 1964). During a period of hydrograph recession, the rate of change in shallow saturated zone water S(t) (cm) is given by the linear reservoir relationship

$$\frac{dS}{dt} = -rS \qquad \text{(B-1)}$$

or,

$$S(t) = S(0)\, e^{-rt} \qquad \text{(B-2)}$$

where S(0) is the shallow saturated zone moisture at t = 0. Groundwater discharge to the stream G(t) (cm) at time t is

$$G(t) = r\,S(t) = r\,S(0)\, e^{-rt} \qquad \text{(B-3)}$$

During periods of streamflow recession, it is assumed that runoff is negligible, and hence streamflow F(t) (cm) consists of groundwater discharge given by Equation B-3; i.e., F(t) = G(t). A recession constant can be estimated from two streamflows $F(t_1)$, $F(t_2)$ measured on days t_1 and t_2 ($t_2 > t_1$) during the hydrograph recession. The ratio $F(t_1)/F(t_2)$ is

$$\frac{F(t_1)}{F(t_2)} = \frac{r\,S(0)\, e^{-rt_1}}{r\,S(0)\, e^{-rt_2}} = e^{r(t_2 - t_1)} \qquad \text{(B-4)}$$

The recession constant is thus given by

$$r = \frac{\ln [F(t_1)/F(t_2)]}{t_2 - t_1} \qquad \text{(B-5)}$$

Recession constants are measured for a number of hydrographs and an average value is used for the simulations. Typical values range from 0.01 to 0.2

No standard techniques are available for estimating the rate constant for deep seepage loss (s). The most conservative approach is to assume that s = 0 (all precipitation exits the watershed in evapotranspiration or streamflow). Otherwise the constant must be determined by calibration.

Erosion and Sediment. The factors K_k, $(LS)_k$, C_k and P_k for the Universal Soil Loss Equation must be specified as the product $K_k\,(LS)_k\,C_k\,P_k$ for each rural runoff source area. Values K_k, C_k and P_k are given for a range of soils and conditions in Tables B-10 - B-13. More complete sets of values are provided in Mills et al. (1985) and Wischmeier & Smith (1978). The $(LS)_k$ factor is calculated for each source area k as in Wischmeier & Smith (1978):

$$LS = (0.045 x_k)^b\,(65.41 \sin^2 \theta_k + 4.56 \sin \theta_k + 0.065) \qquad \text{(B-6)}$$

$$\theta_k = \tan^{-1}(ps_k/100) \qquad \text{(B-7)}$$

in which x_k = slope length (m) and ps_k = per cent slope. The exponent in Equation B-6 is given by b = 0.5 for ps_k $ 5, b = 0.4 for $5 < ps_k < 3$, b = 0.3 for $3 \le ps_k \le 1$, and b = 0.2 for $ps_k < 1$ (Wischmeier & Smith, 1978).

The rainfall erosivity coefficient a_t for Equation A-12 can be estimated using methods developed by Selker et al. (1990). General values for the rainfall erosivity zones shown in Figure B-1 are given in Table B-14. Watershed sediment delivery ratios are most commonly obtained from the area-based relationship shown in

Figure B-2.

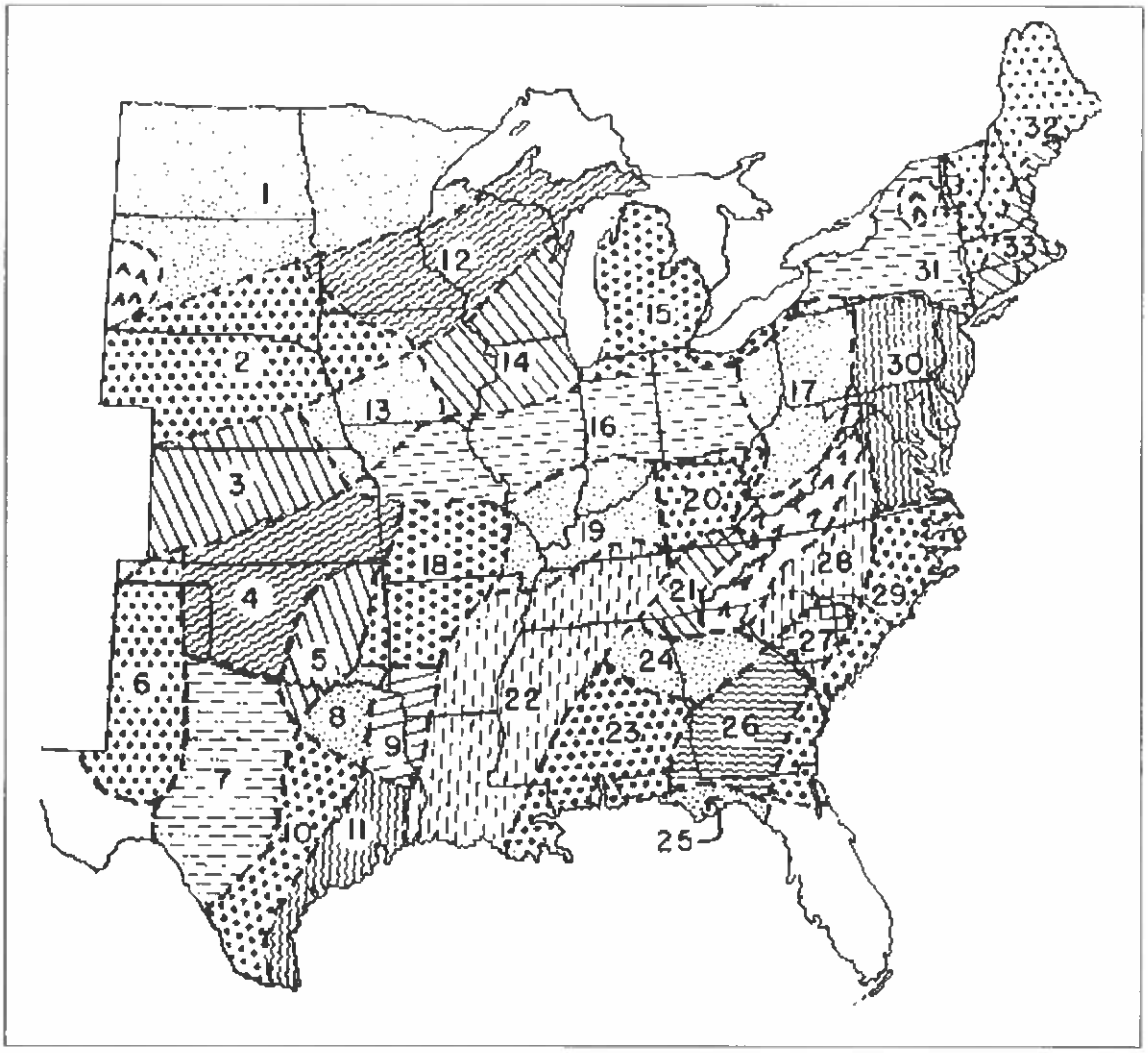


Figure B-1. Rainfall Erosivity Zones in Eastern U.S. (Wischmeier & Smith, 1978).

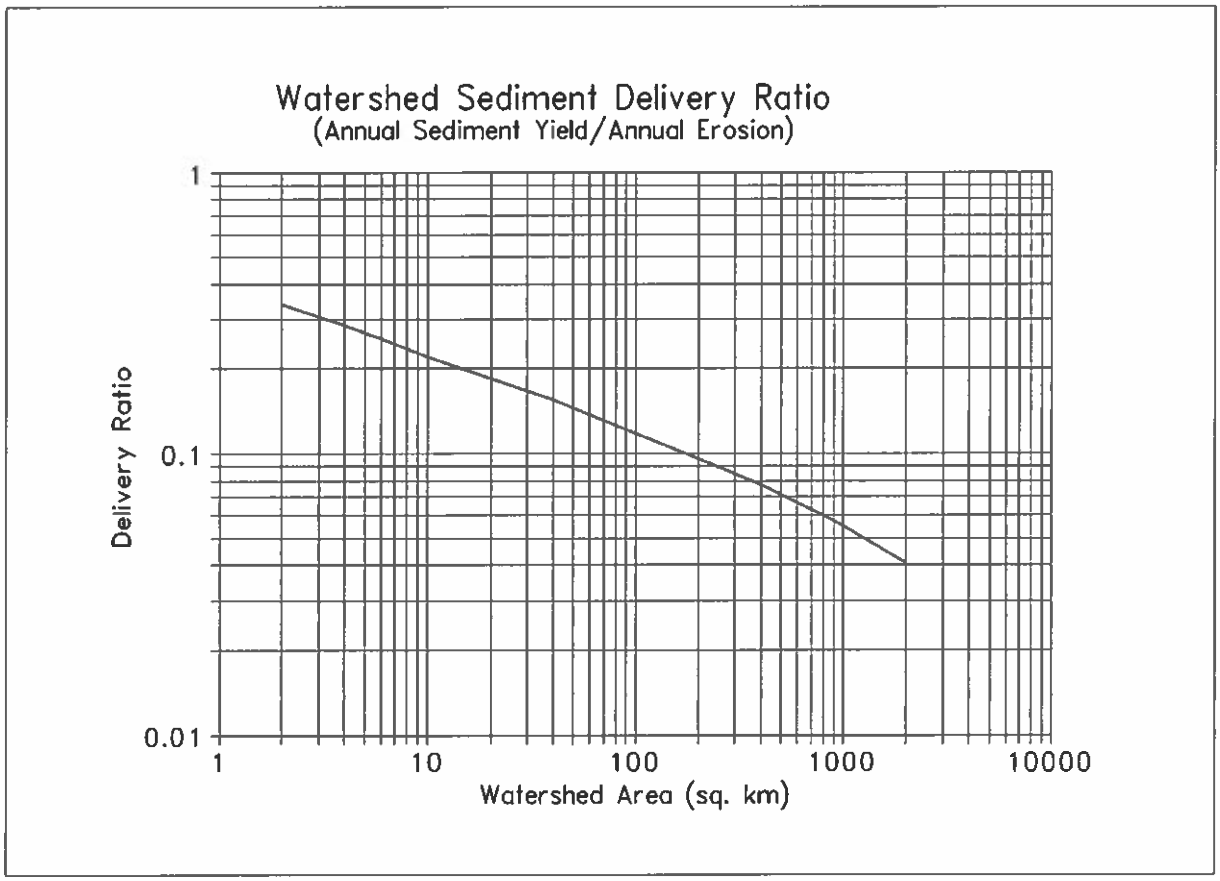


Figure B-2. Watershed Sediment Delivery Ratios (Vanoni, 1975).

Texture	Organic Matter Content (%) <0.5	2	4
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay	-	0.13-0.29	-

Table B-10. Values of Soil Erodibility Factor (K) (Stewart et al., 1975).

	Crop, rotation & management[b/]	Productivity[a/] High	Moderate
	Continuous fallow, tilled up and down slope	1.00	1.00
	CORN		
1	C, RdR, fall TP, conv (1)	0.54	0.62
2	C, RdR, spring TP, conv (1)	0.50	0.59
3	C, RdL, fall TP, conv (1)	0.42	0.52
4	C, RdR, wc seeding, spring TP, conv (1)	0.40	0.49
5	C, RdL, standing, spring TP, conv (1)	0.38	0.48
6	C, fall shred stalks, spring TP, conv (1)	0.35	0.44
7	C(silage)-W(RdL,fall TP) (2)	0.31	0.35
8	C, RdL, fall chisel, spring disk, 40-30% re (1)	0.24	0.30
9	C(silage), W wc seeding, no-till pl in c-k W (1)	0.20	0.24
10	C(RdL)-W(RdL,spring TP) (2)	0.20	0.28
11	C, fall shred stalks, chisel pl, 40-30% re (1)	0.19	0.26
12	C-C-C-W-M, RdL, TP for C, disk for W (5)	0.17	0.23
13	C, RdL, strip till row zones, 55-40% re (1)	0.16	0.24
14	C-C-C-W-M-M, RdL, TP for C, disk for W (6)	0.14	0.20
15	C-C-W-M, RdL, TP for C, disk for W (4)	0.12	0.17
16	C, fall shred, no-till pl, 70-50% re (1)	0.11	0.18
17	C-C-W-M-M, RdL, TP for C, disk for W (5)	0.087	0.14
18	C-C-C-W-M, RdL, no-till pl 2nd & 3rd C (5)	0.076	0.13
19	C-C-W-M, RdL, no-till pl 2d C (4)	0.068	0.11
20	C, no-till pl in c-k wheat, 90-70% re (1)	0.062	0.14
21	C-C-C-W-M-M, no-till pl 2d & 3rd C (6)	0.061	0.11
22	C-W-M, RdL, TP for C, disk for W (3)	0.055	0.095
23	C-C-W-M-M, RdL, no-till pl 2d C (5)	0.051	0.094
24	C-W-M-M, RdL, TP for C, disk for W (4)	0.039	0.074
25	C-W-M-M-M, RdL, TP for C, disk for W (5)	0.032	0.061
26	C, no-till pl in c-k sod, 95-80% re (1)	0.017	0.053
	COTTON[/c]		
27	Cot, conv (western plains) (1)	0.42	0.49
28	Cot, conv (south) (1)	0.34	0.40
	MEADOW (HAY)		
29	Grass & legume mix	0.004	0.01
30	Alfalfa, lespedeza or sericia	0.020	-
31	Sweet clover	0.025	-
	SORGHUM, GRAIN (western plains)		
32	RdL, spring TP, conv (1)	0.43	0.53
33	No-till pl in shredded 70-50% re	0.11	0.18
	SOYBEANS[/c]		
34	B, RdL, spring TP, conv (1)	0.48	0.54
35	C-B, TP annually, conv (2)	0.43	0.51
36	B, no-till pl	0.22	0.28
37	C-B, no-till pl, fall shred C stalks (2)	0.18	0.22

Table B-11. CONTINUED

Crop, rotation & management[b/]	Productivity[a/] High	Moderate
WHEAT		
38 W-F, fall TP after W (2)	0.38	-
39 W-F, stubble mulch, 500 lb re (2)	0.32	-
40 W-F, stubble mulch, 1000 Lb re (2)	0.21	-
41 Spring W, RdL, Sept TP, conv (ND,SD) (1)	0.23	-
42 Winter W, RdL, Aug TP, conv (KS) (1)	0.19	-
43 Spring W, stubble mulch, 750 lb re (1)	0.15	-
44 Spring W, stubble mulch, 1250 lb re (1)	0.12	-
45 Winter W, stubble mulch, 750 lb re (1)	0.11	-
46 Winter W, stubble mulch, 1250 lb re (1)	0.10	-
47 W-M, conv (2)	0.054	-
48 W-M-M, conv (3)	0.026	-
49 W-M-M-M, conv (4)	0.021	-

[a/] High level exemplified by long-term yield averages greater than 75 bu/ac corn or 3 ton/ac hay or cotton management that regularly provides good stands and growth.

[b/] Numbers in parentheses indicate numbers of years in the rotation cycle. (1) indicates a continuous one-crop system.

[c/] Grain sorghum, soybeans or cotton may be substituted for corn in lines 12, 14, 15, 17-19, 21-25 to estimate values for sod-based rotations.

Abbreviations:

B	soybeans	F	fallow
C	corn	M	grass & legume hay
c-k	chemically killed	pl	plant
conv	conventional	W	wheat
cot	cotton	wc	winter cover

lb re	pounds of residue per acre remaining on surface after new crop seeding
% re	percentage of soil surface covered by residue mulch after new crop seeding
xx-yy% re	xx% cover for high productivity, yy% for moderate
RdR	residues (corn stover, straw, etc.) removed or burned
RdL	residues left on field (on surface or incorporated)
TP	turn plowed (upper 5 or more inches of soil inverted, covering residues

Table B-11. Generalized Values of Cover and Management Factor (C) for Field Crops East of the Rocky Mountains (Stewart et al., 1975).

Cover	Value
Permanent pasture, idle land, unmanaged woodland	
95-100% ground cover	
as grass	0.003
as weeds	0.01
80% ground cover	
as grass	0.01
as weeds	0.04
60% ground cover	
as grass	0.04
as weeds	0.09
Managed woodland	
75-100% tree canopy	0.001
40-75% tree canopy	0.002-0.004
20-40% tree canopy	0.003-0.01

Table B-12. Values of Cover and Management Factor (C) for Pasture and Woodland (Novotny & Chesters, 1981).

Practice	Slope(%):	1.1-2	2.1-7	7.1-12	12.1-18	18.1-24
No support practice		1.00	1.00	1.00	1.00	1.00
Contouring		0.60	0.50	0.60	0.80	0.90
Contour strip cropping						
R-R-M-M[a/]		0.30	0.25	0.30	0.40	0.45
R-W-M-M		0.30	0.25	0.30	0.40	0.45
R-R-W-M		0.45	0.38	0.45	0.60	0.68
R-W		0.52	0.44	0.52	0.70	0.90
R-O		0.60	0.50	0.60	0.80	0.90
Contour listing or ridge planting		0.30	0.25	0.30	0.40	0.45
Contour terracing[b/]		0.6/%n	0.5/%n	0.6/%n	0.8/%n	0.9/%n

[a/] R = row crop, W = fall-seeded grain, M = meadow. The crops are grown in rotation and so arranged on the field that row crop strips are always separated by a meadow or winter-grain strip.

[b/] These factors estimate the amount of soil eroded to the terrace channels. To obtain off-field values, multiply by 0.2. n = number of approximately equal length intervals into which the field slope is divided by the terraces. Tillage operations must be parallel to the terraces.

Table B-13. Values of Supporting Practice Factor (P) (Stewart et al., 1975).

Zone[a/]	Location	Season[b/] Cool	Warm
1	Fargo ND	0.08	0.30
2	Sioux City IA	0.13	0.35
3	Goodland KS	0.07	0.15
4	Wichita KS	0.20	0.30
5	Tulsa OK	0.21	0.27
6	Amarillo TX	0.30	0.34
7	Abilene TX	0.26	0.34
8	Dallas TX	0.28	0.37
9	Shreveport LA	0.22	0.32
10	Austin TX	0.27	0.41
11	Houston TX	0.29	0.42
12	St. Paul MN	0.10	0.26
13	Lincoln NE	0.26	0.24
14	Dubuque IA	0.14	0.26
15	Grand Rapids MI	0.08	0.23
16	Indianapolis IN	0.12	0.30
17	Parkersburg WV	0.08	0.26
18	Springfield MO	0.17	0.23
19	Evansville IN	0.14	0.27
20	Lexington KY	0.11	0.28
21	Knoxville TN	0.10	0.28
22	Memphis TN	0.11	0.20
23	Mobile AL	0.15	0.19
24	Atlanta GA	0.15	0.34
25	Apalachacola FL	0.22	0.31
26	Macon GA	0.15	0.40
27	Columbia SC	0.08	0.25
28	Charlotte NC	0.12	0.33
29	Wilmington NC	0.16	0.28
30	Baltimore MD	0.12	0.30
31	Albany NY	0.06	0.25
32	Caribou ME	0.07	0.13
33	Hartford CN	0.11	0.22

[a/] Zones given in Figure B-1.

[b/] Cool season: Oct - Mar; Warm season: Apr - Sept.

Table B-14. Rainfall Erosivity Coefficients (a) for Erosivity Zones in Eastern U.S. (Selker et al., 1990).

Initial Conditions. Several initial conditions must be provided in the **TRANSPRT.DAT** file: initial unsaturated and shallow saturated zone soil moistures (U_1 and S_1), snowmelt water (SN_1) and antecedent rain + snowmelt for the five previous days. It is likely that these values will be uncertain in many applications. However, they will not affect model results for more than the first month or two of the simulation period. It is generally most practical to assign arbitrary initial values (U^* for U_1 and zero for the remaining variables) and to discard the first year of the simulation results.

Nutrient Parameters

A sample set of nutrient parameters required for the data file **NUTRIENT.DAT** is given in Appendix D.

Although the GWLF model will be most accurate when nutrient data are calibrated to local conditions, a set of default parameters has been developed to facilitate uncalibrated applications. Obviously these parameters, which are average values obtained from published water pollution monitoring studies, are only approximations of conditions in any watershed.

Rural and Groundwater Sources. Solid-phase nutrients in sediment from rural sources can be estimated as the average soil nutrient content multiplied by an enrichment ratio. Soil nutrient levels can be determined from soil samples, soil surveys or general maps such as those given in Figures B-3 and B-4. A value of 2.0 for the enrichment ratio falls within the mid-range of reported ratios and can be used in absence of more specific data (McElroy et al., 1976; Mills et al., 1985).

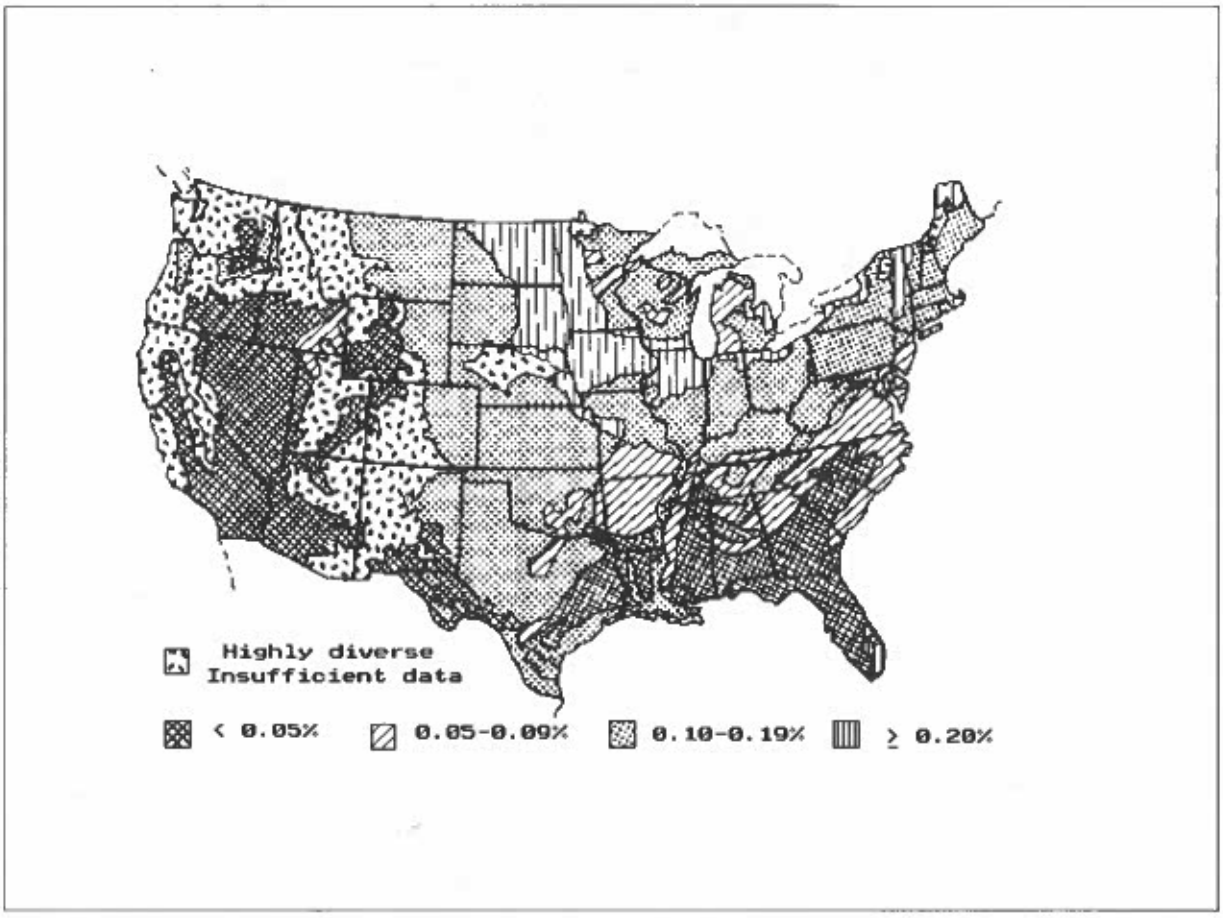


Figure B-3. Nitrogen in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

Default flow-weighted mean concentrations of dissolved nitrogen and phosphorus in agricultural runoff are given in Table B-15. The cropland and barnyard data are from multi-year storm runoff sampling studies in South Dakota (Dornbush et al., 1974) and Ohio (Edwards et al., 1972). The concentrations for snowmelt runoff from fields with manure on the soil surface are taken from a manual prepared by U. S. Department of Agriculture scientists (Gilbertson et al., 1979).

Default values for nutrient concentrations in groundwater discharge can be inferred from the U.S. Eutrophication Survey results (Omernik, 1977) given in Table B-16. These data are mean concentrations

computed from 12 monthly streamflow samples in watersheds free of point sources. Since such limited sampling is unlikely to capture nutrient fluxes from storm runoff, the streamflow concentrations can be assumed to represent groundwater discharges to streams.

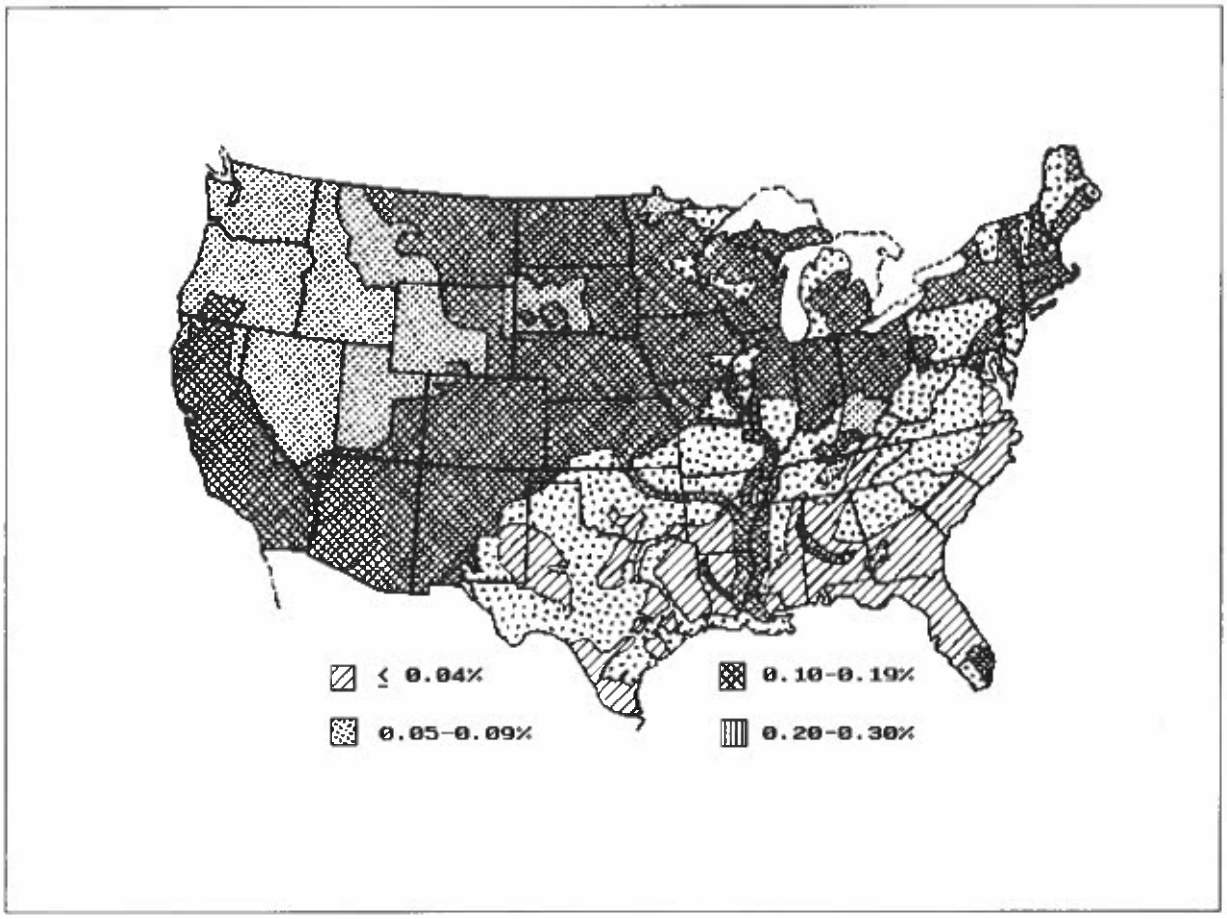


Figure B-4. P_2O_5 (44% phosphorus) in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

Dissolved nutrient data for forest runoff are essentially nonexistent. Runoff is a small component of streamflow from forest areas and studies of forest nutrient flux are based on streamflow rather than runoff sampling. Hence the only possible default option is the use of the streamflow concentrations from the "$ 90% Forest" category in Table B-16 as estimates of runoff concentrations.

Default values for urban nutrient accumulation rates are provided in Table B-17. These values were developed for Northern Virginia conditions and are probably suitable for smaller and relatively new urban areas. They would likely underestimate accumulations in older large cities.

Septic Systems. Representative values for septic system nutrient parameters are given in Table B-18. Per capita nutrient loads in septic tank effluent were estimated from typical flows and concentrations. The EPA Design Manual (U.S. Environmental Protection Agency, 1980) indicates 170 l/day as a representative wastewater flow from on-site wastewater disposal systems. Alhajjar et al. (1989) measured mean nitrogen and phosphorus concentrations in septic tank effluents of 73 and 14 mg/l, respectively. The latter concentration is based on use of phosphate detergents. When non-phosphate detergents are used, the concentration dropped to 7.9 mg/l. These concentrations were combined with the 170 l/day flow to produce the effluent nutrient loads given in Table B-18.

Nutrient uptake by plants (generally grasses) growing over the septic system adsorption field are frankly speculative. Brown & Thomas (1978) suggest that if the grass clippings are harvested, nutrients from a septic system effluent can support at least twice the normal yield of grass over the absorption field. Petrovic & Cornman (1982) suggest that retention of turf grass clippings can reduce required fertilizer applications by 25%, thus implying nutrient losses of 75% of uptakes. It appears that a conservative estimate of nutrient losses from plant cover would be 75% of the nutrient uptake of from a normal annual yield of grass. Reed et al. (1988) reported that Kentucky bluegrass annually utilizes 200-270 kg/ha nitrogen and 45 kg/ha phosphorus. Using the 200 kg/ha nitrogen value, and assuming a six month growing season and a 20 m^2 per capita absorption area, an estimated 1.6 g/day nitrogen and 0.4 g/day phosphorus are lost by plant uptake on a per capita basis during the growing season. The 20 m^2 adsorption area was based on per bedroom adsorption area recommendations by the U.S. Public Health Service for a soil with average percolation rate (.12 min/cm) (U.S. Public Health Service, 1967).

The remaining information needed are the numbers of people served by the four different types of septic systems (normal, short-circuited, ponded and direct discharge). A starting point for this data will generally be estimates of the unsewered population in the watershed. Local public health officials may be able to estimate the fractions of systems within the area which are of each type. However, the most direct way of generating the information is through a septic systems survey.

Land Use	Nitrogen (mg/l)	Phosphorus (mg/l)
Fallow[a/]	2.6	0.10
Corn[a/]	2.9	0.26
Small grains[a/]	1.8	0.30
Hay[a/]	2.8	0.15
Pasture[a/]	3.0	0.25
Barn yards[b/]	29.3	5.10
Snowmelt runoff from manured land[c/]:		
Corn	12.2	1.90
Small grains	25.0	5.00
Hay	36.0	8.70

[a/]Dornbush et al. (1974)

[b/]Edwards et al. (1972)

[c/]Gilbertson et al. (1979); manure left on soil surface.

Table B-15. Dissolved Nutrients in Agricultural Runoff.

Watershed Type	Concentrations (mg/l) Eastern U.S.	Central U.S.	Western U.S.
Nitrogen[a/]:			
$ 90% Forest	0.19	0.06	0.07
$ 75% Forest	0.23	0.10	0.07
$ 50% Forest	0.34	0.25	0.18
$ 50% Agriculture	1.08	0.65	0.83
$ 75% Agriculture	1.82	0.80	1.70
$ 90% Agriculture	5.04	0.77	0.71
Phosphorus[b/]:			
$ 90% Forest	0.006	0.009	0.012
$ 75% Forest	0.007	0.012	0.015
$ 50% Forest	0.013	0.015	0.015
$ 50% Agriculture	0.029	0.055	0.083
$ 75% Agriculture	0.052	0.067	0.069
$ 90% Agriculture	0.067	0.085	0.104

[a/]Measured as total inorganic nitrogen.

[b/]Measured as total orthophosphorus

Table B-16. Mean Dissolved Nutrients Measured in Streamflow by the National Eutrophication Survey (Omernik, 1977).

Land Use	Sus-pended Solids	BOD	Total Nitrogen	Total Phosphorus
	(---------- kg/ha-day ----------)			
Impervious Surfaces				
Single family residential				
Low density (units/ha < 1.2)	2.5	0.15	0.045	0.0045
Medium density (units/ha ≥ 1.2)	6.2	0.22	0.090	0.0112
Townhouses & apartments	6.2	0.22	0.090	0.0112
High rise residential	3.9	0.71	0.056	0.0067
Institutional	2.8	0.39	0.056	0.0067
Industrial	2.8	0.71	0.101	0.0112
Suburban shopping center	2.8	0.71	0.056	0.0067
Central business district	2.8	0.85	0.101	0.0112
Pervious Surfaces				
Single family residential				
Low density (units/ha < 1.2)	1.3	0.08	0.012	0.0016
Medium density (units/ha ≥ 1.2)	1.1	0.15	0.022	0.0039
Townhouses & apartments	2.2	0.29	0.045	0.0078
High rise residential	0.8	0.08	0.012	0.0019
Institutional	0.8	0.08	0.012	0.0019
Industrial	0.8	0.08	0.012	0.0019
Suburban shopping center	0.8	0.08	0.012	0.0019
Central business district	0.8	0.08	0.012	0.0019

Table B-17. Contaminant Accumulation Rates for Northern Virginia Urban Areas (Kuo, et al., 1988).

Parameter		Value
e, per capita daily nutrient load in septic tank effluent (g/day)		
Nitrogen		12.0
Phosphorus		
Phosphate detergents use		2.5
Non-phosphate detergents use		1.5
u_m, per capita daily nutrient uptake by plants during month m (g/day)		
Nitrogen:	Growing season	1.6
	Non-growing season	0.0
Phosphorus:	Growing season	0.4
	Non-growing season	0.0

Table B-18. Default Parameter Values for Septic Systems.

APPENDIX C: VALIDATION STUDY

The GWLF model was tested by comparing model predictions with measured streamflow, sediment and nutrient loads from the West Branch Delaware River Basin during a three-year period (April, 1979 - March, 1982). The model was run using the four-year period April, 1978 - March, 1982 and first year results were ignored to eliminate effects of arbitrary initial conditions.

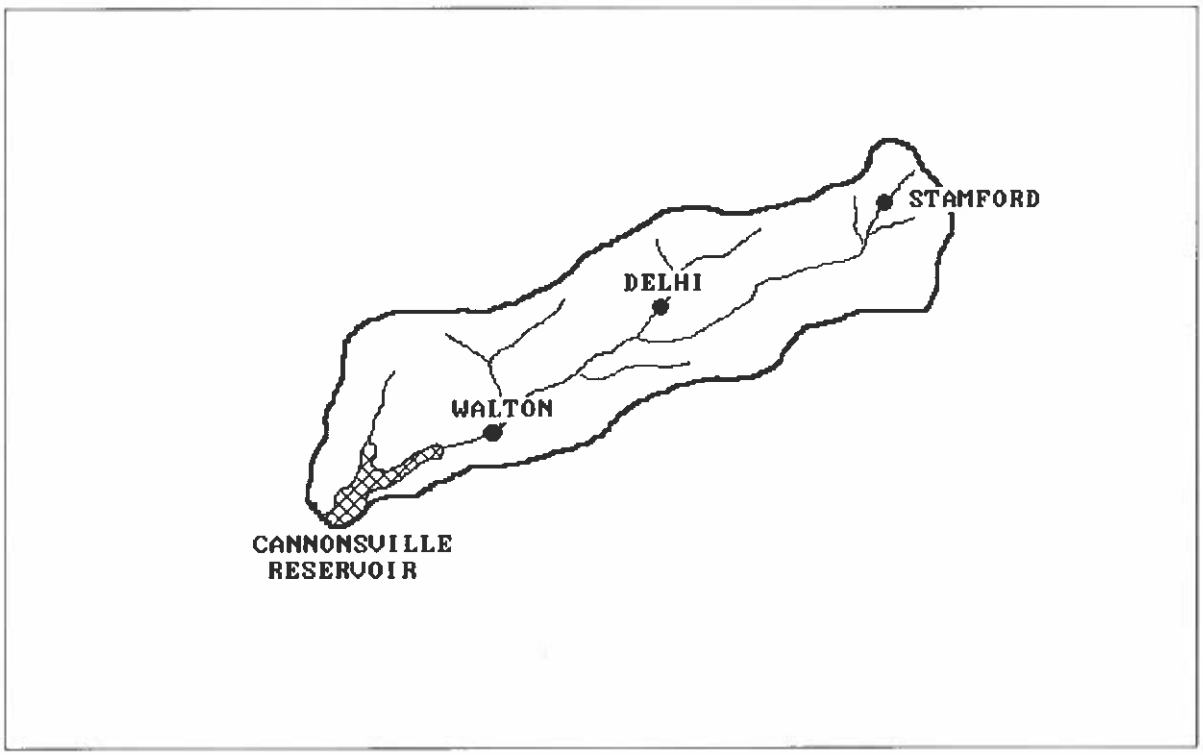


Figure C-1. West Branch Delaware River Watershed.

The 850 km^2 watershed, which is shown in Figure C-1, is in a dairy farming area in southeast New York which consists of 30% agricultural, 67% forested and 2% urban land uses. The river empties into Cannonsville Reservoir, which is a water supply source for the City of New York.

The model was run for the four-year period using daily precipitation and temperature records from the U.S. Environmental Data and Information service weather station at Walton, NY. To test the usefulness of the default parameters presented previously, no attempt was made to calibrate the model. No water quality data from the watershed were used to estimate parameters. All transport and chemical parameters were obtained by the general procedures described in the Appendix B.

Water Quality Observations

Continuous streamflow records were available from a U.S. Geological Survey gauging station at Walton, NY. Nutrient and sediment data were collected, analyzed and summarized by the N.Y. State Department of Environmental Conservation (Brown et al., 1985). During base flow conditions, samples were collected at approximately one-week intervals. During storm events, samples were collected at 2-4 hour intervals during hydrograph rise and at 6-8 hour intervals in the 2-3 days following flow peak. More frequent sampling was carried out during major snowmelt events. Total and dissolved phosphorus and sediment (suspended solids) data were collected from March, 1980 through March, 1982. The sampling periods for dissolved and total nitrogen were less extensive: March, 1980 - September, 1981 and January, 1981 - September, 1981, respectively.

Mass fluxes were computed by multiplying sediment or nutrient concentrations in a sample by "a volume of water determined by numerically integrating flow over the period of time from half of the preceding sampling time interval through half of the following sampling time interval" (Brown et al., 1985).

Watershed Data

Land Uses. The parameters needed for the agricultural and forest source areas were estimated from a land use sampling procedure similar to that described by Haith & Tubbs (1981). U.S. Geological Survey 1:24,000 topographic maps of the watershed were overlain by land use maps derived from 1971-1974 aerial photography. The maps were then overlain by a grid with 1-ha cells which was the basis of the sampling procedure. The land uses were divided into two general categories: forest and agriculture. Forest areas were subdivided into forest brushland and mature forest, and agricultural areas were subdivided into cropland, pasture and inactive agriculture. A random sample of 500 cells was taken, stratified over the two major land uses to provide more intense sampling of agricultural areas (390 samples vs. 110 for forest).

For each agricultural sample, the following were recorded: land use (cropland, pasture or inactive), soil type and length and gradient of the slope of the field in which the 1-ha sample was located. Crops were separated into two categories, corn or hay, since these two crops make up 99% of the county cropland.

Barnyard areas were identified from examination of conservation plans for 30 watershed dairy farm barnyards. Average earthen and roof drainage areas were 0.1306 ha and 0.0369 ha, respectively. These values were assumed representative of the watershed's 245 barnyards, producing total earth and roof drainage areas of 32 and 9 ha, respectively.

Urban land uses (low-density residential, commercial and industrial) were calculated from Delaware County tax maps. The impervious portions of these areas were 16%, 54% and 34% for residential, commercial and industrial land uses, respectively.

Runoff Curve Numbers. In forest areas, curve numbers were selected by soil type, assuming "good" hydrologic condition. Agricultural curve numbers were selected based on soil type, crop, management practice (e.g., strip cropping) and hydrologic condition. All pasture, hay and corn-hay rotations were assumed to be in good condition. Inactive agricultural areas were assumed to be the same as pasture. Corn grown in continuous rotation was considered in poor condition. Cropland breakdown into hay, continuous corn and rotated corn was determined from county data assembled by Soil Conservation Service (1976) and confirmed from Bureau of the Census (1980).

Rural source areas and curve numbers are listed in Table C-1. These areas were subsequently aggregated for the GWLF input files into the large areas given in Table C-2. Urban and barnyard areas are also given in Table C-2. Curve numbers are area-weighted averages for each source area.

Erosion and Sediment Parameters. Data required for estimation of soil loss parameters for logging sites were obtained from a forestry survey (Slavicek, 1980). Logging areas were located from a 1979 aerial survey. Transects of the logging roads at these sites were measured for soil loss parameters K_k, $(LS)_k$, C_k and P_k, and from this information an average K_k $(LS)_k$ C_k P_k value was calculated.

Soil erodibility factors (K_k) for agricultural land were obtained from the Soil Conservation Service. Cover factors (C) were selected Table B-10 based on several assumptions. For corn, the assumptions were that all residues are removed from the fields (91% of the corn in the county is used for silage (Bureau of the Census, 1980)), and all fields are spring turn-plowed and in the high productivity class (Knoblauch, 1976). A moderate productivity was assumed for hay (Knoblauch, 1976). Supporting practice factors of P = 1 were used for all source areas except strip crop corn. Area-weighted K_k $(LS)_k$ C_k P_k values are given in Table C-2. Coefficients for daily rainfall erosivity were selected from Table B-13 for Zone 31 (Figure B-1) . A watershed sediment delivery ratio of 0.065 was determined from Figure B-2.

Source Area	Soil Hydrologic Group	Area(ha)	Curve Number[a]
Continuous corn	B	414	81
	C	878	88
Rotated corn	B	620	78
	C	1316	85
Strip crop corn	C	202	82
Hay	B	2319	72
	C	10690	81
	D	76	85
Pasture	B	378	61
	C	4639	74
	D	76	80
Inactive agriculture	B	328	61
	C	3227	74
	D	126	80
Forest brushland	B	3118	48
	C	24693	65
	D	510	73
Mature forest	B	510	55
	C	27851	70

[a/] Antecedent moisture condition 2 ($CN2_k$)

Table C-1. Areas and Curve Numbers for Agricultural and Forest Runoff Sources for West Branch Delaware River Basin.

Land Use	Area(ha)	Curve Number[a/]	Erosion Product[b/]
Corn	3430	83.8	0.214
Hay	13085	79.4	0.012
Pasture	5093	73.1	0.016
Inactive Agriculture	3681	73.1	0.017
Barnyards	41	92.2	--
Forest	56682	66.5	--
Logging Trails	20	--	0.217
Residential (Low Density)			
Impervious	104	98.0	--
Pervious	546	74.0	--
Commercial			
Impervious	49	98.0	--
Pervious	41	74.0	--
Industrial			
Impervious	34	98.0	--
Pervious	67	74.0	--

[a/]Antecedent moisture condition 2 ($CN2_k$).

[b/]$K_k (LS)_k C_k P_k$

Table C-2. Aggregated Runoff Source Areas in West Branch Delaware River Basin.

Land Use	Area(ha)	Cover Coefficient May-Oct	Cover Coefficient Nov-Apr
Corn	3430	1.0	0.3
Hay	13085	1.0	1.0
Pasture	5093	1.0	1.0
Inactive Agriculture	3681	1.0	1.0
Forest	56682	1.0	0.3
Logging	20	0.3	0.3
Barn Yards	41	0.3	0.3
Residential	650	0.84	0.84
Commercial	90	0.46	0.46
Industrial	101	0.66	0.66
Watershed Weighted Mean	82873	1.00	0.49

Table C-3. Evapotranspiration Cover Coefficients for West Branch Delaware River Basin.

Other Transport Parameters. For purpose of curve number and evapotranspiration cover coefficient selection, the growing season was assumed to correspond to months during which mean air temperature is at least 10EC (May-October). Cover coefficients were selected from Table B-8 and are listed in Table C-3 along with the area-weighted watershed values. An average groundwater recession constant of r = 0.1 was determined from analysis of 30 hydrograph recessions from the period 1971 - 1978. The seepage constant (s) was assumed to be zero, and the default value of 10 cm was used for unsaturated zone available soil moisture capacity U*.

Nutrient Concentrations and Accumulation Rates. Using the soil nutrient values given in Figures B-3 and B-4 and the previously suggested enrichment ratio of 2.0 produced sediment nutrient concentrations of 3000 mg/kg nitrogen and 1300 mg/kg phosphorus. Rural dissolved nutrient concentrations were selected from Tables B-15 and B-16. Manure is spread on corn land in the watershed and hence the manured land concentrations were used for corn land runoff in snowmelt months (January - March). Inactive agricultural land was assumed to have nutrient concentrations midway between pasture and forest values. Urban nutrient accumulation rates from Table B-17 were used, with "Central business district" values used for commercial land.

Septic System Parameters. The default values for nutrient loads and plant uptake given in Table B-18 were used to model septic systems. The population served by each type of septic system was estimated by determining the percentage of the total number of systems falling within each class and multiplying by the year-round and seasonal (June - August) unsewered populations in the watershed. Table C-4 summarizes the population data for septic systems.

System Type	Percent of Total Population Served		
	Population	Year-round	Seasonal[a/]
Normal	86	7572	1835
Short-circuited	1	88	21
Ponded	10	881	213
Direct discharge	3	264	64

[a/] June - August

Table C-4. Estimated Populations Served by Different Septic System Types in West Branch Delaware River Basin.

The year-round unsewered population estimate for the watershed was based on 1980 Census data. These data were also used to determine the average number of people per household and the number of housing units used on a part-time basis. The seasonal population was then calculated by assuming the number of people per household was the same for seasonal and year-round residents.

A range of values for the current (1991) percentage of each type of system was supplied by the New York City Department of Environmental Protection (Personal Communication, J. Kane, New York City Department of Environmental Protection). A estimate of the percentages for the study period was determined by comparing the range of current values with the percentages from a survey of a neighboring area of Delaware County with construction practices and code enforcement similar to the West Branch Delaware River Watershed at the time of the study (Personal Communication, A. Lemley, Cornell University).

Point Sources. Point sources of nutrients are dissolved loads from five municipal and two industrial wastewater treatment plants. These inputs are 3800 kg/mo nitrogen and 825 kg/mo phosphorus (Brown & Rafferty, 1980; Dickerhoff, 1981).

Complete data inputs for the validation simulation run are given in Appendix D.

Validation Results

The GWLF streamflow predictions are compared with observations in Figure C-2. It is apparent that although the model mirrors the timing of observed streamflow, predictions for any particular month may have substantial errors. Accuracy is poorest for low flows, when predicted streamflows are essentially zero due to the very simple lumped parameter groundwater model.

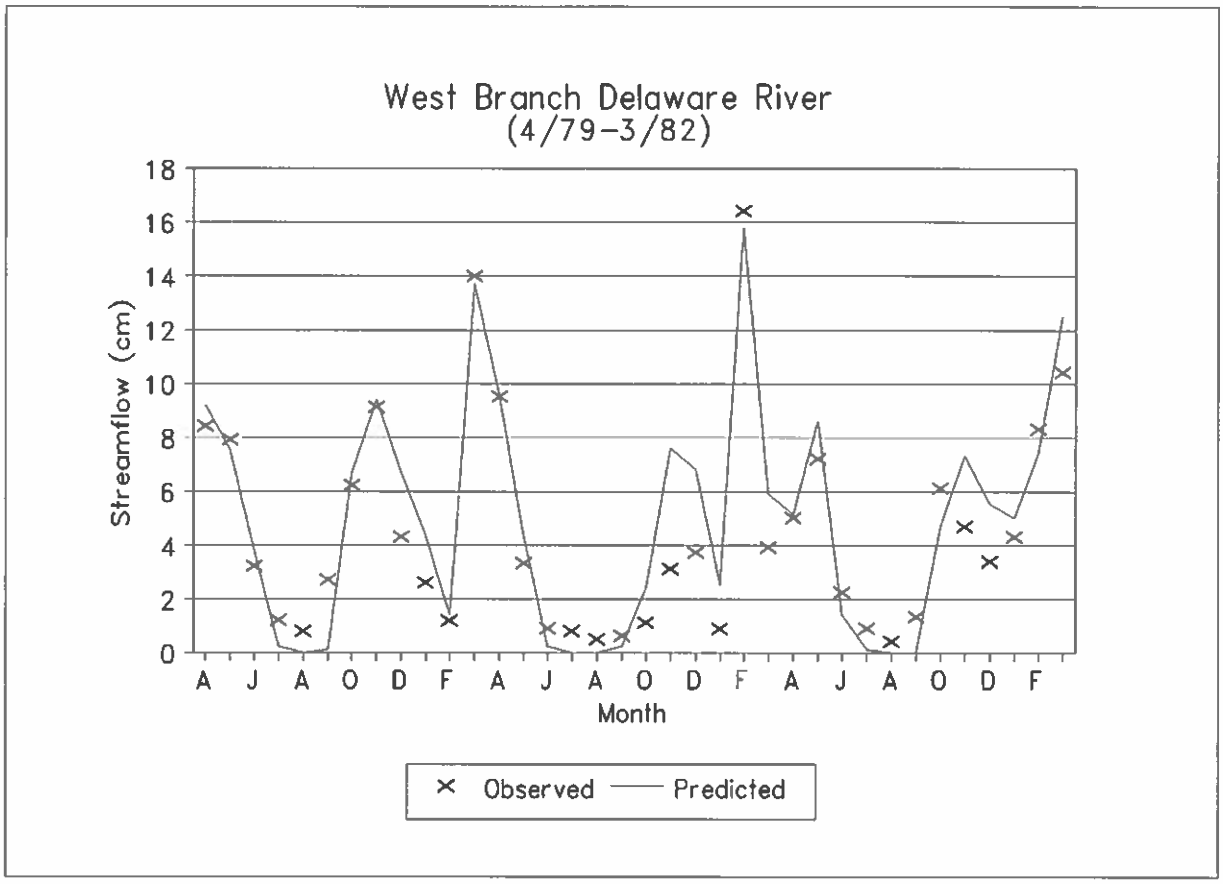


Figure C-2. Observed and Predicted Monthly Streamflow.

Model predictions and observations for total phosphorus and nitrogen are compared in Figures C-3 and C-4. Both sets of predictions match the variations in observations but under-predict the February, 1981 peak values by 35% and 26% for phosphorus and nitrogen, respectively. A quantitative summary of the comparisons of predictions with observations is given in Table C-5. Monthly mean predictions are within 10% of observation means for five of the six model outputs. The predicted mean total nitrogen flux is 73% of the observed mean. No coefficient of determination (R^2) is less than 0.88, indicating that the model explains at least 88% of the observed monthly variation in streamflow, sediment yield and nutrient fluxes.

Mean annual nutrient loads from each source for the four-year simulation period are provided in Table C-6. It is apparent that cropland runoff is a major source of streamflow nitrogen and phosphorus. Groundwater discharge is the largest source of nitrogen, accounting for 41% of dissolved and 36% of total nitrogen loads. Point sources constitute 11% of total nitrogen and 20% of total phosphorus. Septic tank drainage provides nearly as much nitrogen as point sources, but is a minor phosphorus source.

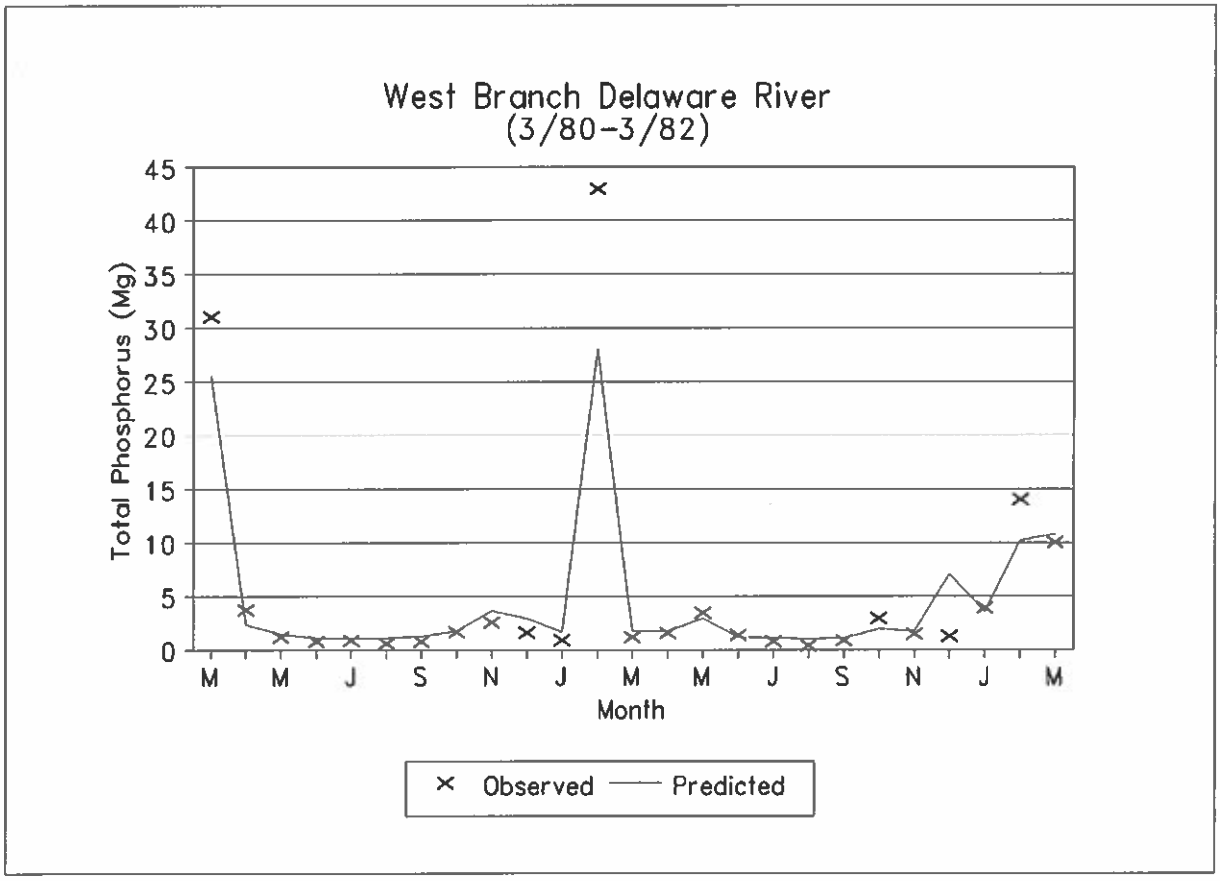


Figure C-3. Observed and Predicted Total Phosphorus in Streamflow.

Constituent	Validation Period	Predicted	Monthly Means Observed	Coefficient of Determination (R^2)
Streamflow (cm)	4/79-3/82	4.9	4.5	0.88
Sediment (1000 Mg)	3/80-3/82	1.6	1.7	0.95
Nitrogen (Mg)				
Dissolved	3/80-9/81	27.8	27.8	0.94
Total	1/81-9/81	32.9	44.8	0.99
Phosphorus (Mg)				
Dissolved	3/80-3/82	2.6	2.4	0.95
Total	3/80-3/82	4.7	5.2	0.95

Table C-5. Comparison of GWLF Predictions and Observations for the West Branch Delaware River Watershed.

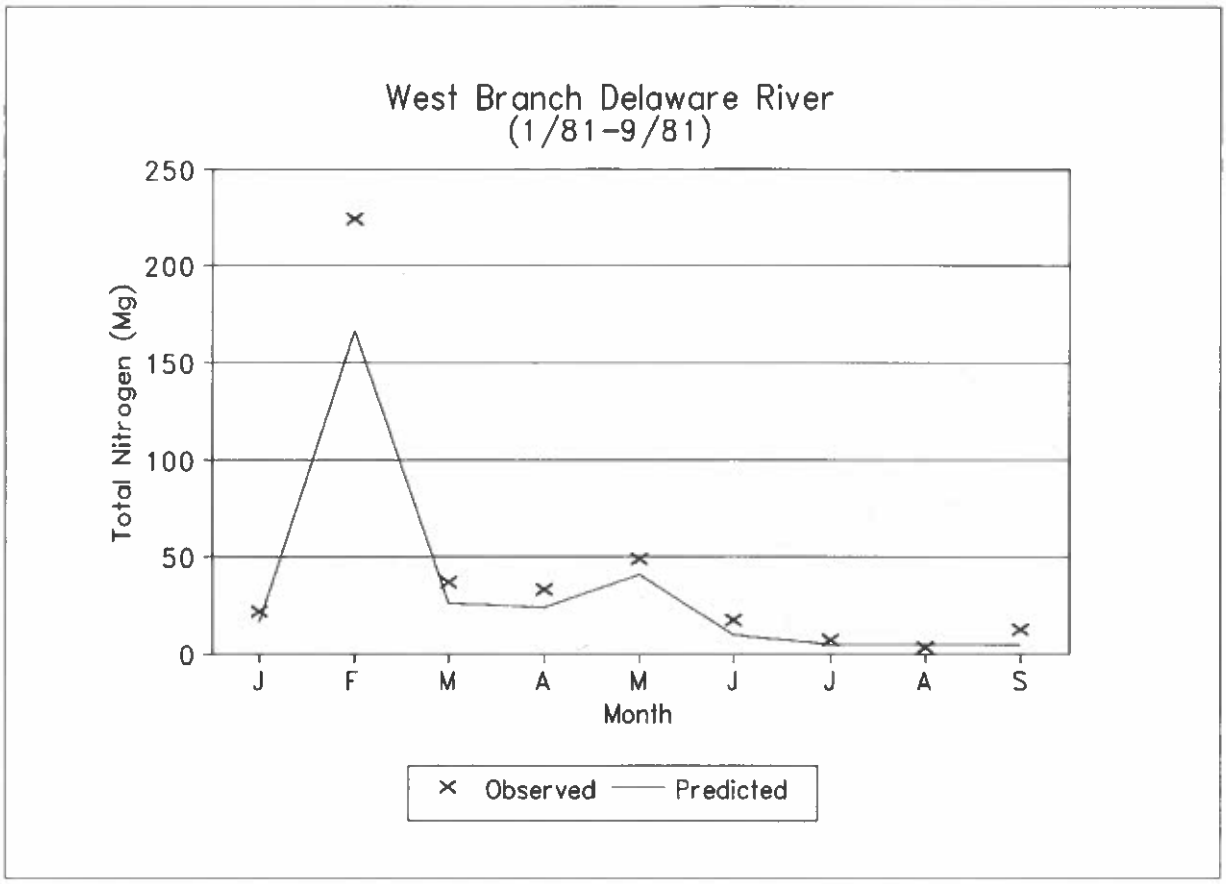


Figure C-4. Observed and Predicted Total Nitrogen in Streamflow.

Conclusions

The watershed loading functions model GWLF is based on simple runoff, sediment and groundwater relationships combined with empirical chemical parameters. The model is unique in its ability to estimate monthly nutrient fluxes in streamflow without calibration. Validation studies in a large New York watershed indicated that the model possesses a high degree of predictive accuracy. Although better results could perhaps be obtained by more detailed chemical simulation models, such models have substantially greater data and computational requirements and must be calibrated from water quality sampling data.

The GWLF model has several limitations. Peak monthly nutrient fluxes were underestimated by as much as 35%. Since nutrient chemistry is not modeled explicitly, the model cannot be used to estimate the effects of fertilizer management or urban storm water storage and treatment. The model has only been validated for a largely rural watershed in which agricultural runoff and groundwater discharge provided most of the nutrient load. Although the urban runoff component is based on well-known relationships which have been used previously in such models as STORM and SWMM, GWLF performance in more urban watersheds is uncertain.

Source	Nitrogen (Mg) Dissolved	Total	Phosphorus (Mg) Dissolved	Total
Runoff				
Corn	52.9	84.6	7.8	21.5
Hay	48.6	55.4	2.6	5.5
Pasture	13.2	16.7	1.1	2.6
Inactive Agriculture	5.1	7.8	0.4	1.6
Forest & logging	5.9	6.1	0.2	0.3
Barn yards	4.3	4.3	0.8	0.8
Urban	--	2.8	--	0.3
Groundwater, Point Sources, & Septic Systems				
Groundwater Discharge	149.6	149.6	5.7	5.7
Point sources	45.6	45.6	9.9	9.9
Septic systems	38.1	38.1	1.1	1.1
Watershed Total	363.4	411.1	29.6	48.3

Table C-6. Mean Annual Nutrient Loads Estimated from GWLF for the West Branch Delaware River Watershed: 4/78 - 3/82.

APPENDIX D: DATA AND OUTPUT LISTINGS FOR VALIDATION STUDY (EXAMPLE 1)

The first listing in this appendix is the set of sequential data input files **TRANSPRT.DAT**, **NUTRIENT.DAT** and **WEATHER.DAT** used in the validation study and Example 1. The first two files are constructed by selecting the appropriate option from GWLF menus. The weather file is arranged by months (April - March, in this application) with the first entry for each month being the number of days in the month, and subsequent entries being temperature (EC) and precipitation (cm) for each day. Only a partial listing of **WEATHER.DAT** is given. The next listings are the text files for the transport and nutrient data (**TRANSPRT.TXT** and **NUTRIENT.TXT**). The remaining listings are text files of the several program outputs (**SUMMARY.TXT** and **MONTHLY.TXT**).

TRANSPRT.DAT

```
7,6
.1,0,10,0,0,.065,10
0
0
0
0
0
"APR",.49,13.1,0,.25
"MAY",1,14.3,1,.25
"JUNE",1,15,1,.25
"JULY",1,14.6,1,.25
"AUG",1,13.6,1,.25
"SEPT",1,12.3,1,.25
"OCT",1,10.9,1,.06
"NOV",.49,9.7,0,.06
"DEC",.49,9,0,.06
"JAN",.49,9.3,0,.06
"FEB",.49,10.4,0,.06
"MAR",.49,11.7,0,.06
"CORN",3430,83.8,.214
"HAY",13085,79.4,.012
"PASTURE",5093,73.1,.016
"INACTIVE",3681,73.1,.017
"FOREST",56682,66.5,0
"LOGGING",20,0,.217
"BARN YARDS",41,92.2,0
"RES-imperv",104,98,0
"RES-perv",546,74,0
"COMM-imperv",49,98,0
"COMM-perv",41,74,0
"INDUS-imperv",34,98,0
"INDUS-perv",67,74,0
```

NUTRIENT.DAT

```
3000,1300,.34,.013      30
1,10,12
2.9,.26
2.8,.15
3,.25
1.6,.13
.19,.006
0,0
29.3,5.1
0.045,0.0045
0.012,0.0016
0.101,0.0112
0.012,0.0019
0.101,0.0112
0.012,0.0019
12.2,1.9
3800,825
3800,825
3800,825
3800,825
3800,825
3800,825
3800,825
3800,825
3800,825
3800,825
3800,825
1
7572,881,88,264
7572,881,88,264
9407,1094,109,328
9407,1094,109,328
9407,1094,109,328
7572,881,88,264
7572,881,88,264
7572,881,88,264
7572,881,88,264
7572,881,88,264
7572,881,88,264
7572,881,88,264
12,2.5,1.6,.4
```

WEATHER.DAT

```
11,.2
2,.4
-3,.1
2,0
3,1
4,0
9,.4
2,.1
2,.1
4,0
12,.1
10,.6
12,0
5,.1
2,.1
5,0
4,0
5,.1
7,0
8,1.3
4,.4
6,.1
4,0
6,0
7,0
8,0
9,0
8,0
7,0
5,.1
31
-1,0
6,0
6,0
5,0
7,.3
6,1.3
11,.6
9,0
15,.8
10,.2
15,0
13,0
16,0
14,0
12,.5
11,.4
11,.8
14,.4
17,.2
!
!
!
```

TRANSPRT.TXT

TRANSPRT DATA

LAND USE	AREA(ha)	CURVE NO	KLSCP
CORN	3430.	83.8	0.21400
HAY	13085.	79.4	0.01200
PASTURE	5093.	73.1	0.01600
INACTIVE	3681.	73.1	0.01700
FOREST	56682.	66.5	0.00000
LOGGING	20.	0.0	0.21700
BARN YARDS	41.	92.2	0.00000
RES-imperv	104.	98.0	0.00000
RES-perv	546.	74.0	0.00000
COMM-imperv	49.	98.0	0.00000
COMM-perv	41.	74.0	0.00000
INDUS-imperv	34.	98.0	0.00000
INDUS-perv	67.	74.0	0.00000

MONTH	ET CV()	DAY HRS	GROW. SEASON	EROS. COEF
APR	0.490	13.1	0	.25
MAY	1.000	14.3	1	.25
JUNE	1.000	15	1	.25
JULY	1.000	14.6	1	.25
AUG	1.000	13.6	1	.25
SEPT	1.000	12.3	1	.25
OCT	1.000	10.9	1	.06
NOV	0.490	9.7	0	.06
DEC	0.490	9	0	.06
JAN	0.490	9.3	0	.06
FEB	0.490	10.4	0	.06
MAR	0.490	11.7	0	.06

ANTECEDENT RAIN+MELT FOR DAY -1 TO DAY -5

0	0	0	0	0

INITIAL UNSATURATED STORAGE (cm) = 10
INITIAL SATURATED STORAGE (cm) = 0
RECESSION COEFFICIENT (1/day) = .1
SEEPAGE COEFFICIENT (1/day) = 0
INITIAL SNOW (cm water) = 0
SEDIMENT DELIVERY RATIO = 0.065
UNSAT AVAIL WATER CAPACITY (cm) = 10

NUTRIENT.TXT

NUTRIENT DATA

RURAL LAND USE	DIS.NITR IN RUNOFF(mg/l)	DIS.PHOS IN RUNOFF(mg/l)
CORN	2.9	.26
HAY	2.8	.15
PASTURE	3	.25
INACTIVE	1.6	.13
FOREST	.19	.006
LOGGING	0	0
BARN YARDS	29.3	5.1

NUTRIENT CONCENTRATIONS IN RUNOFF FROM MANURED AREAS

LAND USE	NITROGEN(mg/l)	PHOSPHORUS(mg/l)
CORN	12.2	1.9

URBAN LAND USE	NITR.BUILD-UP(kg/ha-day)	PHOS.BUILD-UP(kg/ha-day)
RES-imperv	.045	.0045
RES-perv	.012	.0016
COMM-imperv	.101	.0112
COMM-perv	.012	.0019
INDUS-imperv	.101	.0112
INDUS-perv	.012	.0019

MONTH	POINT SOURCE NITR.(kg)	POINT SOURCE PHOS.(kg)
APR	3800	825
MAY	3800	825
JUNE	3800	825
JULY	3800	825
AUG	3800	825
SEPT	3800	825
OCT	3800	825
NOV	3800	825
DEC	3800	825
JAN	3800	825
FEB	3800	825
MAR	3800	825

NITROGEN IN GROUNDWATER (mg/l):	0.340
PHOSPHORUS IN GROUNDWATER (mg/l):	0.013
NITROGEN IN SEDIMENT (mg/kg):	3000
PHOSPHORUS IN SEDIMENT (mg/kg):	1300

MANURE SPREADING JAN THRU MAR

SEPTIC SYSTEMS

	POPULATION SERVED			
MONTH	NORMAL SYSTEMS	PONDING SYSTEMS	SHORT-CIRCUIT SYSTEMS	DISCHARGE SYSTEMS
APR	7572	881	88	264
MAY	7572	881	88	264
JUNE	9407	1094	109	328
JULY	9407	1094	109	328
AUG	9407	1094	109	328
SEPT	7572	881	88	264
OCT	7572	881	88	264
NOV	7572	881	88	264
DEC	7572	881	88	264
JAN	7572	881	88	264
FEB	7572	881	88	264
MAR	7572	881	88	264

PER CAPITA TANK EFFLUENT NITROGEN (g/day)	=	12
PER CAPITA TANK EFFLUENT PHOSPHORUS (g/day)	=	2.5
PER CAPITA GROWING SEASON NITROGEN UPTAKE (g/day)	=	1.6
PER CAPITA GROWING SEASON PHOSPHORUS UPTAKE (g/day)	=	.4

SUMMARY.TXT

W. Branch Delaware River 4/78-3/82 4 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	1.9	6.5	0.3	6.7
MAY	9.8	7.5	5.3	0.3	5.6
JUNE	8.3	9.7	1.8	0.0	1.8
JULY	8.6	11.3	0.1	0.0	0.2
AUG	10.4	9.2	1.2	0.9	2.0
SEPT	11.6	5.8	0.1	0.1	0.2
OCT	11.5	3.1	4.3	0.1	4.4
NOV	8.2	0.7	6.6	0.4	7.0
DEC	8.0	0.2	5.6	0.4	6.0
JAN	8.1	0.1	5.0	1.1	6.1
FEB	8.5	0.2	5.7	1.8	7.4
MAR	9.8	0.8	10.9	2.4	13.3
ANNUAL	112.3	50.7	53.1	7.8	60.8

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	29.2	0.0	30.7	31.1	1.9	2.0
MAY	35.7	0.2	26.9	27.7	1.8	2.1
JUNE	23.5	0.0	10.7	10.9	1.1	1.2
JULY	28.1	0.0	4.9	5.2	1.0	1.0
AUG	45.8	1.2	17.2	21.0	1.7	3.2
SEPT	45.0	0.0	6.2	6.6	1.1	1.1
OCT	11.2	0.1	21.3	21.8	1.6	1.7
NOV	6.3	0.9	33.3	36.1	2.1	3.2
DEC	0.8	1.1	28.9	32.3	1.9	3.3
JAN	0.4	1.1	41.4	45.0	3.6	5.1
FEB	0.5	4.4	55.4	68.8	4.9	10.6
MAR	3.7	6.0	86.6	104.8	7.0	14.8
ANNUAL	230.4	15.0	363.4	411.0	29.6	49.3

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
CORN	3430.	18.03	47.43	52.92	84.64	7.78	21.52
HAY	13085.	13.27	2.66	48.60	55.39	2.60	5.54
PASTURE	5093.	8.65	3.55	13.22	16.74	1.10	2.63
INACTIVE	3681.	8.65	3.77	5.10	7.80	0.41	1.59
FOREST	56682.	5.47	0.00	5.89	5.89	0.19	0.19
LOGGING	20.	0.00	48.10	0.00	0.19	0.00	0.08
BARN YARDS	41.	36.11	0.00	4.34	4.34	0.76	0.76
RES-imperv	104.	74.11	0.00	0.00	0.86	0.00	0.09
RES-perv	546.	9.20	0.00	0.00	0.29	0.00	0.04
COMM-imperv	49.	74.11	0.00	0.00	0.91	0.00	0.10
COMM-perv	41.	9.20	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	74.11	0.00	0.00	0.63	0.00	0.07
INDUS-perv	67.	9.20	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				149.58	149.58	5.72	5.72
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.13	38.13	1.11	1.11
TOTAL				363.37	411.05	29.57	49.34

MONTHLY.TXT

W. Branch Delaware River 4/78-3/82 YEAR 1

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	5.2	1.7	3.1	0.0	3.1
MAY	7.9	7.4	2.1	0.0	2.1
JUNE	10.5	9.7	1.8	0.0	1.8
JULY	10.8	10.9	0.3	0.0	0.4
AUG	17.0	10.4	4.6	3.4	8.1
SEPT	7.6	5.5	0.4	0.1	0.4
OCT	11.6	3.1	3.9	0.0	3.9
NOV	4.7	0.7	3.7	0.1	3.8
DEC	12.6	0.2	5.2	0.0	5.2
JAN	19.1	0.2	8.7	3.8	12.6
FEB	4.0	0.1	4.6	0.5	5.1
MAR	10.9	1.1	16.5	4.6	21.0
YEAR	121.9	50.9	54.9	12.6	67.4

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	8.3	0.0	14.9	15.0	1.3	1.3
MAY	13.3	0.0	11.3	11.5	1.1	1.2
JUNE	29.3	0.0	10.8	11.0	1.2	1.2
JULY	39.4	0.0	5.8	6.1	1.0	1.0
AUG	109.6	4.7	54.9	69.5	3.8	10.0
SEPT	35.4	0.0	6.8	6.9	1.1	1.1
OCT	10.3	0.0	17.8	18.1	1.4	1.4
NOV	1.4	0.0	18.2	18.4	1.4	1.4
DEC	1.8	0.0	22.1	22.3	1.5	1.5
JAN	0.0	3.8	100.4	112.2	8.9	13.9
FEB	0.0	0.2	32.7	33.5	2.8	3.1
MAR	5.0	7.7	139.6	163.2	11.2	21.3
YEAR	253.8	16.5	435.3	487.5	36.6	58.3

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
CORN	3430.	24.70	52.26	81.18	116.13	12.18	27.33
HAY	13085.	19.27	2.93	70.59	78.06	3.78	7.02
PASTURE	5093.	13.86	3.91	21.18	25.06	1.76	3.45
INACTIVE	3681.	13.86	4.15	8.16	11.14	0.66	1.95
FOREST	56682.	9.81	0.00	10.57	10.57	0.33	0.33
LOGGING	20.	0.00	52.99	0.00	0.21	0.00	0.09
BARN YARDS	41.	44.22	0.00	5.31	5.31	0.92	0.92
RES-imperv	104.	82.95	0.00	0.00	0.86	0.00	0.09
RES-perv	546.	14.52	0.00	0.00	0.30	0.00	0.04
COMM-imperv	49.	82.95	0.00	0.00	0.90	0.00	0.10
COMM-perv	41.	14.52	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	82.95	0.00	0.00	0.63	0.00	0.07
INDUS-perv	67.	14.52	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				154.61	154.61	5.91	5.91
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				435.30	487.55	36.58	58.33

W. Branch Delaware River 4/78-3/82 YEAR 2

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	11.0	1.8	8.5	0.7	9.2
MAY	15.3	7.6	6.8	0.6	7.5
JUNE	4.2	9.6	3.8	0.0	3.8
JULY	7.2	11.5	0.2	0.0	0.2
AUG	9.2	7.6	0.0	0.0	0.0
SEPT	14.3	6.0	0.0	0.1	0.1
OCT	11.2	3.4	6.7	0.1	6.7
NOV	13.5	0.9	8.6	0.8	9.4
DEC	5.0	0.4	6.7	0.0	6.7
JAN	3.7	0.2	4.3	0.0	4.3
FEB	4.0	0.1	1.4	0.0	1.4
MAR	14.8	0.7	10.7	3.0	13.7
YEAR	113.4	49.8	57.6	5.4	63.0

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	35.1	0.2	43.4	44.2	2.6	2.8
MAY	66.9	0.5	37.6	39.3	2.4	3.1
JUNE	11.2	0.0	17.2	17.3	1.3	1.4
JULY	15.4	0.0	4.9	5.1	0.9	1.0
AUG	19.1	0.0	4.4	4.6	0.9	1.0
SEPT	64.7	0.1	6.5	7.0	1.1	1.2
OCT	8.2	0.0	27.9	28.2	1.7	1.8
NOV	21.0	2.6	45.2	53.3	2.7	6.1
DEC	0.7	0.0	27.6	27.9	1.7	1.7
JAN	1.7	0.0	18.9	19.0	1.4	1.4
FEB	0.0	0.0	10.2	10.3	1.2	1.2
MAR	8.6	13.0	99.0	138.5	8.5	25.5
YEAR	252.7	16.4	342.6	394.6	26.4	48.1

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR (Mg)	TOT.NITR (Mg)	DIS.PHOS (Mg)	TOT.PHOS (Mg)
CORN	3430.	15.22	52.02	37.28	72.08	5.26	20.34
HAY	13085.	10.54	2.92	38.60	46.05	2.07	5.29
PASTURE	5093.	6.11	3.89	9.33	13.19	0.78	2.45
INACTIVE	3681.	6.11	4.13	3.60	6.56	0.29	1.58
FOREST	56682.	3.26	0.00	3.51	3.51	0.11	0.11
LOGGING	20.	0.00	52.75	0.00	0.21	0.00	0.09
BARN YARDS	41.	33.71	0.00	4.05	4.05	0.70	0.70
RES-imperv	104.	74.86	0.00	0.00	0.88	0.00	0.09
RES-perv	546.	6.62	0.00	0.00	0.28	0.00	0.04
COMM-imperv	49.	74.86	0.00	0.00	0.93	0.00	0.10
COMM-perv	41.	6.62	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	74.86	0.00	0.00	0.64	0.00	0.07
INDUS-perv	67.	6.62	0.00	0.00	0.03	0.00	0.01
GROUNDWATER				162.40	162.40	6.21	6.21
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.21	38.21	1.12	1.12
TOTAL				342.59	394.64	26.44	48.10

W. Branch Delaware River 4/78-3/82 YEAR 3

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	11.9	2.1	9.3	0.2	9.5
MAY	3.2	7.6	4.3	0.0	4.3
JUNE	10.4	9.1	0.2	0.0	0.2
JULY	9.5	11.5	0.0	0.0	0.0
AUG	9.9	10.3	0.0	0.0	0.0
SEPT	10.7	6.3	0.0	0.2	0.2
OCT	10.0	3.0	2.2	0.2	2.4
NOV	8.8	0.5	6.7	0.9	7.6
DEC	6.3	0.1	6.2	0.6	6.8
JAN	2.8	0.0	2.4	0.1	2.5
FEB	16.8	0.6	10.7	5.1	15.8
MAR	4.3	0.8	5.9	0.0	5.9
YEAR	104.6	52.0	47.8	7.4	55.2

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	45.5	0.0	40.9	41.2	2.2	2.3
MAY	6.7	0.0	19.2	19.3	1.4	1.4
JUNE	38.2	0.0	5.4	5.7	1.0	1.0
JULY	37.6	0.0	4.5	4.7	1.0	1.0
AUG	41.7	0.0	5.2	5.4	1.0	1.0
SEPT	36.6	0.1	7.1	7.5	1.1	1.2
OCT	15.9	0.1	16.3	17.0	1.5	1.7
NOV	0.5	0.8	40.3	43.1	2.5	3.6
DEC	0.2	0.6	33.9	35.8	2.1	2.9
JAN	0.0	0.0	15.6	15.8	1.5	1.6
FEB	2.1	13.0	126.8	166.2	11.1	28.0
MAR	0.7	0.0	25.7	26.0	1.7	1.7
YEAR	225.7	14.7	340.9	387.6	28.1	47.5

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR (Mg)	TOT.NITR (Mg)	DIS.PHOS (Mg)	TOT.PHOS (Mg)
CORN	3430.	17.55	46.48	48.63	79.72	7.06	20.53
HAY	13085.	12.74	2.61	46.69	53.34	2.50	5.38
PASTURE	5093.	8.17	3.47	12.48	15.93	1.04	2.54
INACTIVE	3681.	8.17	3.69	4.81	7.46	0.39	1.54
FOREST	56682.	5.14	0.00	5.54	5.54	0.17	0.17
LOGGING	20.	0.00	47.13	0.00	0.18	0.00	0.08
BARN YARDS	41.	35.45	0.00	4.26	4.26	0.74	0.74
RES-imperv	104.	70.37	0.00	0.00	0.85	0.00	0.08
RES-perv	546.	8.69	0.00	0.00	0.28	0.00	0.04
COMM-imperv	49.	70.37	0.00	0.00	0.90	0.00	0.10
COMM-perv	41.	8.69	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	70.37	0.00	0.00	0.62	0.00	0.07
INDUS-perv	67.	8.69	0.00	0.00	0.03	0.00	0.01
GROUNDWATER				134.79	134.79	5.15	5.15
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				340.89	387.61	28.08	47.45

W. Branch Delaware River 4/78-3/82 YEAR 4

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	10.3	2.1	5.0	0.1	5.1
MAY	13.0	7.4	8.1	0.5	8.6
JUNE	8.1	10.4	1.4	0.0	1.4
JULY	7.0	11.4	0.1	0.0	0.1
AUG	5.4	8.7	0.0	0.0	0.0
SEPT	13.7	5.4	0.0	0.0	0.0
OCT	13.1	2.9	4.6	0.2	4.7
NOV	5.9	0.7	7.3	0.0	7.3
DEC	8.2	0.1	4.3	1.1	5.5
JAN	6.6	0.1	4.6	0.4	5.0
FEB	9.1	0.1	5.9	1.5	7.4
MAR	9.0	0.7	10.7	1.8	12.5
YEAR	109.4	50.0	52.0	5.7	57.7

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	28.0	0.0	23.5	23.9	1.6	1.7
MAY	55.8	0.4	39.3	40.8	2.3	2.9
JUNE	15.4	0.0	9.3	9.4	1.1	1.1
JULY	20.1	0.0	4.6	4.8	0.9	1.0
AUG	12.7	0.0	4.3	4.5	0.9	0.9
SEPT	43.2	0.0	4.6	4.9	1.0	1.0
OCT	10.5	0.2	23.0	23.8	1.6	1.9
NOV	2.4	0.0	29.5	29.7	1.7	1.7
DEC	0.5	3.6	32.0	43.2	2.2	7.0
JAN	0.0	0.7	30.6	32.9	2.6	3.5
FEB	0.0	4.3	51.9	65.1	4.5	10.1
MAR	0.7	3.1	82.0	91.6	6.7	10.7
YEAR	189.3	12.3	334.7	374.4	27.2	43.5

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
CORN	3430.	14.66	38.98	44.57	70.64	6.60	17.89
HAY	13085.	10.52	2.19	38.54	44.12	2.06	4.48
PASTURE	5093.	6.48	2.91	9.90	12.79	0.82	2.08
INACTIVE	3681.	6.48	3.10	3.81	6.04	0.31	1.27
FOREST	56682.	3.67	0.00	3.95	3.95	0.12	0.12
LOGGING	20.	0.00	39.52	0.00	0.15	0.00	0.07
BARN YARDS	41.	31.05	0.00	3.73	3.73	0.65	0.65
RES-imperv	104.	68.27	0.00	0.00	0.87	0.00	0.09
RES-perv	546.	6.96	0.00	0.00	0.30	0.00	0.04
COMM-imperv	49.	68.27	0.00	0.00	0.92	0.00	0.10
COMM-perv	41.	6.96	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	68.27	0.00	0.00	0.64	0.00	0.07
INDUS-perv	67.	6.96	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				146.50	146.50	5.60	5.60
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				334.70	374.40	27.18	43.49

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Appendix E
Calculation Details

This appendix provides details for the computation of GWLF input parameters requiring multiple steps.

Curve Number

The curve number must be developed within an ArcView project named *iepa_prepro.apr*, which contains all of the necessary extensions except Spatial Analyst. The Spatial Analyst extension of ArcView must be available for this calculation.

1. Add the landuse and STATSGO shapefiles and the landuse grid to the View. Open the attribute table for the STATSGO shapefile.
2. Add the attribute tables lookup.dbf and statsgoc.dbf to the project. The lookup table is common to any soil/landuse combination, but the STATSGO table must reflect the area for which the curve number is being calculated. In the statsgoc.dbf table, the field *comppct* identifies the percentage of each soil type in a map unit. This field is a string field and must be converted to a number field.
3. To convert the string field to a number field: add a new number field to the statsgoc.dbf attribute table named *comppct2*, and fill it with the values of the field *comppct* (to fill a number field with values from a string field, the calculation should read "*comppct.AsNumber*"). Delete the field *comppct*. Create a new number field, *comppct*, and fill it with the values of *comppct2*. Delete the field *commct2*. The *comppct* field now exists as a number field.
4. From the CRWR-PrePro menu, select "Soil Group Percentages". When prompted, input statsgo.dbf for the map unit table and statsgoc.dbf for the component table. The script will automatically create an output table, muidjoin.dbf, listing the percentage of each hydrologic soil group in each map unit.
5. From the CRWR-PrePro menu, select "Curve Number Grid". When prompted, select the STATSGO shapefile as the soils theme, the landuse shapefile as the landuse theme, lookup.dbf as the lookup table, muidjoin.dbf as the table with the soil group percentages, and set the analysis extent and the cell size to the landuse grid. The curve number grid can take between 2 and 15 minutes to compute depending on the computer speed and size of the basin.
6. Save the temporary curve number grid as a permanent grid named *CN_grid*.
7. To average the curve number grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table E-1 lists the curve numbers for each landuse in the Kinkaid Lake Watershed.

Table E-1 Curve Numbers in Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
Row-Crop	82.1	81.9	77.5	83.1
Small Grains	80.1	77.7	75.2	79.8
Rural Grassland	68.7	68.6	61.7	72.5
Urban Grassland	74.2	---	---	---
Deciduous1	59.4	62.2	65.5	65
Deciduous2	66.2	82.2	89.4	62.1
Coniferous	61.1	63.6	60.3	---

Cattle Feedlot	74.2	---	---	73.9
Open Water	99.8	100	99.9	100
Shallow Marsh	99.6	89.5	---	100
Deep Marsh	100	---	---	100
Forested Wetland	100	100	100	99.7
Shallow Water Wetland	100	94.6	100	98.8
Barren Land	100	---	---	---
High Density	90.1	---	---	---
Medium Density	81.2	---	---	---

Soil Erodibility Factor (K)

The K factor is developed in ArcView and Excel.

1. In ArcView, add the attribute tables statsgoc.dbf and statsgol.dbf to the Table list. Join the statsgoc.dbf table to the statsgol.dbf table by field *muidsegnum*. This appends the percentage of each soil type to the soils in each layer. Export the joined table as a .dbf named statsgo_kf.dbf.
    1. Open the table statsgo_kf.dbf in Excel. Remove all fields except *muid, layernum, kffact, kfact,* and *comppct*.
    2. Sort the entire table by *layernum* then by *muid*. This promotes all soils in layer 1 to the top of the spreadsheet.
    3. Remove all records for soils below layer 1.
    4. Ensure the sum of the *comppct* field for each muid is equal to 100.
    5. In a new column labeled *product*, multiply *kffact* by *comppct* and divide by 100 for each record. If the value in the *kffact* field is zero, use the value in the *kfact* field
    6. In a new column labeled *kffact_r* (revised), sum *product* over each muid to obtain the revised K factor for each muid.
    7. Copy the *kffact_r* column and use the "Paste Special/Values" option to paste the column into the *layernum* column. This is done so that the *kffact_r* values will be retained when the statsgo_kf.dbf table is saved and used again in ArcView.
    8. Delete all columns except for *muid* and *kffact_r*. Delete any rows without a value in the *kffact_r* field.
    9. Save the table.
    10. In ArcView, add the table statsgo_kf.dbf, the STATSGO shapefile in UTM 16 projection, and the landuse grid. Join the statsgo_kf.dbf table to the statsgo.dbf table by *muid*. This attaches the average K factor to each muid in statsgo.dbf.
    11. Set the analysis extent and cell size to the landuse grid.
    12. Convert the SATSGO shapefile to a grid using the *kffact_r* field as the grid value.
    13. To average the K factor grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table E-2 presents the resulting K-factors associated with each landuse and used in the GWLF program.

Table E-2 Weighted K factors for the Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4

Row Crop	0.39	0.39	0.37	0.40
Small Grains	0.39	0.38	0.37	0.39
Urban Grassland	0.41	---	---	---
Rural Grassland	0.39	0.39	0.37	0.39
Deciduous1	0.38	0.37	0.37	0.37
Deciduous2	0.39	0.37	0.37	0.38

Topographic Factor (LS)

The topographic factor is calculated from a series of equations presented below.

$L = (\Lambda/72.6)^m$

$m = B/(1+B)$

$B = (\sin\Theta/0.0896) / (3.0(\sin\Theta)^{0.8} + 0.56)$

$\Theta = \arctan(\text{slope}/100)$

$S = 10.8\sin\Theta + 0.03$ where slope $\leq$ 9%

$S = 16.8\sin\Theta - 0.50$ where slope > 9%

Computation of the LS factor is done in the ArcView project *iepa_prepro.apr*.

1. In ArcView, add the Digital Elevation Model (DEM) to the View
2. Set the analysis extent and cell size to the DEM.
3. Select "Fill Sinks" from the CRWR-PrePro menu to fill sinks in the DEM. Save the temporary grid as a permanent grid named *Fill_grid*.
4. Open the script "New_Slope" from the project window, and press the "Run" button to compute percent slopes from the filled DEM. Save the temporary grid as a permanent grid named *Slope_grid*.
5. Select "Flow Direction" from the CRWR-PrePro menu to derive the direction of flow through each grid cell. Save the temporary grid as a permanent grid named *Fdr_grid*.
6. Compute the theta grid (in radians) with the map calculator.
   Map Calc. Statement: (([slope_grid] / 100)).Atan
   Save Map Calc 1 as a permanent grid named *Theta_grid*.
7. Compute the S grid with the map calculator and a succession of calculations
   Map Calc. 1: ([slope_grid] <= 9)
   Output: 1 in cells where slope is less or equal to 9; zero elsewhere
   Map Calc. 2: ((([theta_grid].Sin) * 10.8) + 0.03)
   Output: S-value computed for slopes <= 9 in all cells
   Map Calc. 3: ([Map Calculation 2 * [Map Calculation 1])
   Output: Correct S-value in cells with slope <= 9; zero elsewhere
   Map Calc. 4: ([slope_grid] > 9)
   Output: 1 in cells where slope > 9, zero elsewhere
   Map Calc. 5: ((([theta_grid].Sin) * 16.8) - 0.5)
   Output: S-value computed for slopes > 9 in all cells
   Map Calc. 6: ([Map Calculation 5] * [Map Calculation 4])
   Output: Correct S-value in cells with slope > 9; zero elsewhere

Map Calc. 7: ([Map Calculation 3] + [Map Calculation 6])
Output: Correct S-value in each cell
Save Map Calculation 7 as a permanent grid named *S_grid*.

8. Compute the Beta grid with the map calculator.
Map Calc. 1: (([theta_grid].Sin) / 0.0896) /
((([theta_grid].Sin).Pow(0.8)) * 3.0 + 0.56)
Save Map Calculation 1 as a permanent grid named *Beta_grid*.

9. Compute the M grid with the map calculator.
Map Calc. 1: ([beta_grid] / ([beta_grid] + 1))
Save Map Calculation 1 as permanent grid named *M_grid*.

10. Compute the flow length (Lambda) grid with the map calculator and a succession of calculations
Map Calc. 1: ([fdr] = 1 OR [fdr] = 4 OR [fdr] = 16 OF [fdr] = 64)
Output: 1 in cells flowing in cardinal direction and 0 in other cells
Map Calc. 2: ([Map Calculation 1] * 30.8875)
{30.885 = cell length}
Output: 30.885 in cells flowing in cardinal direction and 0 in others.
Map Calc. 3: ([Map Calculation 2] = 0)
Output: 0 in cells flowing in cardinal direction and 1 in others
Map Calc. 4: ([Map Calculation 3] * 43.682)
{43.682= length across cell diagonal}
Output: 43.682 in cells flowing in non-cardinal direction, 0 in others.
Map Calc. 5: ([Map Calculation 4] + [Map Calculation 2])
Output: correct flow lengths in each cell – 30.885 in cardinal, 43.682 in others
Map Calc. 6: ([Map Calculation 5] * 100 / 2.54 / 12
Output: flow length grid in feet
Save Map Calculation 6 as a permanent grid named *Lambda_grid*

11. Compute the L with the map calculator.
Map Calc. Statement: ([lambda_grid] / 72.6).Pow([m_grid])
Save Map Calculation 1 as a permanent grid named *L_grid*.

12. Compute the LS grid with the map calculator.
Map Calc. Statement: ([L-grid] * [S_grid])
Save Map Calculation 1 as a permanent grid named *LS_grid*.

13. To average the LS grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table E-3 presents the resulting LS factors for each rural landuse used in GWLF.

Table E-3 Weighted LS factors for the Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
Row Crop	0.891	1.163	2.105	0.597
Small Grains	0.879	0.793	0.584	0.614
Urban Grassland	0.358	---	---	---

Rural Grassland	1.023	0.819	1.242	0.797
Deciduous1	1.886	2.554	2.890	2.086
Deciduous2	0.931	1.297	2.311	1.571

In the following discussions, fields in bold type represent calculations in Excel. Fields in non-bold type are input fields.

Cropping Management Factor (C factor)

The C factor is calculated in Excel. C factors were selected for each crop by tillage practice and crop rotation from the table provided by the Jackson County NRCS office included as Appendix F. The Jackson County NRCS office also provided an estimate of the percentage of each crop rotation across the Kinkaid Lake Watershed. The spreadsheet used to calculate a weighted c-factor for corn, soybeans, and small grains is shown at the end of this appendix. The values in the Table 1 of the spreadsheet are a weighted average of values from columns C and F. This weighted average allows the influence of crop rotations to be included in the c-factors for the Kinkaid Lake Watershed. The values in the Table 1 are then weighted by the percentage of each tillage practice in Table 2 to determine a single c-factor for corn, soybeans, and small grains.

The weighted C factor for each crop is then appended to the table of Cropland Data Layer landuses and areas in the Kinkaid Lake watershed. Table E-4 shows the Cropland Data Layer landuse areas, and C factors. C factors for landuses other than corn, soybean, and small grains were obtained from the table included as Appendix F.

Table E-4 Cropland Data Layer C factors for Kinkaid Lake Watershed

Landuse	Subbasin 1 C-factor	Subbasin 2 C-factor	Subbasin 3 C-factor	Subbasin 4 C-factor
High Density	---	---	---	---
Medium Density	---	---	---	---
Row Crop	0.14	0.11	0.12	0.14
Small Grains	0.13	0.13	0.13	0.13
Urban Grassland	0.02	---	---	---
Rural Grassland	0.02	0.02	0.02	0.02
Deciduous	0.003	0.003	0.003	0.003
Deciduous	0.003	0.003	0.003	0.003
Coniferous	0.003	0.003	0.003	---

The landuse classes in GWLF are represented by the Critical Trends Land Assessment classes rather than the Cropland Data Layer classes, so an area-weighted average was used to calculate the C factor coefficients for "Row Crop" and "Small Grains" in the Critical Trends Land Assessment landuse file. Table E-5 shows the Critical Trends Land Assessment landuse classes and the calculated C factor coefficients. The coefficient for "Row Crop" was calculated with an area-weighed average of the C factors for corn, soybeans, and half of the double-cropped WW/SB area in the Cropland Data Layer. The coefficient for "Small Grains" was calculated with an area-weighted average of the C factors for winter wheat, other small grains and hay, and half of double-cropped WW/SB area from the Cropland Data Layer.

Table E-5 C Factors by Critical Trends Assessment Landuse Classes in the Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
Row Crop	0.14	0.11	0.12	0.14
Small Grains	0.13	0.13	0.13	0.13
Urban Grassland	0.02	---	---	---
Rural Grassland	0.02	0.02	0.02	0.02
Deciduous	0.003	0.003	0.003	0.003
Coniferous	0.003	0.003	0.003	---

Evapotranspiration (ET) Cover Coefficient

The ET cover coefficient was calculated in an Excel spreadsheet. The cover coefficients for crops available in the GWLF Manual and the crops listed in the Cropland Data Layer landuse file differ. Therefore, crops in the Cropland Data Layer file were summed into classes matching the available crop cover coefficients. Table E-6 shows the original and adjusted areas for Kinkaid Lake. The adjusted sorghum area is the sum of sorghum and other small grains and hay, and the adjusted soybean area represents soybeans plus half of the double-cropped WW/SB area. Adjusted area from winter wheat represents winter wheat plus half the double-cropped WW/SB area.

Table E-6 Cropland Data Layer Landuses, Areas and Adjusted Areas

	Subbasin 1		Subbasin 2		Subbasin 3		Subbasin 4	
Landuse	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)
Corn	4802400	4802400	316800	316800	36000	36000	1279800	1279800
Sorghum	---	4111200	---	295200	---	53100	---	860400
Soybeans	4550400	6004800	897300	1093500	86400	96750	1354500	1793700
Winter Wheat	864900	2319300	96300	292500	19800	30150	117000	556200
Other Small Grains & Hay	4111200		295200		53100		860400	
Double-Cropped WW/SB	2908800		392400		20700		878400	
Idle Cropland/ CRP	61200	61200	1800	1800	900	900	16200	16200
Fallow/ Idle Cropland	5445900	5445900	1684800	1684800	151200	151200	2065500	2065500
Pasture/Grassland/ Nonagricultural	20782800	20782800	3417300	3417300	912600	912600	7005600	7005600
Woods	42413400	42413400	16074900	16074900	7675200	7675200	11617200	11617200
Clouds	203400	203400	63900	63900	8100	8100	78300	78300
Urban	965700	965700	47700	47700	11700	11700	277200	277200
Water	607500	607500	1380600	1380600	1232100	1232100	4717800	4717800
Buildings/Homes/ Subdivisions	1317600	1317600	92700	92700	37800	37800	325800	325800
Wetlands	834300	834300	225000	225000	99900	99900	411300	411300
Total	89869500	89869500	24986700	24986700	10345500	10345500	31005000	31005000

Table E-7 shows the calculation of a single crop coefficient for each 10% of the growing season and for each calendar month. The ET cover coefficients for each crop were obtained from page 29 of the GWLF Manual. To create the coefficient for each 10% of the growing season, each crop coefficient in columns B-E was weighted by its corresponding area in Table A-8. An average monthly ET coefficient (column G) was

calculated from the coefficients in Column F, and then each growing season was assigned to a calendar month (Column H).

Table E-7 Calculation of the Monthly Crop Evapotranspiration Cover Coefficients for Subbasin 1 of the Kinkaid Lake Watershed

A	B	C	D	E	F	G	H
% of Growing Season	Field Corn	Grain Sorghum	Winter Wheat	Soybeans	**Weighted Average ET Coefficient**	**Average Monthly ET Coefficient**	Month
0	0.45	0.3	1.08	0.3	**0.45**	**0.45**	Nov - Apr
10	0.51	0.4	1.19	0.35	**0.52**		
20	0.58	0.65	1.29	0.58	**0.69**	**0.61**	May
30	0.66	0.9	1.35	1.05	**0.95**		
40	0.75	1.1	1.4	1.07	**1.03**	**0.99**	June
50	0.85	1.2	1.38	0.94	**1.04**	**1.04**	July
60	0.96	1.1	1.36	0.8	**0.99**		
70	1.08	0.95	1.23	0.66	**0.92**	**0.96**	August
80	1.2	0.8	1.1	0.53	**0.86**		
90	1.08	0.65	0.75	0.43	**0.71**	**0.78**	September
100	0.7	0.5	0.4	0.36	**0.49**		
					0.45	**0.47**	October

Table E-8 shows the calculation of a single area-weighted crop coefficient for each month. First, the crop coefficients from Table E-7 were entered into Column B of Table E-8. The monthly ET values in Columns C, D, E, F, and G were obtained from the GWLF Manual, pages 29 and 30. A monthly cover coefficient for water and wetlands was assumed to be 0.75. Finally, a single area-weighted crop coefficient for each month was calculated (Column H) from the adjusted areas in Table E-6 and the monthly ET cover coefficients in Table E-8.

Table E-8 Calculation of a Monthly ET Cover Coefficient in Subbasin 1 of the Kinkaid Lake Watershed

A	B	C	D	E	F	G	H
	Crop	Pasture	Forest	68% Urban	30% Urban	Water/ Wetland	**Weighted Average ET**
April	0.45	1.09	0.3	0.32	0.7	0.75	**0.58**
May	0.61	0.95	1	0.32	0.7	0.75	**0.90**
June	0.99	0.83	1	0.32	0.7	0.75	**0.94**
July	1.04	0.79	1	0.32	0.7	0.75	**0.93**
August	0.96	0.8	1	0.32	0.7	0.75	**0.92**
September	0.78	0.91	1	0.32	0.7	0.75	**0.92**
October	0.47	0.91	1	0.32	0.7	0.75	**0.86**
November	0.45	0.83	0.3	0.32	0.7	0.75	**0.50**
December	0.45	0.69	0.3	0.32	0.7	0.75	**0.46**
January	0.45	1.16	0.3	0.32	0.7	0.75	**0.60**
February	0.45	1.23	0.3	0.32	0.7	0.75	**0.62**
March	0.45	1.19	0.3	0.32	0.7	0.75	**0.61**

Table E-9 shows the calculated ET cover coefficients for each subbasin in the Kinkaid Lake Watershed.

Table E-9 ET Cover Coefficients in the Kinkaid Lake Watershed

Month	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
April	0.58	0.50	0.44	0.63
May	0.90	0.94	0.95	0.88
June	0.94	0.95	0.95	0.90
July	0.93	0.94	0.95	0.89
August	0.92	0.93	0.94	0.89
September	0.92	0.94	0.95	0.89
October	0.86	0.92	0.95	0.85
November	0.50	0.45	0.42	0.56
December	0.46	0.42	0.40	0.52
January	0.60	0.52	0.45	0.66
February	0.62	0.53	0.46	0.68
March	0.61	0.52	0.45	0.66

A B C

Corn-Soybean Rotation
75% of watershed

Conventional Till (Spring Plow)	
Corn after Soybean	0.3
Soybean after Corn*	0.25
Reduced-Till (20% Cover)	
Corn after Soybean	0.35
Soybean after Corn*	0.17
Mulch-Till (30% cover)	
Corn after Soybean	0.32
Soybean after Corn*	0.15
No-Till (70%/30% Cover)	
Corn after Soybean	0.16
Soybean after Corn*	0.06

*Assumed Drilled

D E F

Corn-Soybean-Wheat Rotation
25% of watershed

Conventional Till (Spring Plow)	
Corn after Wheat**	0.25
Soybean after Corn*	0.25
Wheat after Soybean#	0.15
Reduced-Till (20% Cover)	
Corn after Wheat**	0.21
Soybean after Corn*	0.17
Wheat after Soybean#	0.13
Mulch-Till (30% cover)	
Corn after Wheat**	0.18
Soybean after Corn*	0.15
Wheat after Soybean#	0.12
No-Till (70%/30% Cover)	
Corn after Wheat**	0.05
Soybean after Corn*	0.06
Wheat after Soybean#	0.09

*Assumed Drilled
**Used Corn after Small Grain
#Used Small Grain after Soybean

G H I J

Table 1 - C-factors Weighted by Percent of Crop Rotation in the Watershed

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	0.29	0.25	0.15
Reduced Till	0.32	0.17	0.13
Mulch-Till	0.29	0.15	0.12
No-Till	0.13	0.06	0.09

Table 2 - Tillage Practice Percentages in Kinkaid Lake Watershed

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	20%	0%	20%
Reduced Till	15%	10%	50%
Mulch-Till	15%	5%	10%
No-Till	50%	85%	20%

C-factors Weighted by Percent of Each Tillage Practice

Corn	Soybeans	Small Grains
0.21	0.08	0.13

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Appendix F
Crop Management "C" Factor Values for Rainfall E.I. Distribution Curve #19

TABLE 3 - CROP MANAGEMENT "C" FACTOR VALUES FOR RAINFALL "E.I." DISTRIBUTION CURVE # 19 1/

CROP SEQUENCE		FALL PLOW	SPRING PLOW	CHISEL - DISK - RIDGE 2/ % Cover After Plant				No-Till % Cover After Plant			
				20%	30%	40%	50%	60%	70%	80%	90%
CORN after Soybeans		.43	.30	.35	.32	.27	---	20% .20	30% .16	40% .12	3/
CORN after Corn		.38	.25	.20	.18	.15	.13	.07	.05	.04	.03
CORN after Small Grain		.39	.25	.21	.18	.16	.14	.07	.05	.04	.03
CORN after Meadow 4/		.17	.11	.11	.09	.08	.07	.03	.02	.01	.01
CORN 2nd yr. after Meadow 4/		.33	.21	.18	.16	.14	.12	.06	.05	.04	.03
SOYBEANS after Soybeans 5/	Wide Row	.48	.37	.37	.36	---	---	20% .22	30% .17	40% .13	3/
	Drill	.42	.29	.34	.33	---	---	.19	.14	.10	
SOYBEANS after Corn 5/	Wide Row	.40	.31	.19	.16	.14	.12	.08	.06	.04	.03
	Drill	.34	.25	.17	.15	.13	.11	.07	.06	.04	.03
SOYBEANS after Sm. Grain 5/	Wide Row	.45	.27	.22	.19	.17	.15	.08	.07	.04	.03
	Drill	.38	.22	.18	.16	.14	.12	.08	.07	.04	.03
SOYBEANS after Meadow 4, 5/	Wide Row	.19	.14	.09	.07	.06	.05	.03	.02	.01	.01
	Drill	.16	.11	.08	.07	.06	.05	.03	.02	.01	.01
SOYBEANS after Corn 2nd year after meadow 5/	Wide Row	.35	.26	.16	.14	.12	.11	.08	.06	.04	.03
	Drill	.30	.21	.15	.13	.11	.10	.07	.06	.04	.03
SMALL GRAIN after Corn (Grain) 6/		.15	.14	.11	.10	.09	.08	.06	.05	.04	.03
SMALL GRAIN after Corn (Silage) 7/		.22	---	.22	---	---	---	.16	---	---	---
SMALL GRAIN after Soybeans 6/		.17	.15	.13	.12	---	---	20% .10	30% .09	40% .08	3/

WHEAT/SOYBEANS (Double Crop)

		Tillage for Soybeans: Plow	Disk	No-Till
Tillage for Wheat	Plow	.32	.20	.16
	Disk	.24	.12	.08
	No-Till	.20	.08	.04

Meadow (Full year-Established)
Grass-Legume .004
Legume only .02

USDA-SCS-Illinois
February, 1982 *

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Footnotes for "C" Factor Tables

1. Values in this table are based on high level management with yields equal to or exceeding the following: corn - 100 bu/ac; soybeans - 40 bu/ac; wheat - 45 bu/ac; oats - 60 bu/ac; meadow - 3 tons/ac. For medium level management multiply factors by 1.2.

2. Values for chisel and disk systems are for fall primary tillage and two secondary tillage operations prior to planting. For primary tillage in the spring and ridge planting up and down hill multiply values by the appropriate factor: E.I. Curve 14-.9; E.I. Curve 16-.8; E.I. Curve 19-.7. For ridge planting on the contour, multiply values by the appropriate factor: E.I. Curve 14-.7; E.I. Curve 16-.6; E.I. Curve 19-.5. (These factors are in addition to the appropriate "P" factor.) Ridge planting is applicable only for row crops following row crops.

3. Percentages apply only to crops following soybeans.

4. Values are based on sod or a grass-legume mixture consisting of at least 50% grass and has been established at least one full growing season. If meadow stand is primarily legume, multiply factor by 1.2.

5. Use wide row factors for row widths greater than 20 inches and drill factors for 20 inches and less.

6. The same factors are applicable for both small grain with and without meadow seedings.

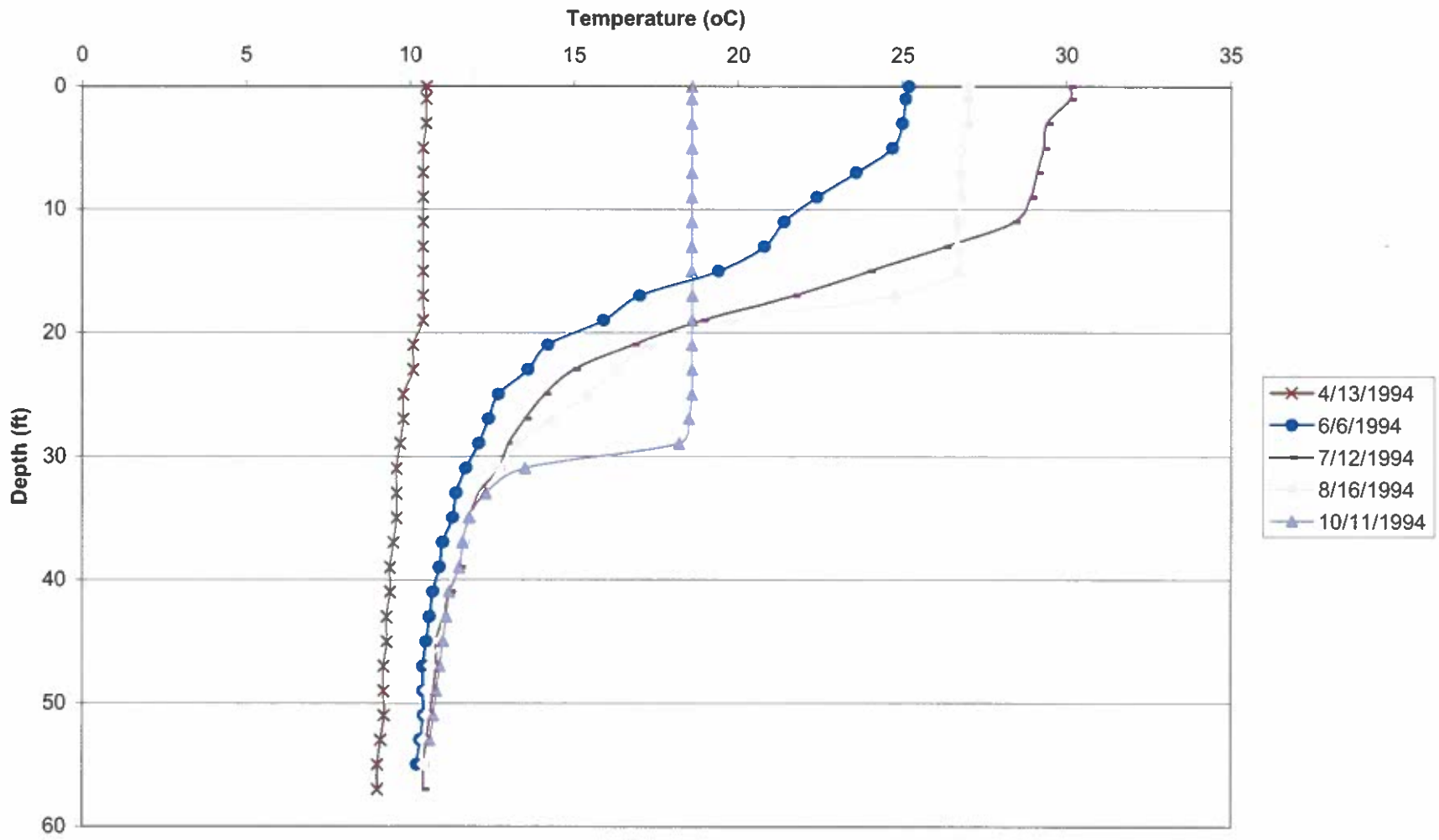
7. Factors for Disk and No-till are for the tillage system with no residue on surface after planting.

RLD:tm:6/7

R02175

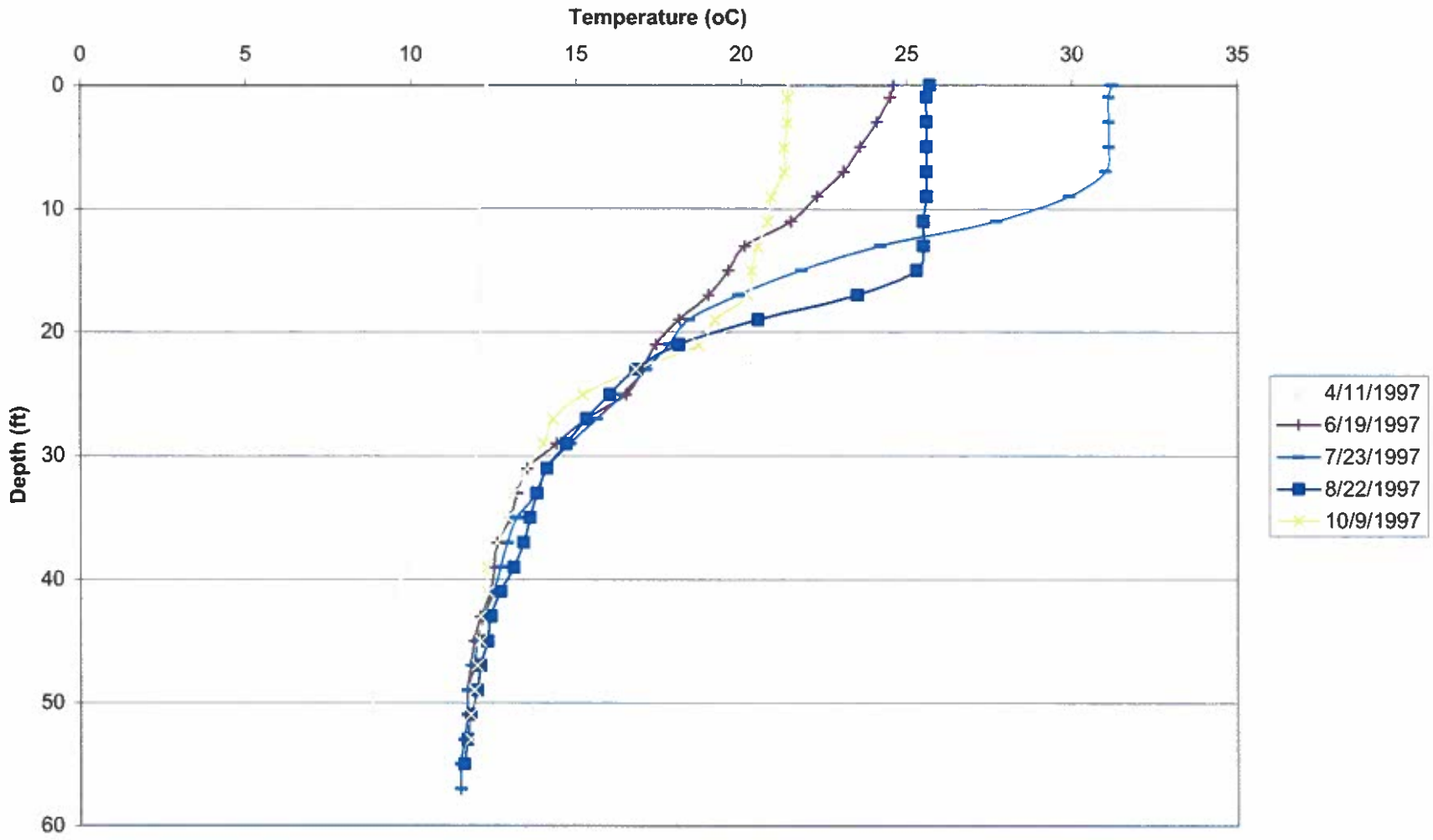
Appendix G
Metalimnion Charts

1994 Temperature Profile
Kinkaid Lake (RNC-1)



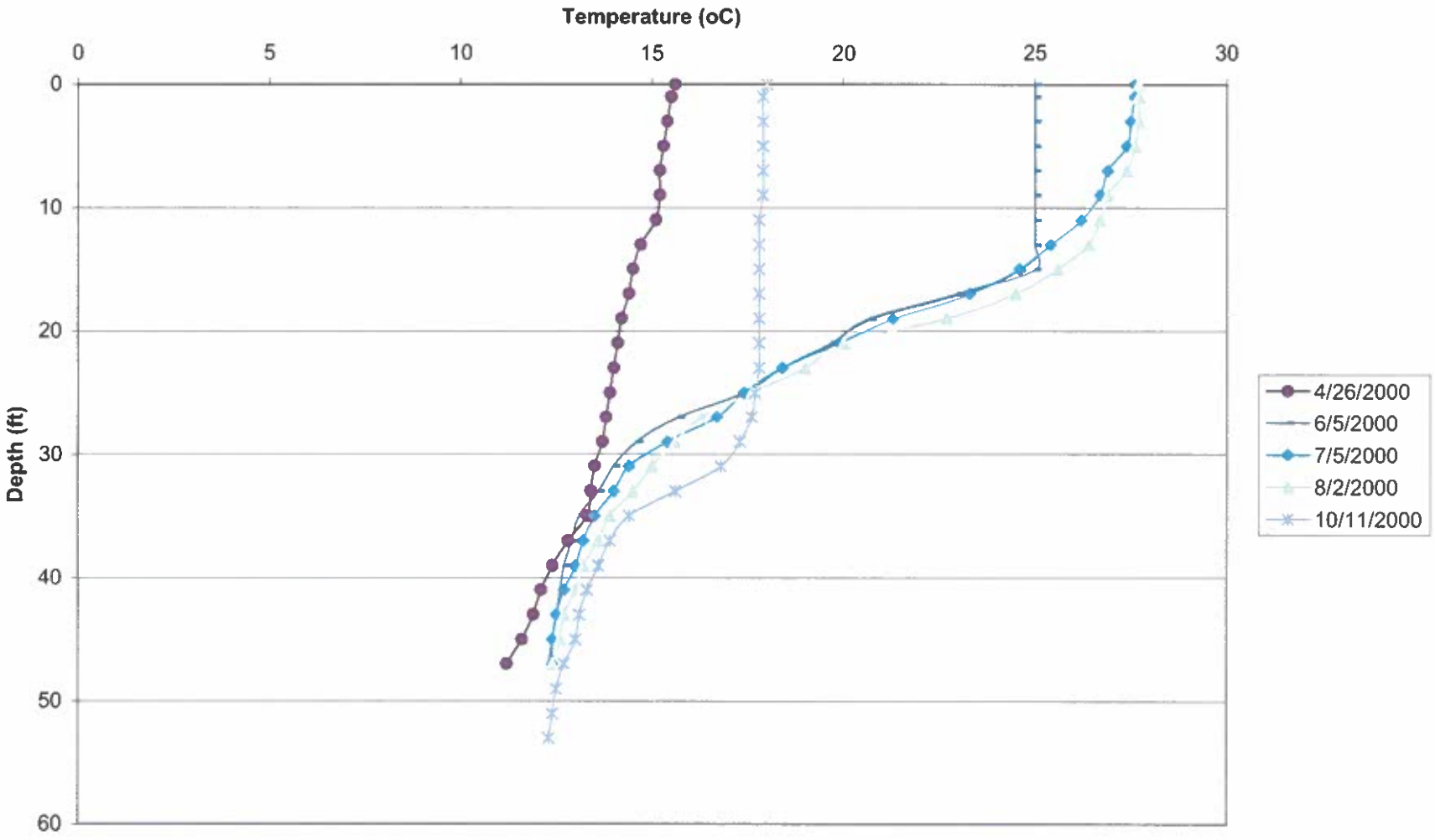
R02177

1997 Temperature Profile
Kinkaid Lake (RNC-1)

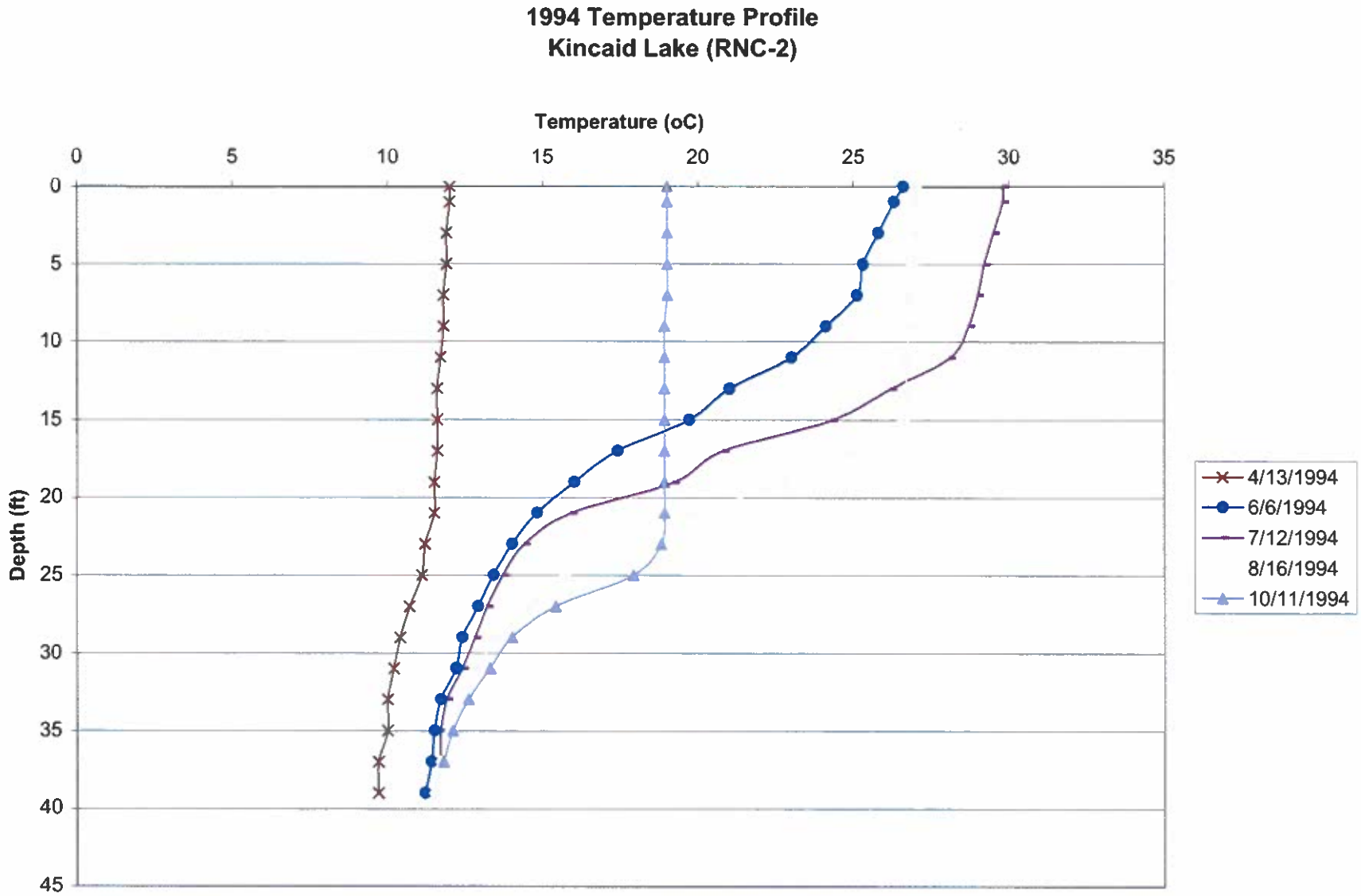


R02178

2000 Temperature Profile
Kinkaid Lake (RNC-1)

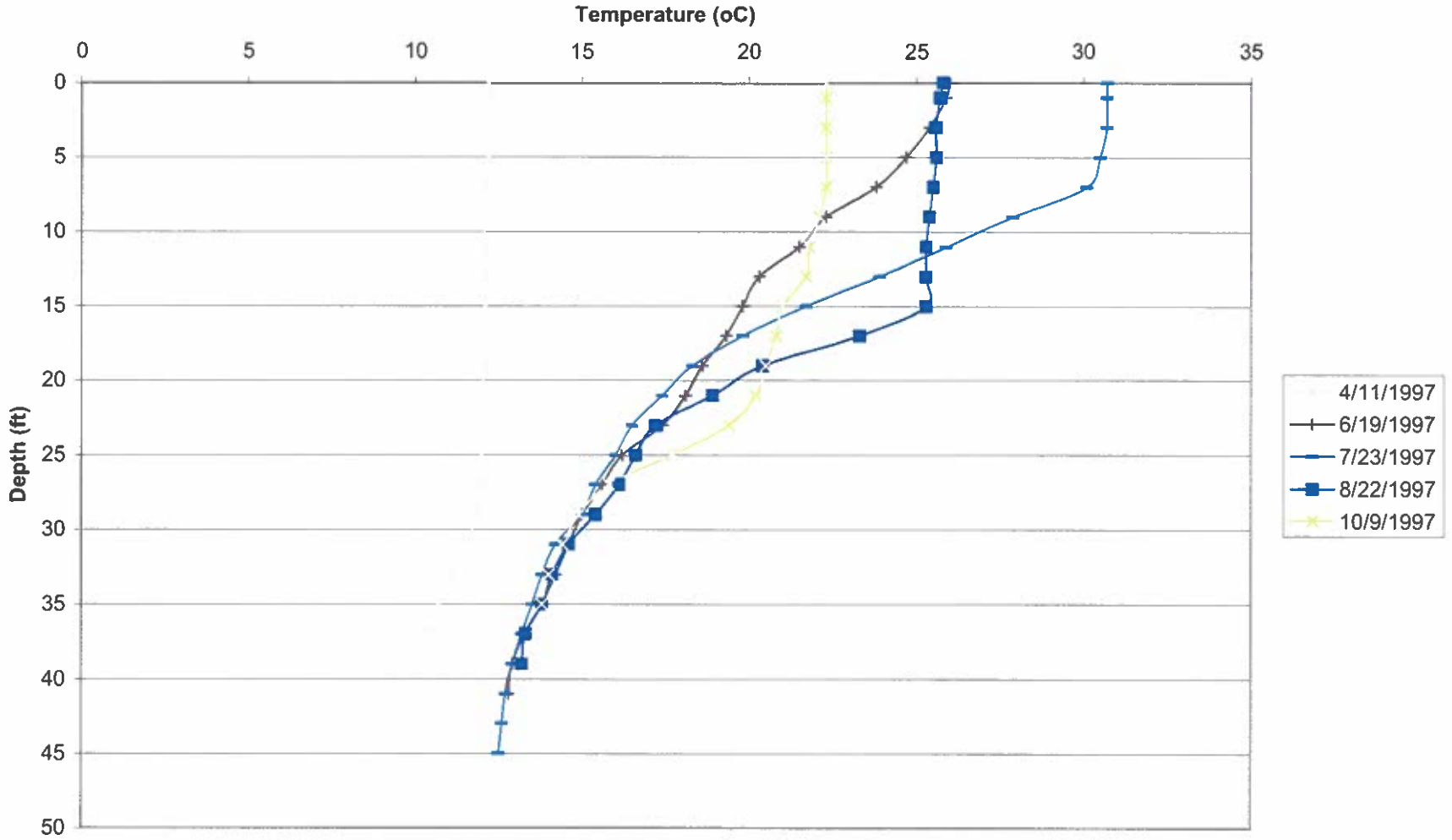


R02179


1994 Temperature Profile
Kincaid Lake (RNC-2)
Temperature (oC)
0
5
10
15
20
25
30
35
Depth (ft)
0
5
10
15
20
25
30
35
40
45
4/13/1994
6/6/1994
7/12/1994
8/16/1994
10/11/1994

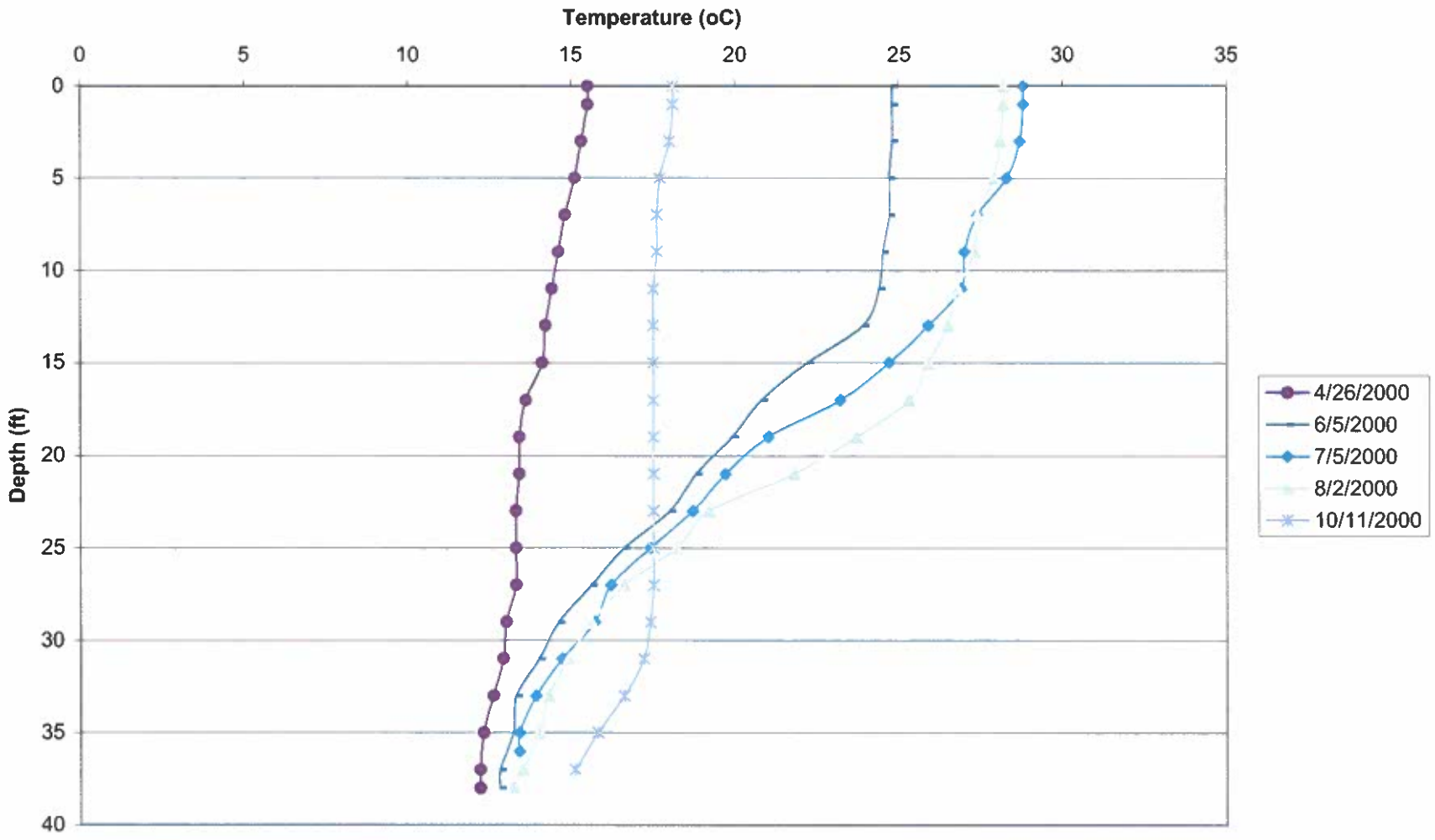
R02180

1997 Temperature Profile
Kincaid Lake (RNC-2)

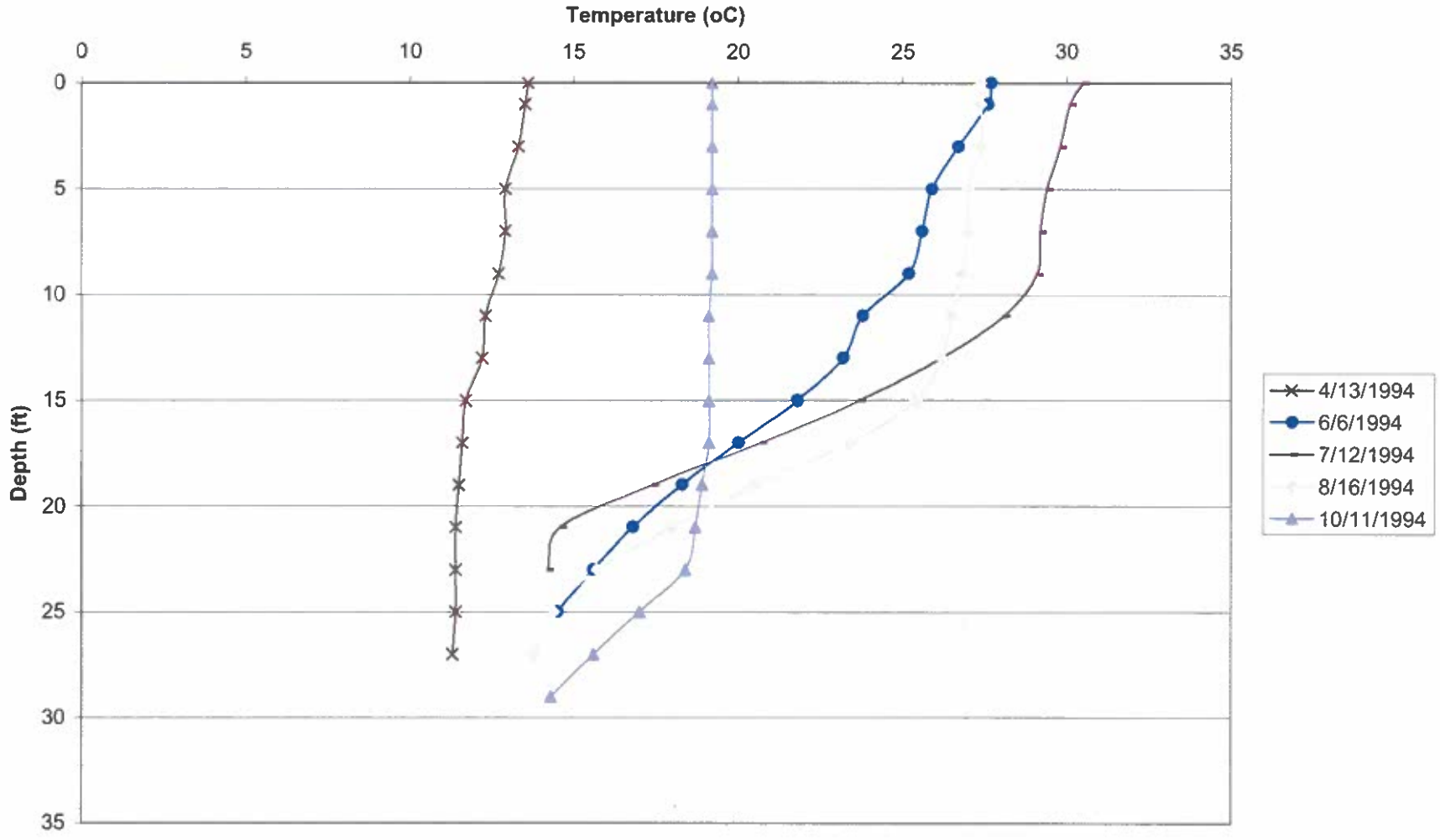


R02181

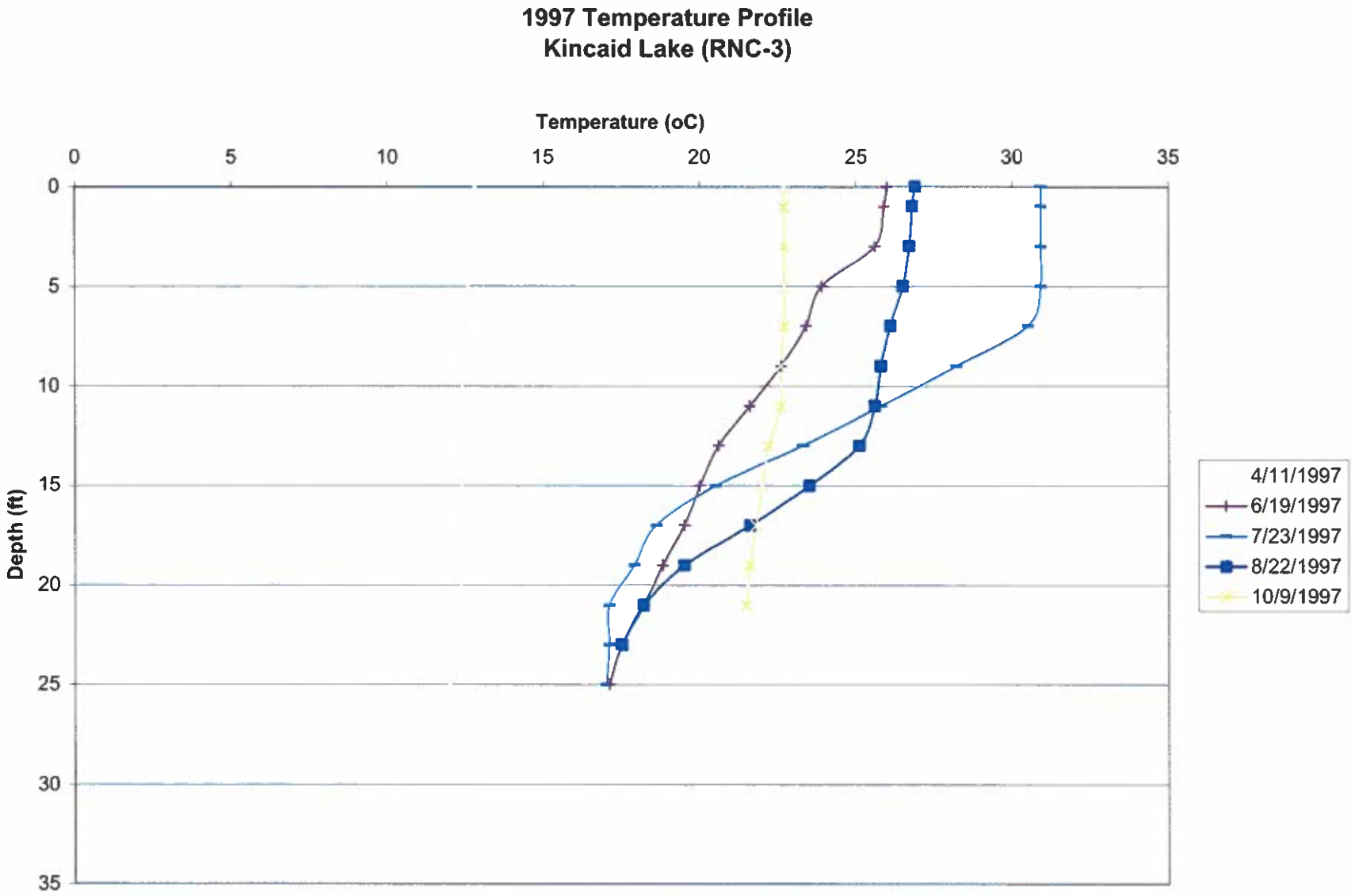
2000 Temperature Profile
Kincaid Lake (RNC-2)



R02182

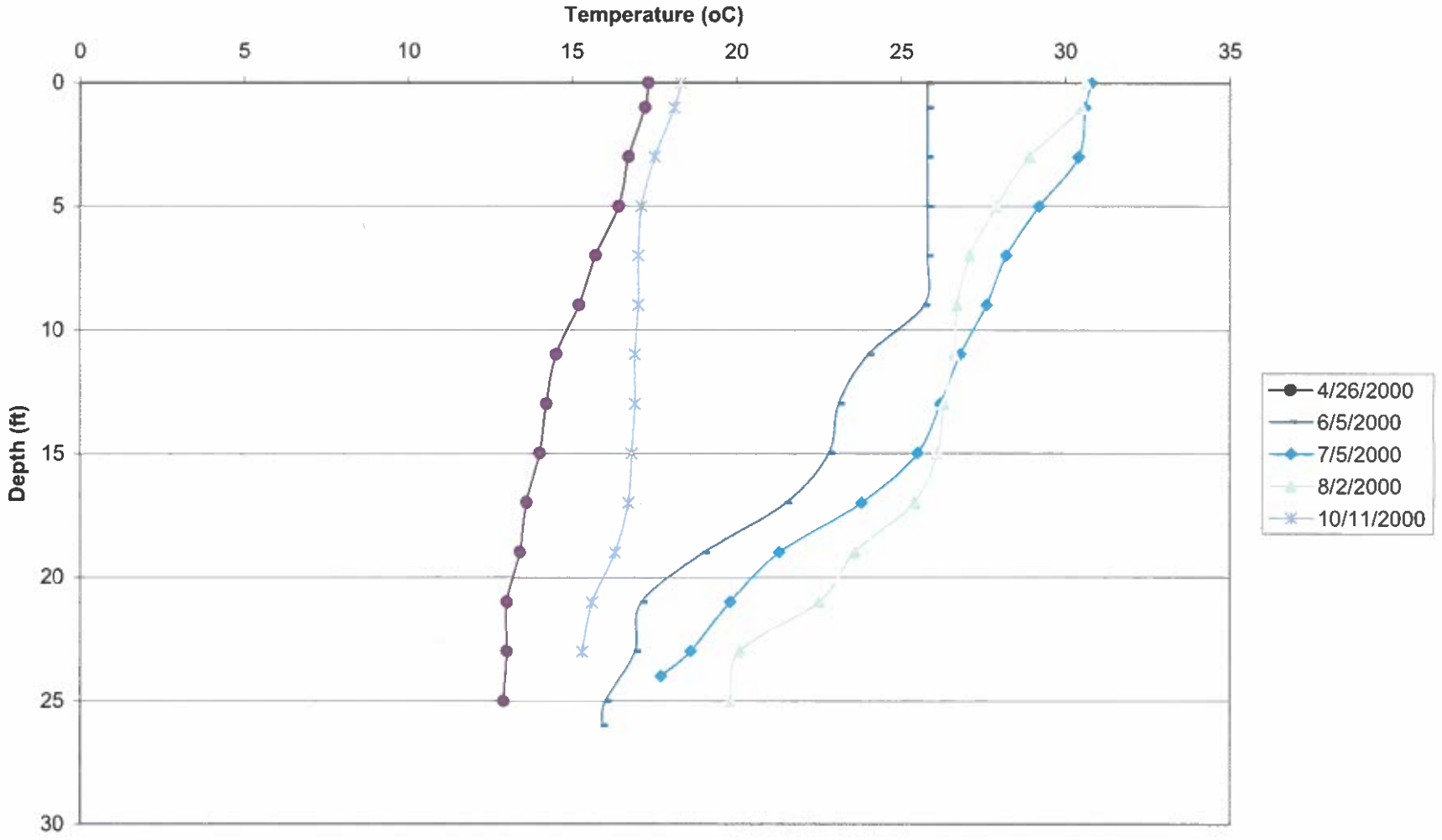

1994 Temperature Profile
Kincaid Lake (RNC-3)
Temperature (oC)
0
5
10
15
20
25
30
35
Depth (ft)
0
5
10
15
20
25
30
35
4/13/1994
6/6/1994
7/12/1994
8/16/1994
10/11/1994

R02183


1997 Temperature Profile
Kincaid Lake (RNC-3)
Temperature (oC)
0
5
10
15
20
25
30
35
Depth (ft)
0
5
10
15
20
25
30
35
4/11/1997
6/19/1997
7/23/1997
8/22/1997
10/9/1997

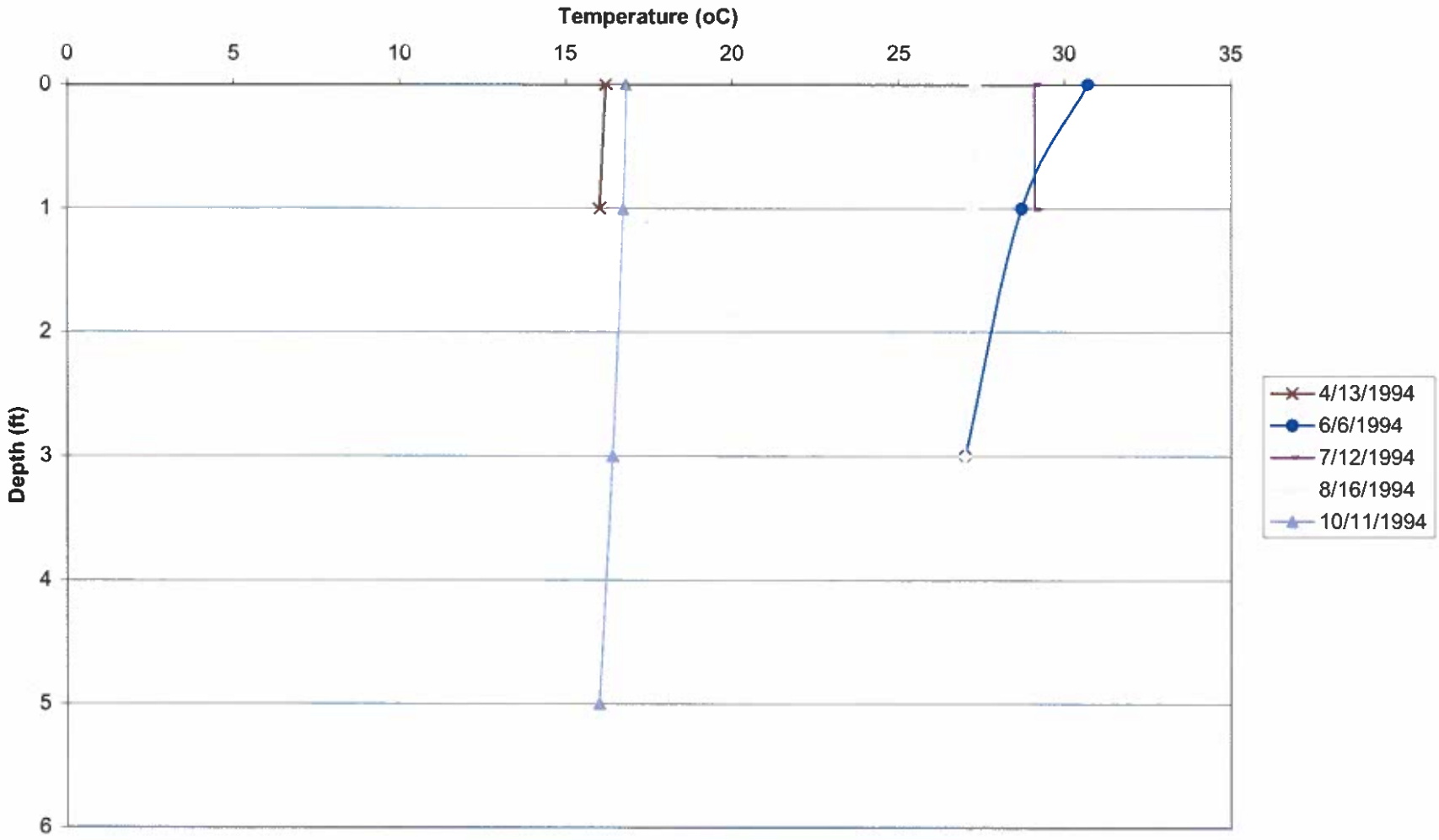
R02184

2000 Temperature Profile
Kincaid Lake (RNC-3)



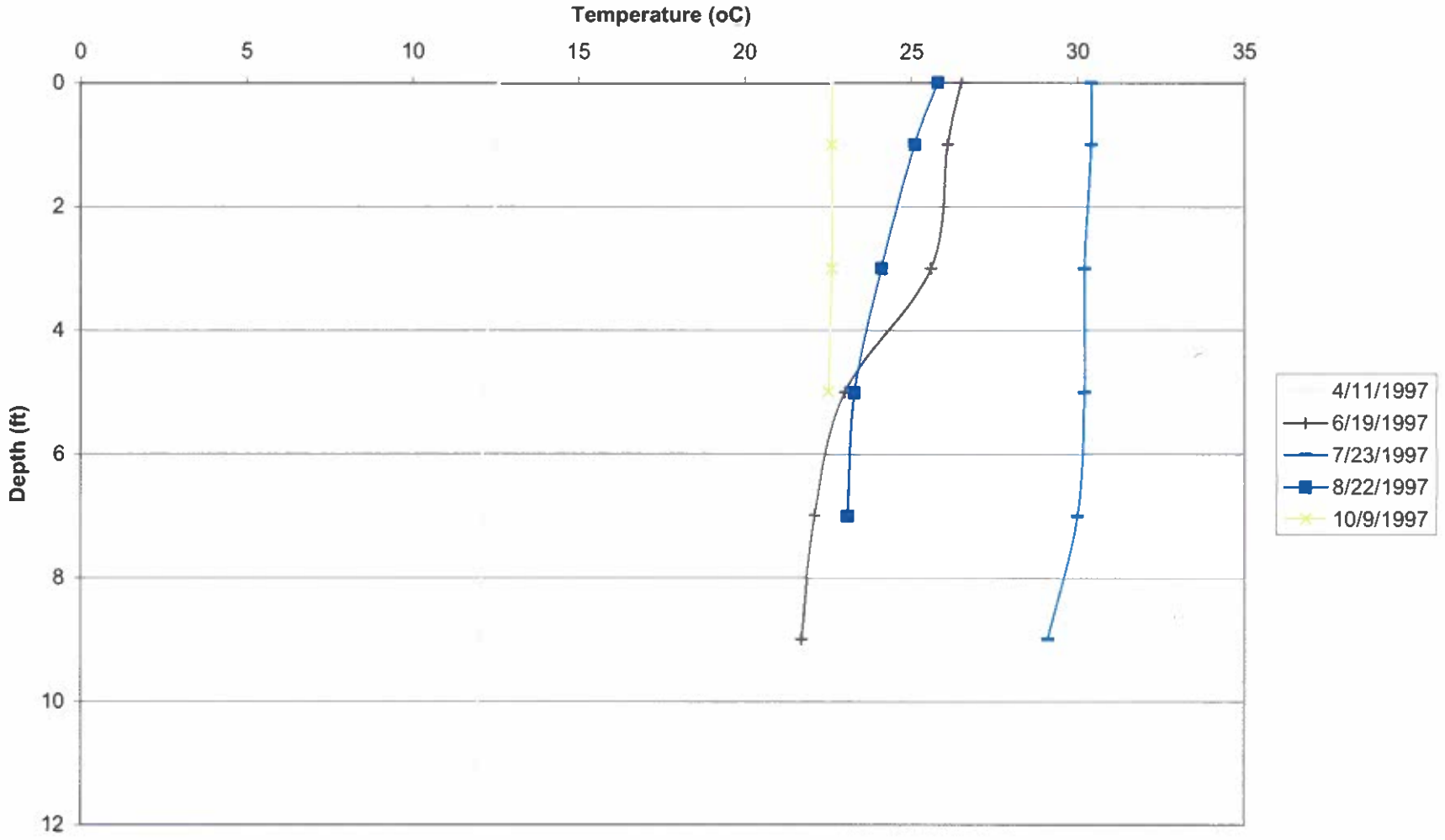
R02185

1994 Temperature Profile
Kincaid Lake (RNC-4)



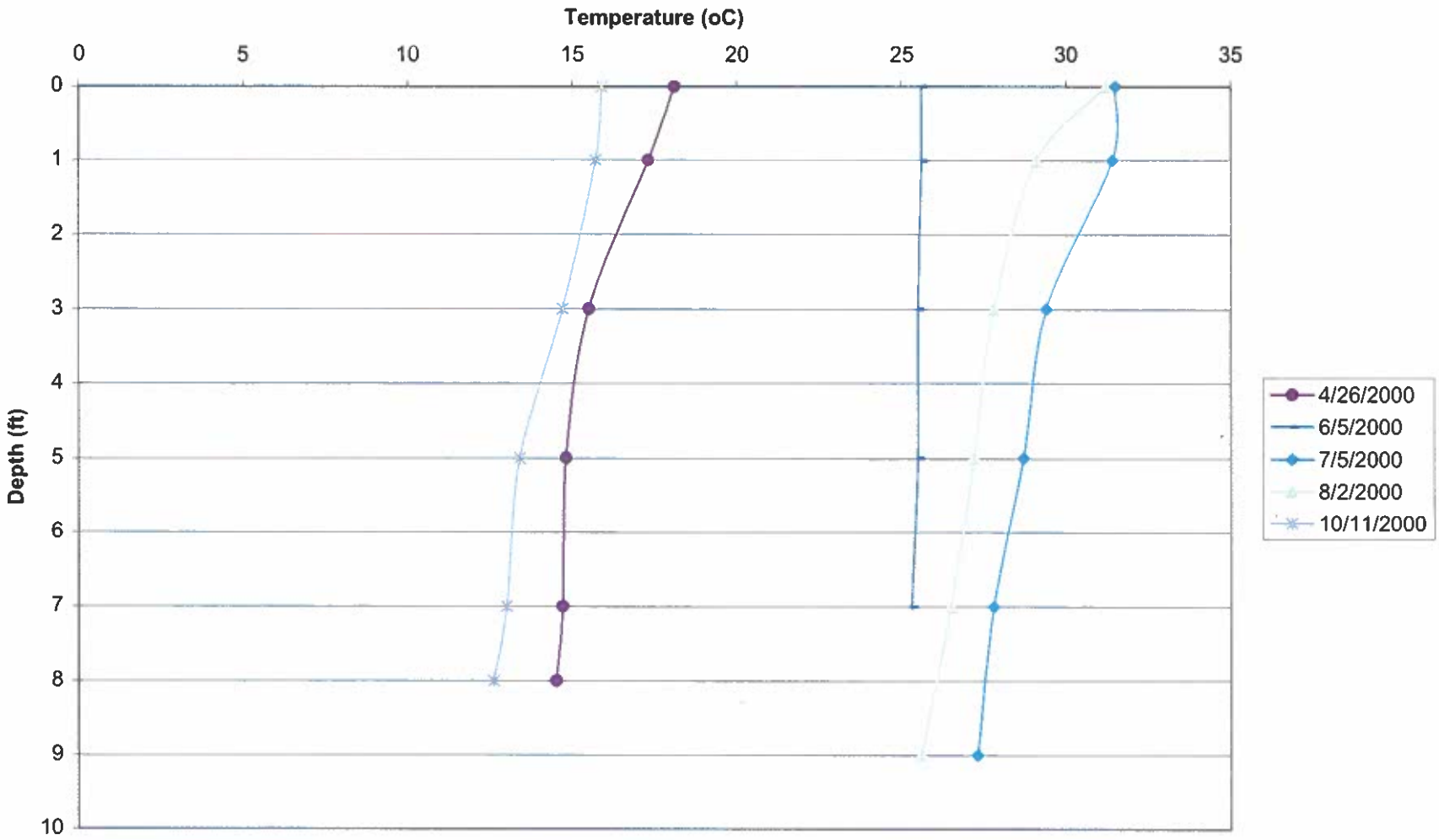
R02186

1997 Temperature Profile
Kincaid Lake (RNC-4)



R02187

2000 Temperature Profile
Kincaid Lake (RNC-4)



R02188

Appendix H
Sensitivity Analysis - BATHTUB Output Files

H.1 BATHTUB Sensitivity

This appendix provides the BATHTUB output files for the soil phosphorus sensitivity analysis. For each modeled year, the BATHTUB model was run with soil phosphorus values of 440 ppm and 660 ppm. The output concentrations from BATHTUB were not calibrated so that the raw model results could be compared.

BATHTUB Output for 1994 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 440 mg/kg

CASE: Kinkaid 1994 - Sed 440
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	135.4	.29	88.9	.48	1.52	1.44	1.56	.75
CHL-A	MG/M3	52.1	.56	50.7	.59	1.03	.05	.08	.03
SECCHI	M	.4	.72	.5	.67	.98	-.02	-.06	-.02
ORGANIC N	MG/M3	.0	.00	1381.7	.47	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	108.0	.45	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.8	.73	49.8	.45	.74	-.41	-1.13	-.35
CHL-A	MG/M3	24.3	.44	17.5	.65	1.39	.75	.95	.42
SECCHI	M	1.3	.67	1.7	.66	.77	-.38	-.91	-.27
ORGANIC N	MG/M3	.0	.00	566.7	.41	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	30.5	.43	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	22.2	.46	30.4	.45	.73	-.69	-1.17	-.49
CHL-A	MG/M3	23.4	.44	13.0	.64	1.80	1.32	1.69	.76
SECCHI	M	1.6	.59	2.5	.86	.64	-.76	-1.59	-.43
ORGANIC N	MG/M3	.0	.00	460.1	.38	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	21.0	.54	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	25.2	.53	16.2	.46	1.55	.83	1.64	.63
CHL-A	MG/M3	19.1	.52	5.9	.72	3.24	2.24	3.39	1.32
SECCHI	M	1.9	.65	4.4	1.98	.43	-1.30	-3.01	-.40
ORGANIC N	MG/M3	.0	.00	297.7	.38	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	8.3	1.65	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.7	.48	31.0	.45	1.18	.35	.63	.26
CHL-A	MG/M3	23.6	.50	13.1	.54	1.81	1.18	1.71	.80
SECCHI	M	1.6	.64	3.3	1.56	.49	-1.10	-2.52	-.42
ORGANIC N	MG/M3	.0	.00	467.5	.36	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	23.1	.61	.00	.00	.00	.00

CASE: Kinkaid 1994 - Sed 440
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	32.800	.000E+00	.000	.364
2	1	Subbasin 2	25.100	10.000	.000E+00	.000	.398
3	1	Subbasin 3	10.400	4.700	.000E+00	.000	.452
4	1	Subbasin 4	31.100	15.400	.000E+00	.000	.495
PRECIPITATION			9.509	10.555	.446E+01	.200	1.110
TRIBUTARY INFLOW			156.700	62.900	.000E+00	.000	.401
***TOTAL INFLOW			166.209	73.455	.446E+01	.029	.442
ADVECTIVE OUTFLOW			166.209	65.448	.102E+02	.049	.394
***TOTAL OUTFLOW			166.209	65.448	.102E+02	.049	.394
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	3899.9	67.4	.000E+00	.0	.000	118.9	43.3
2	1	Subbasin 2	600.0	10.4	.000E+00	.0	.000	60.0	23.9
3	1	Subbasin 3	198.8	3.4	.000E+00	.0	.000	42.3	19.1
4	1	Subbasin 4	802.3	13.9	.000E+00	.0	.000	52.1	25.8
PRECIPITATION			285.3	4.9	.203E+05	100.0	.500	27.0	30.0
TRIBUTARY INFLOW			5501.1	95.1	.000E+00	.0	.000	87.5	35.1
***TOTAL INFLOW			5786.3	100.0	.203E+05	100.0	.025	78.8	34.8
ADVECTIVE OUTFLOW			1062.1	18.4	.236E+06	1158.9	.457	16.2	6.4
***TOTAL OUTFLOW			1062.1	18.4	.236E+06	1158.9	.457	16.2	6.4
***RETENTION			4724.2	81.6	.249E+06	1223.5	.106	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
6.88	1.9902	36.7	.8252	1.2118	.8164

1994 – *Constant Sediment Phosphorus Concentration of 616 mg/kg*

CASE: Kinkaid 1994 - No Calibration
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	135.4	.29	105.9	.48	1.28	.84	.91	.44
CHL-A	MG/M3	52.1	.56	58.7	.57	.89	-.21	-.34	-.15
SECCHI	M	.4	.72	.4	.60	1.07	.10	.26	.08
ORGANIC N	MG/M3	.0	.00	1564.9	.46	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	122.3	.43	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.8	.73	56.2	.45	.65	-.58	-1.57	-.49
CHL-A	MG/M3	24.3	.44	18.8	.63	1.29	.58	.74	.33
SECCHI	M	1.3	.67	1.6	.60	.82	-.30	-.71	-.22
ORGANIC N	MG/M3	.0	.00	597.1	.42	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	32.9	.42	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	22.2	.46	33.1	.45	.67	-.87	-1.48	-.62
CHL-A	MG/M3	23.4	.44	14.0	.63	1.67	1.16	1.49	.67
SECCHI	M	1.6	.59	2.3	.80	.68	-.66	-1.39	-.39
ORGANIC N	MG/M3	.0	.00	482.0	.39	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	22.7	.52	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	25.2	.53	17.9	.46	1.41	.64	1.28	.49
CHL-A	MG/M3	19.1	.52	6.7	.72	2.84	1.99	3.02	1.17
SECCHI	M	1.9	.65	4.0	1.84	.47	-1.17	-2.70	-.39
ORGANIC N	MG/M3	.0	.00	316.4	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	9.8	1.47	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.7	.48	35.0	.45	1.05	.10	.17	.07
CHL-A	MG/M3	23.6	.50	14.6	.53	1.61	.95	1.39	.66
SECCHI	M	1.6	.64	3.0	1.44	.54	-.97	-2.23	-.40
ORGANIC N	MG/M3	.0	.00	503.4	.36	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	25.9	.58	.00	.00	.00	.00

CASE: Kinkaid 1994 - No Calibration
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	32.800	.000E+00	.000	.364
2	1	Subbasin 2	25.100	10.000	.000E+00	.000	.398
3	1	Subbasin 3	10.400	4.700	.000E+00	.000	.452
4	1	Subbasin 4	31.100	15.400	.000E+00	.000	.495
PRECIPITATION			9.509	10.555	.446E+01	.200	1.110
TRIBUTARY INFLOW			156.700	62.900	.000E+00	.000	.401
***TOTAL INFLOW			166.209	73.455	.446E+01	.029	.442
ADVECTIVE OUTFLOW			166.209	65.448	.102E+02	.049	.394
***TOTAL OUTFLOW			166.209	65.448	.102E+02	.049	.394
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	4798.6	67.7	.000E+00	.0	.000	146.3	53.3
2	1	Subbasin 2	700.0	9.9	.000E+00	.0	.000	70.0	27.9
3	1	Subbasin 3	198.8	2.8	.000E+00	.0	.000	42.3	19.1
4	1	Subbasin 4	1102.6	15.6	.000E+00	.0	.000	71.6	35.5
PRECIPITATION			285.3	4.0	.203E+05	100.0	.500	27.0	30.0
TRIBUTARY INFLOW			6800.1	96.0	.000E+00	.0	.000	108.1	43.4
***TOTAL INFLOW			7085.4	100.0	.203E+05	100.0	.020	96.5	42.6
ADVECTIVE OUTFLOW			1170.7	16.5	.286E+06	1405.4	.457	17.9	7.0
***TOTAL OUTFLOW			1170.7	16.5	.286E+06	1405.4	.457	17.9	7.0
***RETENTION			5914.7	83.5	.300E+06	1472.9	.093	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
6.88	1.9902	36.7	.6739	1.4839	.8348

BATHTUB Output for 1997 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 440 mg/kg

CASE: Kinkaid 1997 - Sed 400
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	129.6	.56	96.1	.45	1.35	.53	1.11	.41
CHL-A	MG/M3	48.9	.57	19.5	.49	2.51	1.62	2.66	1.23
SECCHI	M	.3	.34	.4	.45	.79	-.70	-.85	-.42
ORGANIC N	MG/M3	.0	.00	769.3	.25	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	83.6	.33	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	44.6	.23	47.0	.45	.95	-.23	-.19	-.10
CHL-A	MG/M3	27.5	.38	16.3	.49	1.68	1.35	1.50	.84
SECCHI	M	.9	.26	1.2	.42	.75	-1.11	-1.03	-.59
ORGANIC N	MG/M3	.0	.00	561.2	.32	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	34.9	.39	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.2	.26	28.6	.45	.95	-.19	-.19	-.10
CHL-A	MG/M3	19.4	.45	8.7	.53	2.22	1.79	2.31	1.16
SECCHI	M	1.1	.26	1.7	.46	.69	-1.40	-1.30	-.69
ORGANIC N	MG/M3	.0	.00	385.4	.28	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	20.6	.42	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	42.5	1.09	16.7	.45	2.54	.85	3.47	.79
CHL-A	MG/M3	13.2	.40	5.1	.59	2.57	2.39	2.73	1.34
SECCHI	M	1.3	.30	1.8	.44	.74	-1.03	-1.09	-.57
ORGANIC N	MG/M3	.0	.00	307.2	.24	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	15.4	.46	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	48.3	.75	31.1	.45	1.55	.59	1.64	.50
CHL-A	MG/M3	19.9	.44	9.0	.47	2.21	1.82	2.30	1.23
SECCHI	M	1.1	.29	1.5	.34	.73	-1.08	-1.11	-.70
ORGANIC N	MG/M3	.0	.00	406.4	.26	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	25.8	.34	.00	.00	.00	.00

CASE: Kinkaid 1997 - Sed 400
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	36.500	.000E+00	.000	.405
2	1	Subbasin 2	25.100	10.900	.000E+00	.000	.434
3	1	Subbasin 3	10.400	5.100	.000E+00	.000	.490
4	1	Subbasin 4	31.100	16.600	.000E+00	.000	.534
PRECIPITATION			9.509	11.886	.565E+01	.200	1.250
TRIBUTARY INFLOW			156.700	69.100	.000E+00	.000	.441
***TOTAL INFLOW			166.209	80.986	.565E+01	.029	.487
ADVECTIVE OUTFLOW			166.209	72.980	.114E+02	.046	.439
***TOTAL OUTFLOW			166.209	72.980	.114E+02	.046	.439
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	4898.3	68.2	.000E+00	.0	.000	134.2	54.4
2	1	Subbasin 2	698.7	9.7	.000E+00	.0	.000	64.1	27.8
3	1	Subbasin 3	199.9	2.8	.000E+00	.0	.000	39.2	19.2
4	1	Subbasin 4	1097.3	15.3	.000E+00	.0	.000	66.1	35.3
PRECIPITATION			285.3	4.0	.203E+05	100.0	.500	24.0	30.0
TRIBUTARY INFLOW			6894.2	96.0	.000E+00	.0	.000	99.8	44.0
***TOTAL INFLOW			7179.4	100.0	.203E+05	100.0	.020	88.7	43.2
ADVECTIVE OUTFLOW			1220.4	17.0	.307E+06	1511.3	.454	16.7	7.3
***TOTAL OUTFLOW			1220.4	17.0	.307E+06	1511.3	.454	16.7	7.3
***RETENTION			5959.0	83.0	.320E+06	1575.0	.095	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.67	1.8016	48.3	.8848	1.1303	.8300

1997 - *Constant Sediment Phosphorus Concentration of 616 mg/kg*

CASE: Kinkaid 1997 - No Calibration
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	129.6	.56	110.9	.45	1.17	.28	.58	.22
CHL-A	MG/M3	48.9	.57	21.0	.47	2.33	1.49	2.45	1.14
SECCHI	M	.3	.34	.4	.44	.80	-.66	-.81	-.41
ORGANIC N	MG/M3	.0	.00	803.8	.24	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	86.3	.31	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	44.6	.23	53.7	.45	.83	-.82	-.69	-.37
CHL-A	MG/M3	27.5	.38	18.0	.47	1.53	1.10	1.22	.70
SECCHI	M	.9	.26	1.2	.40	.79	-.93	-.86	-.51
ORGANIC N	MG/M3	.0	.00	599.0	.32	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	37.9	.38	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.2	.26	32.0	.45	.85	-.63	-.61	-.31
CHL-A	MG/M3	19.4	.45	9.6	.51	2.02	1.58	2.03	1.04
SECCHI	M	1.1	.26	1.6	.44	.72	-1.26	-1.18	-.64
ORGANIC N	MG/M3	.0	.00	405.3	.28	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	22.2	.40	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	42.5	1.09	18.5	.45	2.30	.76	3.10	.70
CHL-A	MG/M3	13.2	.40	5.7	.57	2.31	2.12	2.42	1.20
SECCHI	M	1.3	.30	1.7	.43	.76	-.94	-1.00	-.54
ORGANIC N	MG/M3	.0	.00	320.3	.25	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	16.5	.45	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	48.3	.75	35.2	.45	1.37	.42	1.18	.36
CHL-A	MG/M3	19.9	.44	9.9	.45	2.01	1.60	2.02	1.11
SECCHI	M	1.1	.29	1.5	.33	.76	-.98	-1.00	-.64
ORGANIC N	MG/M3	.0	.00	427.0	.26	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	27.4	.34	.00	.00	.00	.00

CASE: Kinkaid 1997 - No Calibration
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	36.500	.000E+00	.000	.405
2	1	Subbasin 2	25.100	10.900	.000E+00	.000	.434
3	1	Subbasin 3	10.400	5.100	.000E+00	.000	.490
4	1	Subbasin 4	31.100	16.600	.000E+00	.000	.534
PRECIPITATION			9.509	11.886	.565E+01	.200	1.250
TRIBUTARY INFLOW			156.700	69.100	.000E+00	.000	.441
***TOTAL INFLOW			166.209	80.986	.565E+01	.029	.487
ADVECTIVE OUTFLOW			166.209	72.980	.114E+02	.046	.439
***TOTAL OUTFLOW			166.209	72.980	.114E+02	.046	.439
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	5898.4	65.7	.000E+00	.0	.000	161.6	65.5
2	1	Subbasin 2	1097.6	12.2	.000E+00	.0	.000	100.7	43.7
3	1	Subbasin 3	299.9	3.3	.000E+00	.0	.000	58.8	28.8
4	1	Subbasin 4	1397.7	15.6	.000E+00	.0	.000	84.2	44.9
PRECIPITATION			285.3	3.2	.203E+05	100.0	.500	24.0	30.0
TRIBUTARY INFLOW			8693.6	96.8	.000E+00	.0	.000	125.8	55.5
***TOTAL INFLOW			8978.9	100.0	.203E+05	100.0	.016	110.9	54.0
ADVECTIVE OUTFLOW			1348.7	15.0	.375E+06	1844.8	.454	18.5	8.1
***TOTAL OUTFLOW			1348.7	15.0	.375E+06	1844.8	.454	18.5	8.1
***RETENTION			7630.2	85.0	.389E+06	1911.5	.082	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.67	1.8016	48.3	.7074	1.4135	.8498

BATHTUB Output for 2000 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 440 mg/kg

CASE: Kinkaid 2000 - Sed 440
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	54.8	.33	124.0	.45	.44	-2.46	-3.04	-1.46
CHL-A	MG/M3	38.0	.40	21.4	.35	1.78	1.44	1.66	1.08
SECCHI	M	.3	.12	.4	.21	.86	-1.26	-.55	-.63
ORGANIC N	MG/M3	.0	.00	790.8	.23	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	80.1	.23	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	21.2	.10	57.9	.45	.37	-10.36	-3.74	-2.17
CHL-A	MG/M3	16.4	.40	13.8	.44	1.18	.43	.49	.29
SECCHI	M	.9	.34	1.0	.35	.94	-.18	-.22	-.13
ORGANIC N	MG/M3	.0	.00	521.9	.27	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	36.0	.31	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	12.4	.07	35.4	.45	.35	-14.58	-3.90	-2.30
CHL-A	MG/M3	12.6	.38	11.1	.47	1.14	.33	.37	.21
SECCHI	M	1.4	.29	1.5	.35	.95	-.19	-.20	-.12
ORGANIC N	MG/M3	.0	.00	440.7	.29	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	25.1	.39	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	29.0	1.14	21.8	.45	1.33	.25	1.05	.23
CHL-A	MG/M3	18.4	1.24	8.8	.72	2.08	.59	2.12	.51
SECCHI	M	1.8	.24	3.1	1.94	.57	-2.32	-1.98	-.28
ORGANIC N	MG/M3	.0	.00	365.7	.45	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	14.0	1.39	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.4	.77	39.6	.45	.69	-.48	-1.37	-.41
CHL-A	MG/M3	18.9	.87	11.2	.53	1.69	.60	1.51	.52
SECCHI	M	1.4	.26	2.2	1.57	.65	-1.70	-1.56	-.28
ORGANIC N	MG/M3	.0	.00	443.3	.33	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	25.6	.56	.00	.00	.00	.00

CASE: Kinkaid 2000 - Sed 440
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	38.000	.000E+00	.000	.422
2	1	Subbasin 2	25.100	11.300	.000E+00	.000	.450
3	1	Subbasin 3	10.400	5.300	.000E+00	.000	.510
4	1	Subbasin 4	31.100	17.400	.000E+00	.000	.559
PRECIPITATION			9.509	12.267	.602E+01	.200	1.290
TRIBUTARY INFLOW			156.700	72.000	.000E+00	.000	.459
***TOTAL INFLOW			166.209	84.267	.602E+01	.029	.507
ADVECTIVE OUTFLOW			166.209	76.260	.118E+02	.045	.459
***TOTAL OUTFLOW			166.209	76.260	.118E+02	.045	.459
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	7311.2	64.7	.000E+00	.0	.000	192.4	81.1
2	1	Subbasin 2	1200.1	10.6	.000E+00	.0	.000	106.2	47.8
3	1	Subbasin 3	499.8	4.4	.000E+00	.0	.000	94.3	48.1
4	1	Subbasin 4	2002.7	17.7	.000E+00	.0	.000	115.1	64.4
PRECIPITATION			285.3	2.5	.203E+05	100.0	.500	23.3	30.0
TRIBUTARY INFLOW			11013.8	97.5	.000E+00	.0	.000	153.0	70.3
***TOTAL INFLOW			11299.1	100.0	.203E+05	100.0	.013	134.1	68.0
ADVECTIVE OUTFLOW			1665.9	14.7	.570E+06	2802.5	.453	21.8	10.0
***TOTAL OUTFLOW			1665.9	14.7	.570E+06	2802.5	.453	21.8	10.0
***RETENTION			9633.2	85.3	.584E+06	2870.2	.079	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
8.02	1.5738	27.4	.2907	3.4400	.8526

2000 - *Constant Sediment Phosphorus Concentration of 616 mg/kg*

CASE: Kinkaid 2000 - No Calibration
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	54.8	.33	144.4	.45	.38	-2.92	-3.60	-1.73
CHL-A	MG/M3	38.0	.40	22.7	.34	1.68	1.29	1.49	.99
SECCHI	M	.3	.12	.4	.21	.87	-1.15	-.51	-.58
ORGANIC N	MG/M3	.0	.00	820.7	.23	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	82.4	.23	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	21.2	.10	65.2	.45	.33	-11.58	-4.18	-2.43
CHL-A	MG/M3	16.4	.40	14.8	.43	1.11	.26	.30	.18
SECCHI	M	.9	.34	1.0	.34	.96	-.11	-.14	-.08
ORGANIC N	MG/M3	.0	.00	543.4	.27	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	37.7	.30	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	12.4	.07	38.8	.45	.32	-15.84	-4.24	-2.50
CHL-A	MG/M3	12.6	.38	11.9	.46	1.06	.15	.17	.10
SECCHI	M	1.4	.29	1.4	.34	.98	-.09	-.09	-.06
ORGANIC N	MG/M3	.0	.00	459.3	.29	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	26.6	.38	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	29.0	1.14	24.3	.45	1.20	.16	.66	.15
CHL-A	MG/M3	18.4	1.24	10.1	.74	1.81	.48	1.72	.41
SECCHI	M	1.8	.24	2.8	1.79	.63	-1.91	-1.63	-.25
ORGANIC N	MG/M3	.0	.00	395.9	.48	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	16.4	1.27	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.4	.77	44.6	.45	.61	-.63	-1.81	-.54
CHL-A	MG/M3	18.9	.87	12.4	.53	1.53	.49	1.22	.42
SECCHI	M	1.4	.26	2.1	1.42	.70	-1.38	-1.27	-.24
ORGANIC N	MG/M3	.0	.00	470.1	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	27.7	.56	.00	.00	.00	.00

CASE: Kinkaid 2000 - No Calibration
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	38.000	.000E+00	.000	.422
2	1	Subbasin 2	25.100	11.300	.000E+00	.000	.450
3	1	Subbasin 3	10.400	5.300	.000E+00	.000	.510
4	1	Subbasin 4	31.100	17.400	.000E+00	.000	.559
PRECIPITATION			9.509	12.267	.602E+01	.200	1.290
TRIBUTARY INFLOW			156.700	72.000	.000E+00	.000	.459
***TOTAL INFLOW			166.209	84.267	.602E+01	.029	.507
ADVECTIVE OUTFLOW			166.209	76.260	.118E+02	.045	.459
***TOTAL OUTFLOW			166.209	76.260	.118E+02	.045	.459
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	9013.6	63.9	.000E+00	.0	.000	237.2	100.0
2	1	Subbasin 2	1600.1	11.3	.000E+00	.0	.000	141.6	63.7
3	1	Subbasin 3	600.0	4.3	.000E+00	.0	.000	113.2	57.7
4	1	Subbasin 4	2603.0	18.5	.000E+00	.0	.000	149.6	83.7
PRECIPITATION			285.3	2.0	.203E+05	100.0	.500	23.3	30.0
TRIBUTARY INFLOW			13816.7	98.0	.000E+00	.0	.000	191.9	88.2
***TOTAL INFLOW			14101.9	100.0	.203E+05	100.0	.010	167.3	84.8
ADVECTIVE OUTFLOW			1850.4	13.1	.702E+06	3452.5	.453	24.3	11.1
***TOTAL OUTFLOW			1850.4	13.1	.702E+06	3452.5	.453	24.3	11.1
***RETENTION			12251.5	86.9	.717E+06	3523.1	.069	.0	.0

HYDRAULIC		TOTAL P			
OVERFLOW RATE M/YR	RESIDENCE TIME YRS	POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
8.02	1.5738	27.4	.2329	4.2933	.8688

Appendix I
Reduction Analyses - BATHTUB Output Files

BATHTUB Output for 1994 Reduction Analysis

CASE: Kinkaid 1994 - Reduced

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	135.4	.29	48.9	.46	2.77	3.48	3.79	1.87
CHL-A	MG/M3	52.1	.56	18.2	.67	2.86	1.89	3.04	1.21
SECCHI	M	.4	.72	.7	1.32	.62	-.67	-1.71	-.32
ORGANIC N	MG/M3	.0	.00	641.3	.54	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	50.2	1.04	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.8	.73	21.6	.45	1.71	.73	1.99	.62
CHL-A	MG/M3	24.3	.44	13.1	.74	1.86	1.40	1.79	.72
SECCHI	M	1.3	.67	2.1	.91	.63	-.70	-1.65	-.41
ORGANIC N	MG/M3	.0	.00	466.5	.43	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	22.7	.56	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	22.2	.46	15.6	.45	1.42	.77	1.31	.55
CHL-A	MG/M3	23.4	.44	13.3	.71	1.75	1.27	1.62	.67
SECCHI	M	1.6	.59	2.4	.88	.65	-.73	-1.53	-.41
ORGANIC N	MG/M3	.0	.00	467.1	.44	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	21.5	.64	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	25.2	.53	20.2	.45	1.25	.42	.83	.32
CHL-A	MG/M3	19.1	.52	16.6	.67	1.16	.28	.42	.17
SECCHI	M	1.9	.65	2.0	.68	.93	-.10	-.24	-.07
ORGANIC N	MG/M3	.0	.00	540.5	.45	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	27.3	.60	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	36.7	.48	22.3	.45	1.64	1.03	1.85	.75
CHL-A	MG/M3	23.6	.50	15.6	.61	1.52	.83	1.20	.53
SECCHI	M	1.6	.64	2.0	.56	.81	-.32	-.74	-.24
ORGANIC N	MG/M3	.0	.00	524.9	.41	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	27.6	.59	.00	.00	.00	.00

CASE: Kinkaid 1994 - Reduced
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	32.800	.000E+00	.000	.364
2	1	Subbasin 2	25.100	10.000	.000E+00	.000	.398
3	1	Subbasin 3	10.400	4.700	.000E+00	.000	.452
4	1	Subbasin 4	31.100	15.400	.000E+00	.000	.495
PRECIPITATION			9.509	10.555	.446E+01	.200	1.110
TRIBUTARY INFLOW			156.700	62.900	.000E+00	.000	.401
***TOTAL INFLOW			166.209	73.455	.446E+01	.029	.442
ADVECTIVE OUTFLOW			166.209	65.448	.102E+02	.049	.394
***TOTAL OUTFLOW			166.209	65.448	.102E+02	.049	.394
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	1390.7	37.8	.000E+00	.0	.000	42.4	15.4
2	1	Subbasin 2	700.0	19.0	.000E+00	.0	.000	70.0	27.9
3	1	Subbasin 3	198.8	5.4	.000E+00	.0	.000	42.3	19.1
4	1	Subbasin 4	1102.6	30.0	.000E+00	.0	.000	71.6	35.5
PRECIPITATION			285.3	7.8	.203E+05	100.0	.500	27.0	30.0
TRIBUTARY INFLOW			3392.2	92.2	.000E+00	.0	.000	53.9	21.6
***TOTAL INFLOW			3677.4	100.0	.203E+05	100.0	.039	50.1	22.1
ADVECTIVE OUTFLOW			1321.9	35.9	.358E+06	1758.8	.453	20.2	8.0
***TOTAL OUTFLOW			1321.9	35.9	.358E+06	1758.8	.453	20.2	8.0
***RETENTION			2355.6	64.1	.368E+06	1808.5	.258	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
6.88	1.9902	36.7	1.2984	.7702	.6405

BATHTUB Output for 1997 Reduction Analysis

CASE: Kinkaid 1997 - Reduced

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	129.6	.56	50.0	.45	2.59	1.68	3.54	1.32
CHL-A	MG/M3	48.9	.57	24.5	.57	2.00	1.21	2.00	.86
SECCHI	M	.3	.34	.4	.42	.82	-.57	-.69	-.36
ORGANIC N	MG/M3	.0	.00	884.5	.33	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	92.6	.33	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	44.6	.23	27.1	.45	1.65	2.20	1.86	.99
CHL-A	MG/M3	27.5	.38	18.2	.57	1.51	1.08	1.19	.60
SECCHI	M	.9	.26	1.1	.43	.79	-.91	-.84	-.47
ORGANIC N	MG/M3	.0	.00	602.8	.39	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	38.2	.46	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.2	.26	19.2	.45	1.41	1.32	1.29	.66
CHL-A	MG/M3	19.4	.45	12.0	.58	1.61	1.07	1.38	.65
SECCHI	M	1.1	.26	1.5	.42	.79	-.91	-.85	-.48
ORGANIC N	MG/M3	.0	.00	460.5	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	26.5	.46	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	42.5	1.09	33.6	.45	1.27	.22	.88	.20
CHL-A	MG/M3	13.2	.40	11.9	.48	1.11	.25	.29	.16
SECCHI	M	1.3	.30	1.4	.34	.96	-.14	-.15	-.09
ORGANIC N	MG/M3	.0	.00	462.4	.30	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	27.6	.38	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	48.3	.75	31.7	.45	1.52	.56	1.57	.48
CHL-A	MG/M3	19.9	.44	14.2	.49	1.40	.77	.98	.51
SECCHI	M	1.1	.29	1.2	.29	.90	-.38	-.39	-.27
ORGANIC N	MG/M3	.0	.00	525.3	.32	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	35.1	.38	.00	.00	.00	.00

CASE: Kinkaid 1997 - Reduced
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	FLOW (HM3/YR) CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	36.500	.000E+00	.000	.405
2	1	Subbasin 2	25.100	10.900	.000E+00	.000	.434
3	1	Subbasin 3	10.400	5.100	.000E+00	.000	.490
4	1	Subbasin 4	31.100	16.600	.000E+00	.000	.534
PRECIPITATION			9.509	11.886	.565E+01	.200	1.250
TRIBUTARY INFLOW			156.700	69.100	.000E+00	.000	.441
***TOTAL INFLOW			166.209	80.986	.565E+01	.029	.487
ADVECTIVE OUTFLOW			166.209	72.980	.114E+02	.046	.439
***TOTAL OUTFLOW			166.209	72.980	.114E+02	.046	.439
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	1770.3	36.5	.000E+00	.0	.000	48.5	19.6
2	1	Subbasin 2	1097.6	22.6	.000E+00	.0	.000	100.7	43.7
3	1	Subbasin 3	299.9	6.2	.000E+00	.0	.000	58.8	28.8
4	1	Subbasin 4	1397.7	28.8	.000E+00	.0	.000	84.2	44.9
PRECIPITATION			285.3	5.9	.203E+05	100.0	.500	24.0	30.0
TRIBUTARY INFLOW			4565.5	94.1	.000E+00	.0	.000	66.1	29.1
***TOTAL INFLOW			4850.8	100.0	.203E+05	100.0	.029	59.9	29.2
ADVECTIVE OUTFLOW			2449.5	50.5	.123E+07	6028.8	.452	33.6	14.7
***TOTAL OUTFLOW			2449.5	50.5	.123E+07	6028.8	.452	33.6	14.7
***RETENTION			2401.2	49.5	.123E+07	6053.7	.462	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.67	1.8016	48.3	1.3095	.7637	.4950

BATHTUB Output for 2000 Reduction Analysis

CASE: Kinkaid 2000 - Reduced
T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	54.8	.33	49.4	.45	1.11	.31	.38	.18
CHL-A	MG/M3	38.0	.40	24.1	.48	1.58	1.14	1.32	.73
SECCHI	M	.3	.12	.4	.22	.88	-1.04	-.46	-.50
ORGANIC N	MG/M3	.0	.00	853.1	.32	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	85.0	.28	.00	.00	.00	.00

SEGMENT: 2 Middle Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	21.2	.10	27.1	.45	.78	-2.54	-.92	-.53
CHL-A	MG/M3	16.4	.40	15.5	.55	1.06	.14	.16	.08
SECCHI	M	.9	.34	1.0	.36	.98	-.06	-.07	-.04
ORGANIC N	MG/M3	.0	.00	560.0	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	39.0	.39	.00	.00	.00	.00

SEGMENT: 3 Lower Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	12.4	.07	17.5	.45	.71	-4.75	-1.27	-.75
CHL-A	MG/M3	12.6	.38	11.4	.58	1.11	.27	.30	.15
SECCHI	M	1.4	.29	1.5	.37	.96	-.15	-.16	-.09
ORGANIC N	MG/M3	.0	.00	446.9	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	25.6	.47	.00	.00	.00	.00

SEGMENT: 4 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	29.0	1.14	23.5	.45	1.23	.18	.78	.17
CHL-A	MG/M3	18.4	1.24	19.1	.71	.96	-.03	-.11	-.03
SECCHI	M	1.8	.24	1.7	.76	1.03	.13	.11	.04
ORGANIC N	MG/M3	.0	.00	600.3	.48	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	32.3	.58	.00	.00	.00	.00

SEGMENT: 5 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	27.4	.77	25.6	.45	1.07	.09	.25	.08
CHL-A	MG/M3	18.9	.87	17.7	.59	1.07	.07	.18	.06
SECCHI	M	1.4	.26	1.4	.57	1.01	.04	.04	.02
ORGANIC N	MG/M3	.0	.00	592.3	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	37.2	.46	.00	.00	.00	.00

CASE: Kinkaid 2000 - Reduced
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	90.100	38.000	.000E+00	.000	.422
2	1	Subbasin 2	25.100	11.300	.000E+00	.000	.450
3	1	Subbasin 3	10.400	5.300	.000E+00	.000	.510
4	1	Subbasin 4	31.100	17.400	.000E+00	.000	.559
PRECIPITATION			9.509	12.267	.602E+01	.200	1.290
TRIBUTARY INFLOW			156.700	72.000	.000E+00	.000	.459
***TOTAL INFLOW			166.209	84.267	.602E+01	.029	.507
ADVECTIVE OUTFLOW			166.209	76.260	.118E+02	.045	.459
***TOTAL OUTFLOW			166.209	76.260	.118E+02	.045	.459
***EVAPORATION			.000	8.007	.577E+01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	5407.4	51.5	.000E+00	.0	.000	142.3	60.0
2	1	Subbasin 2	1600.1	15.2	.000E+00	.0	.000	141.6	63.7
3	1	Subbasin 3	600.0	5.7	.000E+00	.0	.000	113.2	57.7
4	1	Subbasin 4	2603.0	24.8	.000E+00	.0	.000	149.6	83.7
PRECIPITATION			285.3	2.7	.203E+05	100.0	.500	23.3	30.0
TRIBUTARY INFLOW			10210.5	97.3	.000E+00	.0	.000	141.8	65.2
***TOTAL INFLOW			10495.8	100.0	.203E+05	100.0	.014	124.6	63.1
ADVECTIVE OUTFLOW			1794.7	17.1	.659E+06	3236.4	.452	23.5	10.8
***TOTAL OUTFLOW			1794.7	17.1	.659E+06	3236.4	.452	23.5	10.8
***RETENTION			8701.0	82.9	.673E+06	3305.8	.094	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
8.02	1.5738	27.4	.3129	3.1954	.8290

Appendix J
Monte Carlo Analyses

J.1 Monte Carlo Analyses

This appendix contains results of the Monte Carlo analyses for manganese and sulfates in the Big Muddy River #1 Watershed. Each analysis generates 10,000 random numbers which can be obtained electronically.

IEPA
Watershed Load Reductions
7/15/2002

Monte Carlo Simulations using @RISK 3.5

Watershed : N12 Big Muddy River #1

Manganese

Cc (Mn)	1	mg/L	- Water quality criterion
Cd (Mn)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (Mn) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Mn) 51.1% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 0.6 mg/L

LTA = mean * (1 - PR99)

LTA (Mn) 0.291 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Mn) 66.8% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 0.6 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 0.198 mg/L

IEPA
Watershed Load Reductions
7/15/2002

Monte Carlo Simulations using @RISK 3.5

Watershed : N12 Big Muddy River #1

Sulfate

Cc (Sulfate) 500 mg/L - Water quality criterion
Cd (Sulfate) #NAME? mg/L - Randomly generated pollutant source concentration base on the observed data

Percent Reduction

PR = Max(0, (1-Cc/Cd))

PR (Sulfate) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Sulfate) 36.2% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 246.9 mg/L

LTA = mean * (1 - PR99)

LTA (Sulfate) 157.576 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Sulfate) 58.0% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

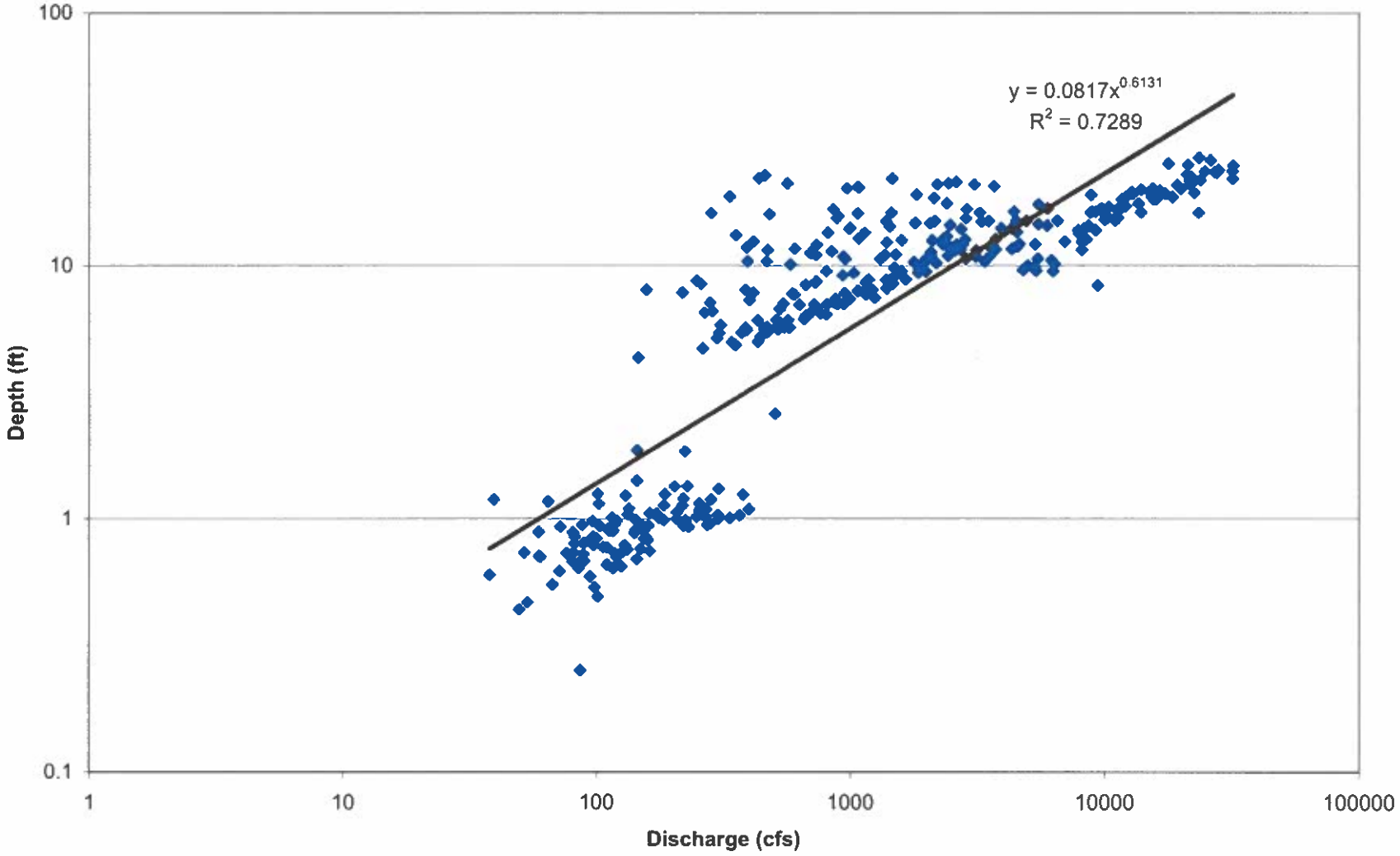
mean 246.9 mg/L

LTA = mean * (1 - PR99.9)

LTA (Sulfate) 103.660 mg/L

Appendix K
Rating Curve for Depth

Depth Rating Curve for the Big Muddy River



R02215

Appendix L
Streeter-Phelps Analyses

Big Muddy Segment N12 Watershed
Aeration Coefficient Summary

Location	Date	DO observed	BOD @ DO Observed	Ka @ DO observed	Ka at DO = 6 mg/L
N12	7/24/2000	7.9	7.3	45.4	11.05
N12	9/6/2000	4.7	7.2	3.2	11.53

Definitions

D	DO Deficit = DO at saturation minus observed DO
D_o	Initial DO deficit
k_a	Reaeration rate
k_d	BOD5 decay rate
x	Distance downstream of discharge
U	Stream velocity
L_o	Initial BOD5 at x=0
C_s	DO at saturation
C	Observed DO
H	Stream depth
T	Stream temperature
Q	Streamflow

R02217

DONE Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
0.376206	4	0.519612	45.4	0.364011	5280	1.1	7.3	8.3	7.9	8.8	25.1	2060
0.375403												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.4

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation 360 feet
DO @ Elev. 8.3 mg/L
DO Elev Factor 0.99

DO @ Temp/Elev 8.3 mg/L

N12_072400

R02218

DONE Used Q from USGS Derived Flows and H calculated from Q. Used Ka and Kd from N12 9/6/00.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
2.276206	4	0.519612	11.04779	0.364011	5280	1.1	7.3	8.3	6	8.8	25.1	2060
2.276206												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.4

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation 360 feet
DO @ Elev. 8.3 mg/L
DO Elev Factor 0.99

DO @ Temp/Elev 8.3 mg/L

R02219

DONE Using Depth and Q Determined from Habitat Survey. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
3.513029	4	1.065987	3.2	0.458047	5280	1.1	7.2	8.2	4.7	5.4	25.5	400
3.503937												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.3

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation 360 feet
DO @ Elev. 8.3 mg/L
DO Elev Factor 0.99

DO @ Temp/Elev 8.2 mg/L

N12_090600

R02220

DONE Using Depth and Q Determined from Habitat Survey. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
2.213029	4	1.065987	11.52703	0.458047	5280	1.1	7.2	8.2	6	5.4	25.5	400
2.213029												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.3

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation	360	feet
DO @ Elev.	8.3	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	8.2	mg/L

R02221

Appendix M
Error Analyses

M.1 Monte Carlo Analysis Development and Results

This appendix provides the results of the Monte-Carlo DO error analysis. The analysis was run on the range of possible values for the BOD_5 decay rate coefficient (k_d) and the reaeration rate coefficient (k_a). The Monte-Carlo program requires a distribution of k_a and k_d values. For each DO sample date, a triangle distribution was chosen to analyze the Big Muddy River segment N12 since data for this site was extremely limited.

Each DO sample date was evaluated separately using @RISK, which is a Microsoft® *Excel* Add-in for the Monte-Carlo analysis. The @RISK analysis package performed 10,000 iterations to determine the range of possible DO predictions over 10,000 combinations of randomly selected k_a and k_d values.

A triangular distribution assumes that the values of a given data set are most often at or near the mode and linearly distributed to the minimum and maximum values. The minimum is the smallest concentration of the sample data set. The maximum value is the largest sample in the sample data set. The mode is the value that is most likely to be observed in a long time series of sample data. Water quality data were not available to determine the actual k_a and k_d, so the estimated values discussed in Section 10.3 and shown in Table 10-3 were used as the mode for each sample date.

In order to define a more appropriate distribution than triangular, more data needs to be collected. In the absence of any drift, or non-random error, 10 samples can be used to define a distribution. As the data set increases, so does the ability to define an appropriate distribution, such a lognormal, normal, etc. The number of samples needed to define the true data distribution depends upon the severity of the drift.

The Monte Carlo simulation was run using 10,000 iterations with the triangular distribution. For each iteration, a DO concentration is randomly generated according to random sampling of the triangular distribution of k_a and k_d. The output of the Monte-Carlo simulation is a population of 10,000 DO concentrations that could be observed across the literature range of k_a and k_d values. Statistics were performed on the Monte-Carlo output to determine the 95th and 99.9th percentile confidence intervals. A confidence interval means that the stated percent of the simulated concentrations fall within the low and high concentrations of the interval.

This appendix shows the set-up for the Monte-Carlo simulation for each segment sample date, a summary of the output, and the 95th and 99.9th percentile confidence intervals for each sample date.

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	1.1	7.3	8.3	7.9	2060	=RiskTriang(0.01,45.4,100	=RiskTriang(0.02,0.364,3.4)

DO= =$F$3-(($B$3*EXP((-$I$3*$C$3)/($D$3*86400)))+($E$3*$J$3/($I$3-$J$3))*(EXP(-$J$3*$C$3/($D$3*86400))-EXP(-$I$3*$C$3/($D$3*86400))))

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	3.7	0.7	0.0
Maximum =	8.2	99.0	3.4
Mean =	7.6	48.7	1.3
Std Deviation =	0.6	20.6	0.8
Variance =	0.4	422.6	0.6
Skewness =	-2.2	0.1	0.6
Kurtosis =	8.4	2.4	2.4
Errors Calculated =	0.0	0.0	0.0
Mode =	7.4	39.2	2.0

95th Percent Confidence Interval
6.3 8.9

99.9th Percent Confidence Interval
5.5 9.7

N12_072400

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	1.0	7.2	8.2	4.7	5.38	=RiskTriang(0.01,3,100)	=RiskTriang(0.02,0.458,3.4)

DO= =$F$3-(($B$3*EXP((-$I$3*$C$3)/($D$3*86400)))+($E$3*$J$3/($I$3-$J$3))*(EXP(-$J$3*$C$3/($D$3*86400))-EXP(-$I$3*$C$3/($D$3*86400))))

Summary of Monte Carlo Results

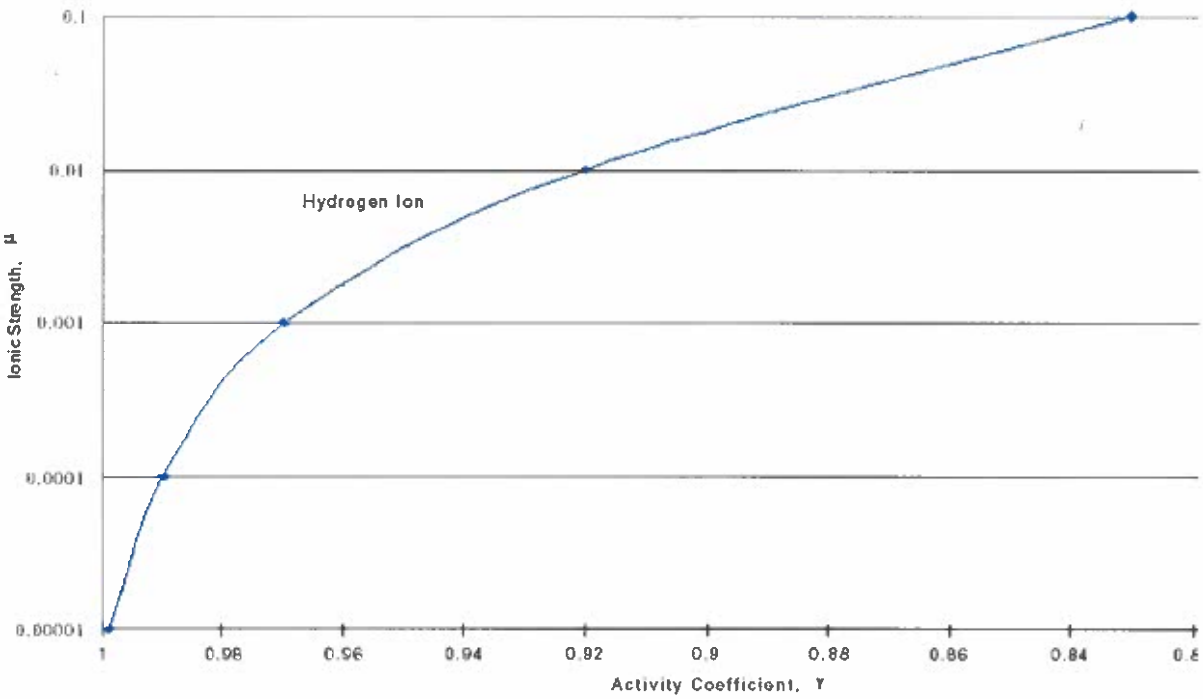
	DO	Ka	Kd
Minimum =	3.3	0.2	0.0
Maximum =	8.2	99.7	3.4
Mean =	6.9	34.4	1.3
Std Deviation =	1.1	23.3	0.7
Variance =	1.3	542.5	0.6
Skewness =	-0.9	0.6	0.5
Kurtosis =	2.7	2.4	2.4
Errors Calculated =	0.0	0.0	0.0
Mode =	6.4	44.1	0.7

95th Percent Confidence Interval
4.7 9.1

99.9th Percent Confidence Interval
3.1 10.6

Appendix N
Chart of Activity Coefficients versus Ionic Strength

Ionic Strength versus Activity Coefficient (Snoeyink 1980)



Appendix O
pH Analyses

IEPA
pH TMDL
9/12/2002

Watershed	Segment	TDS 95 percentile (mg/L)	Ionic Strength (μ)	Activity CorrectionFactor
Big Muddy River	N12	1194	0.02985	0.9

Additional Notes:
- Activity Correction factor computed from Figure 5 (KDEP 2001)
- TDS 95 percentile is computed from observed data

Watershed	Segment	Area (miles^2)	3 yr-Flow (cfs)	Max H+ Ion Loading @ pH of 6.5 (g/day)	Max H+ Ion Loading @ pH of 6.5 (lbs/day)	Actual H+ Ion Loading (g/day)	Actual H+ Ion Loading (lbs/day)	Reduction in H+ Ion Loading (lbs/day)
Big Muddy River	N12	2169	16,425.55	14,198.25	31.30	4,751.91	10.48	(20.83)

Additional Notes:
1) 3-yr flow calculated by the Log Normal Distribution
2) Max H+ concentration @ pH of 6.5 is determined by relationship in QvsLoading_g (6.5)
3) Actual H+ concentration for Big Muddy @ 3 yr flow is determined by relationship in QvsLoading_g (N12)

IEPA
pH TMDL
9/12/2002

Water Quality pH Standard = 6.5
Activity CorrectionFactor (N12) = 0.9 * based upon the TDS concentrations observed in the watershed

	N12	
Flow (cfs)	Max Ion Loading (g/day)	Max Ion Loading (lbs/day)
0	0.00	0.000
500	432.22	0.953
1000	864.45	1.906
1500	1296.67	2.859
2000	1728.89	3.811
2500	2161.12	4.764
3000	2593.34	5.717
3500	3025.56	6.670
4000	3457.78	7.623
4500	3890.01	8.576
5000	4322.23	9.529
5500	4754.45	10.482
6000	5186.68	11.434
6500	5618.90	12.387
7000	6051.12	13.340
7500	6483.35	14.293
8000	6915.57	15.246
8500	7347.79	16.199
9000	7780.02	17.152
9500	8212.24	18.105
10000	8644.46	19.057
10500	9076.68	20.010
11000	9508.91	20.963
11500	9941.13	21.916
12000	10373.35	22.869
12500	10805.58	23.822
13000	11237.80	24.775
13500	11670.02	25.728
14000	12102.25	26.680
14500	12534.47	27.633
15000	12966.69	28.586
15500	13398.92	29.539
16000	13831.14	30.492
16500	14263.36	31.445
17000	14695.58	32.398
17500	15127.81	33.351
18000	15560.03	34.303
18500	15992.25	35.256
19000	16424.48	36.209
19500	16856.70	37.162
20000	17288.92	38.115
20500	17721.15	39.068
21000	18153.37	40.021
21500	18585.59	40.974
22000	19017.82	41.926
22500	19450.04	42.879
23000	19882.26	43.832
23500	20314.48	44.785
24000	20746.71	45.738
24500	21178.93	46.691
25000	21611.15	47.644

IEPA
pH TMDL
9/12/2002

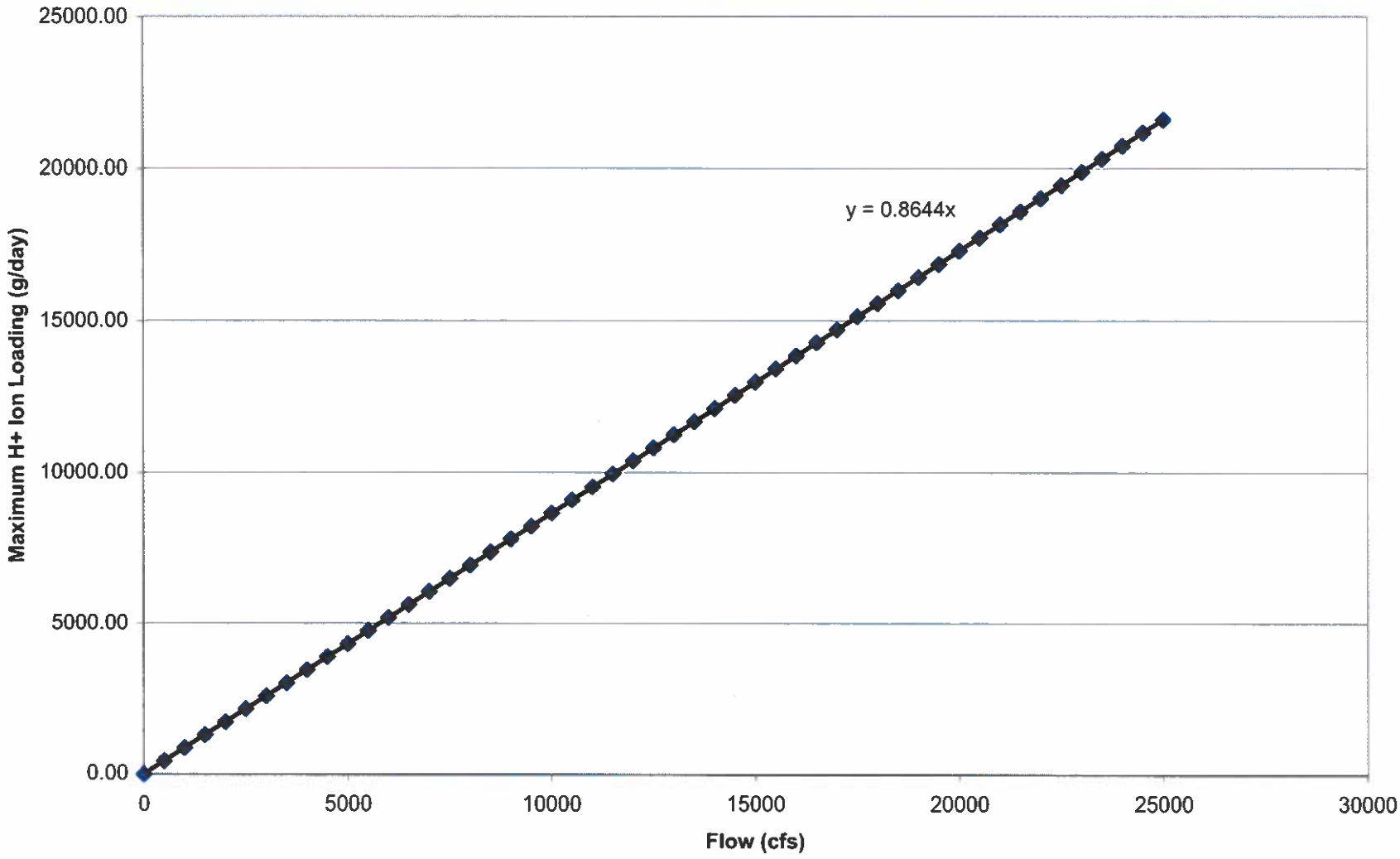
Big Muddy River (N12)

Water Quality pH Standard = 6 5
Activity Correction Factor = 0 9

Max Ion Loading (g/day)	Max Ion Loading (lbs/day)	pH (measured)	Flow (cfs)
0 68	0 000	7 800	1 898
0 68	0 000	7 800	1 898
0 36	0 001	8 300	26 386
0 36	0 001	8 300	26 386
2 27	0 005	7 500	26 386
0 36	0 001	8 300	26 386
0 11	0 000	8 600	26 386
0 11	0 000	8 600	26 386
0 72	0 002	8 000	26 386
15 11	0 033	7 000	55 600
15 11	0 033	7 000	55 600
87 27	0 148	8 900	196 551
134 21	0 296	6 600	196 551
0 45	0 001	7 900	13 112
1 79	0 004	7 300	13 112
2 25	0 005	7 200	13 112
2 25	0 005	7 200	13 112
2 25	0 005	7 200	13 112
2 25	0 005	7 200	13 112
1 79	0 004	7 300	13 112
1 79	0 004	7 300	13 112
0 28	0 001	7 500	3 285
0 56	0 001	7 200	3 285
0 56	0 001	7 200	3 285
0 15	0 000	7 800	3 541
0 03	0 000	8 200	1 506
0 03	0 000	8 200	1 506
158 81	0 350	6 400	146 740
158 81	0 350	6 400	146 740
13 14	0 029	7 100	60 850
13 14	0 029	7 1	60 850
16 54	0 036	7	60 850
13 14	0 029	7 1	60 850
13 14	0 029	7 1	60 850
26 22	0 058	6 8	60 850
26 22	0 058	6 8	60 850
16 54	0 036	7	60 850
16 54	0 036	7	60 850
2 39	0 005	7 4	22 078
2 39	0 005	7 4	22 078
1 49	0 003	7 3	10 972
1 88	0 004	7 2	10 972
0 09	0 000	7 9	2 571
0 14	0 000	7 7	2 571
0 09	0 000	7 9	2 571
0 11	0 000	7 8	2 571
0 11	0 000	7 8	2 571
0 11	0 000	7 8	2 571
0 11	0 000	7 8	2 571
0 28	0 001	6 9	0 868
0 28	0 001	6 9	0 868
0 19	0 000	7 05	0 781
0 57	0 001	7	2 087
0 57	0 001	7	2 087
9 54	0 021	6 9	27 867
7 58	0 017	7	27 867
7 58	0 017	7	27 867
7 58	0 017	7	27 867
7 58	0 017	7	27 867
7 58	0 017	7	27 867
7 58	0 017	7	27 867
5 93	0 013	7 2	34 598
5 93	0 013	7 2	34 598
1 36	0 003	7 3	10 164
1 36	0 003	7 3	10 164
1 00	0 002	7 44	10 164
1 29	0 003	7 33	10 164
1 42	0 003	7 29	10 164
1 42	0 003	7 29	10 164
1 18	0 003	7 1	5 479
0 43	0 001	7 1	1 979
0 43	0 001	7 1	1 979
0 06	0 000	7 7	1 104
12 46	0 027	7 4	114 565
1 56	0 003	7 6	22 886
7 52	0 017	7 7	138 663
3 77	0 008	8	138 663
5 97	0 013	7 8	138 663
7 52	0 017	7 7	138 663
9 47	0 021	7 6	138 663
7 52	0 017	7 7	138 663
1 19	0 003	8 5	138 663
3 77	0 008	8	138 663
4 75	0 010	7 9	138 663
9 47	0 021	7 6	138 663
4 75	0 010	7 9	138 663
23 78	0 052	7 7	138 663
37 69	0 083	7	138 663
18 89	0 042	7 3	138 663
4 75	0 010	7 9	138 663
18 89	0 042	7 3	138 663
0 17	0 000	7 1	0 794
1 02	0 002	7 2	5 937
1 23	0 003	7 4	11 335
0 42	0 001	7 4	3 891
12 41	0 027	6 8	18 174
169 37	0 373	6 8	393 103
17 40	0 038	6 8	40 387
1 32	0 003	7 3	9 693
8 21	0 018	7 2	48 465
9 49	0 021	6 9	27 733
4 63	0 010	6 5	5 385
0 49	0 001	7 2	2 881
2 65	0 006	6 4	2 456
0 91	0 001	7 5	5 950
2 96	0 007	7 5	34 464
9 07	0 020	7 2	52 907
17 31	0 038	7	63 677
10 17	0 022	7 1	47 118
10 22	0 023	6 7	18 647
4 82	0 011	6 4	4 456
1 16	0 002	7 3	8 677
0 18	0 000	7 3	1 306
0 84	0 001	8 1	20 194
13 81	0 030	7 3	99 891
10 21	0 023	7 2	99 504
4 18	0 009	7 4	38 637
10 76	0 024	6 5	12 520
0 10	0 000	7 3	0 754
0 06	0 000	7 4	0 512
0 35	0 001	7	1 306
4 76	0 010	6 6	6 879
5 23	0 012	6 6	7 660
1 26	0 003	7 1	5 629
0 90	0 002	7 6	13 153
9 49	0 021	6 9	27 733
4 63	0 010	6 5	5 385

Gage	Date	Time of pH Sample	pH (S U)	Flow (cfs)
S999500	1/8/1990	10 30	7 8	1 898
S999500	1/8/1990	10 45	7 8	1 898
S999500	2/8/1990	13 00	8 3	26 386
S999500	2/8/1990	13 30	8 3	26 386
S999500	2/8/1990	13 32	7 5	26 386
S999500	2/8/1990	13 35	8 3	26 386
S999500	2/8/1990	13 37	8 6	26 386
S999500	2/8/1990	13 38	8 6	26 386
S999500	2/8/1990	13 40	8	26 386
S999500	4/16/1990	15 00	7	55 600
S999500	4/16/1990	15 15	7	55 600
S999500	5/22/1990	10 00	6 9	196 551
S999500	5/22/1990	10 30	6 6	196 551
S999500	7/9/1990	14 00	7 9	13 112
S999500	7/9/1990	14 02	7 3	13 112
S999500	7/9/1990	14 05	7 2	13 112
S999500	7/9/1990	14 07	7 2	13 112
S999500	7/9/1990	14 10	7 2	13 112
S999500	7/9/1990	14 13	7 2	13 112
S999500	7/9/1990	14 15	7 2	13 112
S999500	7/9/1990	14 45	7 3	13 112
S999500	7/9/1990	15 00	7 3	13 112
S999500	6/21/1990	9 30	7 5	3 285
S999500	6/21/1990	9 45	7 2	3 285
S999500	6/21/1990	10 00	7 2	3 285
S999500	9/24 1990	13 30	7 8	3 541
S999500	11/13/1990	13 00	8 2	1 506
S999500	11/13/1990	13 30	8 2	1 506
S999500	1/8/1991	11 30	6 4	146 740
S999500	1/8/1991	12 00	6 4	146 740
S999500	2/12/1991	12 00	7 1	60 850
S999500	2/12/1991	12 10	7 1	60 850
S999500	2/12/1991	12 20	7	60 850
S999500	2/12/1991	12 30	7 1	60 850
S999500	2/12/1991	12 40	7 1	60 850
S999500	2/12/1991	12 50	6 8	60 850
S999500	2/12/1991	13 00	6 8	60 850
S999500	2/12/1991	13 30	7	60 850
S999500	2/12/1991	14 00	7	60 850
S999500	4/9/1991	13 00	7 4	22 078
S999500	4/9/1991	13 30	7 4	22 078
S999500	6/4/1991	10 00	7 3	10 972
S999500	6/4 1991	10 30	7 2	10 972
S999500	7/16/1991	12 30	7 9	2 571
S999500	7/16/1991	12 35	7 7	2 571
S999500	7/16/1991	12 40	7 9	2 571
S999500	7/16/1991	12 45	7 8	2 571
S999500	7/16/1991	12 50	7 8	2 571
S999500	7/16/1991	13 00	7 8	2 571
S999500	7/16/1991	13 30	7 8	2 571
S999500	8/20/1991	12 30	6 9	0 868
S999500	8/20/1991	13 00	6 9	0 868
S999500	10/15/1991	12 00	7 05	0 781
S999500	11/12/1991	12 00	7	2 087
S999500	11/12/1991	12 30	7	2 087
S999500	1/7/1992	10 15	6 9	27 867
S999500	1/7/1992	10 20	7	27 867
S999500	1/7/1992	10 25	7	27 867
S999500	1/7/1992	10 30	7	27 867
S999500	1/7/1992	10 35	7	27 867
S999500	1/7/1992	10 40	7	27 867
S999500	1/7/1992	11 00	7	27 867
S999500	1/7/1992	11 30	7	27 867
S999500	2/20/1992	11 30	7 2	34 598
S999500	2/20/1992	12 00	7 2	34 598
S999500	4/14/1992	10 30	7 3	10 164
S999500	4/14/1992	11 00	7 3	10 164
S999500	4/14/1992	11 05	7 44	10 164
S999500	4/14/1992	11 10	7 33	10 164
S999500	4/14/1992	11 15	7 29	10 164
S999500	4/14/1992	11 25	7 29	10 164
S999500	5/18/1992	11 00	7 1	5 479
S999500	7/13/1992	12 30	7 1	1 979
S999500	7/13/1992	13 00	7 1	1 979
S999500	8/17/1992	12 00	7 7	1 104
S999500	1/12/1993	7 00	7 4	114 565
S999500	2/16/1993	9 00	7 6	22 886
S999500	1/9/1994	7 00	7 7	138 663
S999500	3/2/1994	7 00	8	138 663
S999500	4/6/1994	6 00	7 8	138 663
S999500	5/23/1994	6 00	7 7	138 663
S999500	7/6/1994	12 00	7 6	138 663
S999500	8/4/1994	6 00	7 7	138 663
S999500	9/19/1994	11 00	8 5	138 663
S999500	11/1/1994	6 00	8	138 663
S999500	12/7/1994	6 00	7 9	138 663
S999500	1/30/1995	6 00	7 6	138 663
S999500	2/21/1995	6 00	7 9	138 663
S999500	4/12/1995	7 00	7 2	138 663
S999500	5/10/1995	6 00	7	138 663
S999500	6/15/1995	6 00	7 3	138 663
S999500	7/20/1995	6 00	7 9	138 663
S999500	8/22/1995	6 00	7 3	138 663
S999500	10/31/1995	6 00	7 1	0 794
S999500	12/18/1995	7 00	7 2	5 937
S999500	1/31/1996	9 00	7 4	11 335
S999500	2/29/1996	6 00	7 4	3 891
S999500	3/25/1996	6 00	6 8	18 174
S999500	5/1/1996	6 00	6 8	393 103
S999500	6/25/1996	6 00	6 8	40 387
S999500	7/31/1996	6 00	7 3	9 693
S999500	4/24/1997	6 00	7 2	48 465
N12	7/24/2000		6 9	27 733
N12	9/6/2000		6 5	5 385
N12	10/27/1997		7 2	2 881
N12	11/20/1997		6 4	2 456
N12	3/3/1998		7 5	5 950
N12	3/5/1998		7 5	34 464
N12	4/16/1998		7 2	52 907
N12	5/14/1998		7	63 677
N12	6/17/1998		7 1	47 118
N12	7/21/1998		6 7	18 647
N12	8/27/1998		6 4	4 456
N12	10/6/1998		7 3	8 677
N12	12/1/1998		7 3	1 306
N12	1/6/1999		8 1	20 194
N12	2/8/1999		7 3	99 891
N12	3/22/1999		7 2	99 504
N12	4/27/1999		7 4	38 637
N12	5/18/1999		6 5	12 520
N12	9/16/1999		7 3	0 754
N12	11/1/1999		7 4	0 512
N12	12/6/1999		7	1 306
N12	1/3/2000		6 6	6 879
N12	3/8/2000		6 6	7 660
N12	4/12/2000		7 1	5 629
N12	5/1/2000		7 6	13 153
N12	7/24/2000		6 9	27 733
N12	9/6/2000		6 5	5 385

Calculated Flow vs. Maximum H^+ Ion Loading

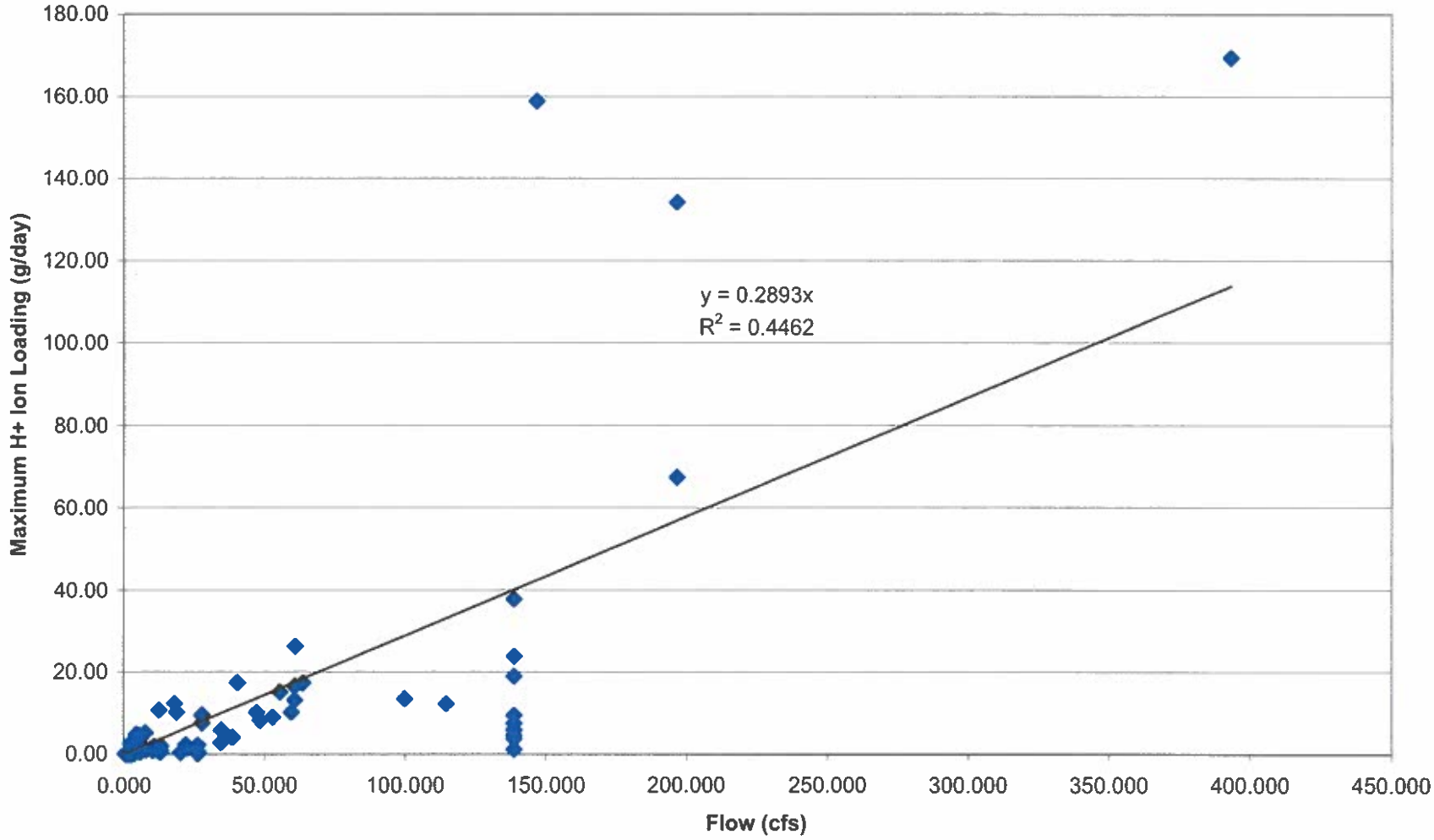


CDM

AppendixO-pHAnalyses.xls, 'QvsLoading_g (6.5)_N12'

R02232

Existing Flow vs. Maximum H^+ Ion Loading in Segment N12 of the Big Muddy River



CDM

AppendixO-pHAnalyses.xls, 'QvsLoading_g (N12)'

R02233

Appendix P
Responsiveness Summary

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Responsiveness Summary

This responsiveness summary responds to substantive questions and comments received during the public comment period from January 23, 2004 to March 29, 2004 postmarked, including those from the February 26, 2004 public meeting discussed below.

What is a TMDL?

A Total Maximum Daily Load (TMDL) is the sum of the allowable amount of a pollutant that a water body can receive from all contributing sources and still meet water quality standards or designated uses. The Big Muddy River TMDL report contains a plan detailing the actions necessary to reduce pollutant loads to the impaired water bodies and ensure compliance with applicable water quality standards. The Illinois EPA implements the TMDL program in accordance with Section 303(d) of the federal Clean Water Act and regulations thereunder.

Background

The watershed targeted for TMDL development is Big Muddy River (ILN12), which originates in Jefferson County, Illinois. The watershed encompasses an area of approximately 200 square miles. Land use in the watershed is predominately forestland followed by rural grassland and agricultural land uses. TMDLs developed for impaired water bodies in the Big Muddy River watershed include Big Muddy River segment N12 and Kinkaid Lake (RNC). In the 2002 Section 303(d) List, Big Muddy River (N12) was listed as impaired for manganese, sulfates, pH, low dissolved oxygen (DO), and total suspended solids (TSS). Kinkaid Lake was listed as impaired for pH, mercury, and siltation. The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) List. Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Therefore, TMDLs were only developed for the following: Big Muddy River (N12): manganese, sulfates, pH, and DO; Kinkaid Lake (RNC): pH. While the impairment caused by mercury is acknowledged, a TMDL will not be developed for it at this time. The Illinois EPA contracted with Camp Dresser & McKee (CDM) to prepare a TMDL report for the Big Muddy River watershed.

Public Meetings

Public meetings were held in the city of Springfield on June 5, 2001 and in the city of Murphysboro on December 12, 2001 and February 26, 2004. The Illinois EPA provided public notice for the February 26, 2004 meeting by placing display ads in the Southern Illinoisan on January 27, 2004, and the Carbondale Times and The Spokesman on January 25, 2004. This notice gave the date, time, location, and purpose of the meeting. The notice also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Approximately 50 individuals and organizations were also sent the public notice by first class mail. The draft TMDL

Report was available for review at the Murphysboro Township office and also on the Agency's web page at http://www.epa.state.il.us/water/tmdl .

The final public meeting started at 6:00 p.m. on Thursday, February 26, 2004. It was attended by approximately 36 people and concluded at 7:25 p.m. with the meeting record remaining open until midnight, March 29, 2004.

Questions and Comments

1. If Kinkaid Lake was listed only for sediment, why were nutrients addressed in the TMDL?

Response: The 2002 303(d) List shows Kinkaid Lake being impaired for pH, mercury, and siltation. As discussed in the report, mercury was not addressed in this TMDL report. Since siltation does not have a numeric water quality standard, a TMDL was not developed for it. A TMDL was developed for pH since it has a numeric water quality standard. During the analysis, an attempt was made to link pH swings to algal blooms that occur in the lake. These algal blooms are a result of increased phosphorus levels within the lake. Therefore, a reduction in phosphorus loading to the lake should help control algal blooms, which in turn should help stabilize pH levels.

2. Only three samples for pH violated the standards. Was this TMDL done just to address these few excursions?

Response: Yes. Any violation of the water quality standard can place that water body on the 303(d) List, for which TMDLs must be developed. Since numeric water quality standards exist for pH, a TMDL was developed for Kinkaid Lake.

3. Why was station RNC-4 high in phosphorus but didn't violate the pH standard? Did the phosphorus from RNC-4 get distributed throughout the rest of the lake?

Response: Phosphorus entering a lake is transported throughout the lake. RNC-4 is at the upper reaches of the reservoir. The phosphorus that was transported to other areas of the reservoir from RNC-4 could cause algal blooms and associated pH violations.

4. When will TMDLs be developed for the listed causes without standards?

Response: TMDLs are currently only conducted for listed causes for which a water quality standard exists. Pending development of appropriate water quality standards, as may be proposed by the Agency or others and adopted by the Illinois Pollution Control Board, we will continue to work with watershed planning groups and others to identify causes and treat potential sources of impairment.

5. The GWLF model assumes that all row crop runoff directly enters the lake. That assumption is not correct.

Response: GWLF does not route flow and data were not available for the tributaries to Kinkaid Lake. Therefore, calibration in these areas could not be completed. The calibration exercise was used to estimate what runoff and associated phosphorus concentrations were entering the lake. The GWLF model was selected based on the amount of data available for calibration.

6. Using the Casey Fork flow gauge for this watershed was not representative for the tributary that runs into the lake. A gauge used to be in the upper tributary years ago. That data could be used to calculate flow in Kinkaid Lake.
Response: It is best to utilize more recent flow data that occurred during the time of data collection for calibration. Use of the Casey Fork gauge was considered conservative because it has a less steep slope than the Kinkaid Lake tributaries.

7. An NRCS study performed by Roger Windhorn looked at erosion and sedimentation rates occurring in Kinkaid Lake watershed. Was that looked at during TMDL development?

Response: Yes this study was part of the Kinkaid Lake Management Plan and was evaluated during TMDL development.

8. Was runoff and erosion from the forestland within the lake watershed considered in the model?

Response: Yes, the contribution of forestland to the phosphorus load was analyzed through the GWLF model. According to the analysis, forestland contributes approximately 3,212 lbs per year, or 15 percent of the total phosphorus load entering the lake.

9. Assuming that no-till, filter strips, and dry dams are already in place, what else can a farmer do to prevent phosphorus loads in the watershed?

Response: Producers in the watershed are encouraged to use soil testing and nutrient management plans to ensure that they are not over-applying fertilizers to their fields. The Agency recommends that producers follow fertilizer recommendations found in the University of Illinois Agronomy Handbook and NRCS 590 Standard. Information pertaining to nutrient management planning and programs that provide financial incentives to develop such plans can be found in the Implementation Plan of the TMDL report.

10. A lot of highly erodable land in the watershed has been enrolled in conservation programs. About one-third of row crops currently in conservation programs have very low P tests. I don't believe the 18 percent reduction in phosphorus through nutrient management planning is achievable for this watershed. There has been a lot of conservation tillage done in the watershed in the last 20 years, so there may not be as much saving in additional conservation tillage practices.

Response: The consultants did not have access to soil test results from individual landowners. The GWLF model was set at a total phosphorus soil concentration of 660 ppm based on comparison with observed data in the BATHTUB model, as well as a sensitivity analysis to confirm that this was within the correct range. The report recognizes the high percentage of no-till being practiced in the watershed,

and encourages those not currently practicing conventional tillage to consider practicing a form of conservation tillage. In the report, the 19 percent reduction in phosphorus from conservation tillage practices is based on an average, so that reduction may or may not be reached. Likewise, the 20 percent reduction in total phosphorus from nutrient management plans is also based on an estimate. The report suggests that stakeholders use an adaptive management approach, in that the effectiveness of a BMP is estimated after it is incorporated into the watershed.

11. Why weren't any reductions recommended for internal cycling in the lake?

Response: Kinkaid Lake is very deep and is less likely to experience internal cycling than other shallower lakes in Illinois. The calibration did not indicate that phosphorus enriched sediment and cycling were causing impairments.

12. Is there a correlation between high phosphorus and low DO in the stream?

Response: There can be, although that correlation was not proved through the analysis in this report. High phosphorus loading to the stream can cause algal blooms. As the algae dies and decay, the consuming bacteria use oxygen in the water, reducing the amount of dissolved oxygen in the stream. For segment N12, we believe that low flow and stagnant conditions, as well as possible BOD loads, are causing low DO to occur in the stream. As stated in the Implementation Plan, further monitoring is required to properly identify these sources.

13. How often are samples taken for stream segment N12?

Response: The station on Segment N12 is part of the Agency's Ambient Water Quality Monitoring Network. Water chemistry samples are taken on approximately a nine-week rotating schedule, year round. This segment is also sampled by the agency every five years through the Intensive Basin Survey, in which water chemistry as well as habitat and biological parameters are assessed.

14. The report doesn't mention that county SWCDs administer the CPP program through the Illinois Department of Agriculture. Some of the practices recommended in the Implementation Plan could be funded through the CPP program as well.

Response: Thank you for your comment. This will be incorporated into the final version of this report.

15. The animal management facility mentioned in the report for Kinkaid Lake is being closed, with the land being seeded to grass, so the erosion and potential phosphorus load contribution from that site won't occur in the future.

Response: Thank you for your comment. This will be mentioned in the final version of this report.

16. At what point will the lake be delisted, or the study be completely finalized?

Response: The lake can be delisted by: 1) having a new assessment show that it is no longer impaired, 2) having an approved TMDL developed for the causes for which it is listed. The study will be finalized after it is approved by USEPA. Once approved, a final version will be printed and made available to the public.

17. At what point will a determination be made that the voluntary measures listed in the Implementation Plan become involuntary?

Response: At this time, the Agency does not foresee any of the recommended actions in the Implementation Plan becoming mandatory for the pollutants addressed in this TMDL report.

18. Would future industry or sewage plant expansion be affected by this TMDL?

Response: Any new wastewater discharge for the causes identified in this TMDL will be affected by the allocations in this report. Appropriate discharge limits for those causes will be established prior to permitting. New data will be reviewed at that time to confirm the impairment continues.

19. Has a study been done about dredging the river?

Response: To the Agency's knowledge, no study has been done for dredging this segment of the Big Muddy River.

20. Who is the contact person at the Agency for lake and stream monitoring?

Response: Mike Bundren (lake monitoring) and Dave Muir (stream monitoring) can be contacted at the Illinois EPA regional office in Marion by calling (618) 993-7200.

21. We are confused by the discussion in Section 7.1 of the basis for requiring a reduction in phosphorus to achieve the pH TMDL. Only data from stations RNC-1 and RNC-3 are presented to support the expected relationship between total phosphorus, chlorophyll-a and pH. [Note: we were not able to replicate the consultant's correlation between total phosphorus and chlorophyll-a at station RNC1. The data set for RNC-1 included in Appendix A includes two values that are not shown in figure 8-3: a chlorophyll-a value of 58.7 on 8/2/2000 (for which there is a corresponding total phosphorus value of 0.009) and a total phosphorus value of 0.654 on 10/22/90. Using those values, we calculated an r^2 of 0.03; substituting the total phosphorus median value of 0.16, results in an r^2 of 0.029. We also note that the chlorophyll-a value of 58.7 on 8/2/2000 appears to have been used in Figure 7.1 to demonstrate the expected relationship between chlorophyll-a and pH. If that value is eliminated from that analysis, the r^2 becomes 0.04.]

For most stations in the lake and for the lake as a whole (considering data from all four stations), there is no correlation (r^2,0.15) between total phosphorus and pH, chlorophyll-a and pH or total phosphorus and chlorophyll-a. Moderate correlations exist between total phosphorus and chlorophyll-a at station RNC-3 (r^2=0.46) and for the entire lake (r^2=0.37), and between chlorophyll-a and pH at station RNC-1 (r^2=0.37). For station RNC-4, which has the highest total phosphorus concentrations, but no exceedences of the pH standard, there is no correlation between any of the variables (r^2 </=0.10).

Response: The relationships presented in Section 7 were intended to confirm that there is a relationship between pH and chlorophyll-a in addition to chlorophyll-a and phosphorus. These general relationships have been established in literature, which suggest that reducing algae (chlorophyll-a) maintains pH and reducing phosphorus concentrations reduce algae (chlorophyll-a). Additional data collection for Kinkaid Lake may establish the same relationships found in literature. All the r^2 values are low, and the figures were intended to show general trends and provide examples of what has been established through literature. The relationships established in literature were used as the basis for the focus of this TMDL – control of phosphorus and thereby control of algae (chlorophyll-a) and pH.

22. We also find the discussion of loading capacity confusing. The section states that load reductions were modeled for RNC-4 because it violates the phosphorus standard (but not the pH standard), but then says that the effects of the modeled reductions are only shown for stations RNC-1 and RNC-3 because they are the only stations that violated the pH standard (RNC-1 never violates the phosphorus standard and at RNC-3 only one sample since 1994 has exceeded the standard. At both stations, the mean total phosphorus concentration is well below the standard).

Response: Phosphorus loadings in sub-basins 2, 3 and 4 were less than sub-basin 1. Therefore sub-basin 1 and its contributions to station RNC-4 were targeted for reductions. Phosphorus flows through the lake as well as settles and can cause algae growth in various parts of the lake. Since the largest loads were generated from sub-basin 1, it was the focus of the reductions to maintain pH throughout the lake.

23. The relationships provided in Figures 7-1 through 7-4 are weak, at best. At RNC-1, there is no relationship between total phosphorus and chlorophyll-a and only a moderate correlation between chlorophyll-a and pH. There is also no direct correlation between total phosphorus and pH (r^2=0.04). At RNC-3, there is only a moderate correlation between total phosphorus and chlorophyll-a and no correlation between chlorophyll-a and pH. There is also no direct correlation between total phosphorus and pH (r^2=0.0007). We also note that the predicted mean total phosphorus values after a 40 percent reduction in phosphorus loadings shown in Table 8-3 exceed the mean of the observed values at RNC-1 in 1997 and 2000 and at RNC-3 in 2000.

Response: See response to question 21.

24. In Section 9.1.2 Implementation Actions and Management Measures Summary, it is not apparent how the "Potential Percent Reductions" values in Table 9-2 were derived. For example, what is the basis for the statement in the preceding paragraph, 3rd bullet: "Nutrient management (reductions of total phosphorus in sediment by 20 percent)"? No citations to the scientific literature are provided, and no data or analysis are presented to support this statement.

Response: This was estimated by the consultant as an initial goal to target for nutrient reduction. As nutrient management plans are implemented, the effectiveness on reducing phosphorus concentrations can be further assessed against this initial target goal.

25. We were not able to find any results of modeling BMP effectiveness in Appendix C, GWLF and BATHTUB input and output files. Table 9-2 shows a potential reduction of 19% for "tillage practices" without specifying what residue levels would be required to achieve that reduction. Conservation tillage systems can result in reductions in sediment-bound phosphorus roughly proportional to the sediment load reductions. However, conservation tillage may also result in increased losses of dissolved phosphorus (McIssac et al, J. Soil and Water Conservation: 50 (4) 383-397 (1995)).

Response: The tillage practices category listed in Table 10.2 refer to conservation tillage practices, and the report has been changed to reflect that. Table 10.6 in the report suggests that it would be beneficial for all of the cropland in the watershed to have some form of conservation tillage implemented. Section 9.1.1.1 on page 9-2 of the report states "Conservation tillage is assumed to include tillage practices that preserve at least 30 percent residue cover of the soil after crops are planted." The GWLF model took into account those cropland acres in which conservation tillage practices, including no-till, have already been implemented. Although conservation tillage practices, such as no-till, can result in an increase in dissolved phosphorus runoff, the benefits gained from reductions in erosion and particulate phosphorus will decrease the loads of total phosphorus as well as sedimentation in the impaired water bodies. McIssaac et al. conclude that "[T]he fate of the dissolved P in runoff from agricultural fields is likely to depend upon the hydrologic context of each particular field in question. Dissolved P may be absorbed by vegetation or soils in buffer strips, wetlands, riparian zones, or stream banks. Whether elevated levels of dissolved P in runoff represents a problem in a watershed depends upon these processes. " If we proceed with an iterative approach to BMP installation and monitor the results, dissolved and total phosphorus loads can be better understood and treated.

26. Because no data are available on phosphorus in the streams within the watershed, it is not possible to determine whether particulate phosphorus or dissolved phosphorus is the form of phosphorus that is of greater concern.

Response: We concur with this statement and have outlined this as a future data collection need within a possible monitoring program in the Implementation Plan.

In 2003, Kinkaid Lake began a Phase I Clean Lakes Study funded through Illinois EPA. A component of this Study is to collect tributary data. Once taken and verified, these data can be analyzed to see how it can compliment or enhance the TMDL analysis.

27. We believe that it would be more helpful to producers and providers of technical assistance within the watershed to provide more readily understandable information on the changes needed to reduce phosphorus loadings. Presenting reductions in terms of soil erosion being reduced by tons per acre and targeted C factors would provide producers with a specific measurable goal rather than an indefinite "tillage practices".

Response: The required reductions in soil loss and C-factor were calculated during the analysis but not specifically stated in the text of the draft final report. These data have since been inserted into the text of the report for the convenience of producers and technical service providers.

28. Estimations of the effectiveness of management practices, such as wetlands or filter strips must account for the proportion of the total runoff in the watershed that will be transported through and effectively treated by the wetland or filter strip. For example, the only water that a filter strip can effectively treat is runoff water that moves through the strip as sheet flow. Water in a concentrated flow channel will not be treated.

Response: Section 9.1.1.2, on page 9-3 of the report states: "To maintain removal efficiency, sheet flow should be maintainted and substrate should be monitored to assess whether the wetland is operating optimally." It is true that sheet flow should be maintained in order for filter strips to properly filter pollutants. This will be reflected in the final version of the report.

29. We noted a significant disagreement between the Agency's contractors on the effectiveness of buffer strips and wetlands in removing phosphorus, and even by CDM in its discussion of BMP for nutrients in different TMDLs. The TMDL for the Charleston Side Channel Reservoir (Section 9.1.4, page 39) used the following values in its discussion of measures to achieve the necessary load reductions:

The combination of the following BMPs result in a reduction of 94.6 percent of the total phosphorus load to the lake

- 33.5 percent reduction through aeration, sediment sealing, or system flushing (90 percent of internal load)
- 20 percent reductions of external load due to cultural practices (primarily through CRP, tillage, and nutrient management practices)
- 70 percent reduction of external load due to buffer strips
- 65 percent reduction of external load due to ponds or wetlands

These values differ greatly from the values used by CDM in their discussions of implementation of the Washington County Lake TMDL (Section 10.2.3, page 10-12) and the Altamont New Reservoir TMDL (Section 9.1.3, page 9.6):

Management Measure	Altamont New Reservoir TMDL (Table 9-2)	Washington County Lake TMDL (Table 10-4)	Kinkaid Lake TMDL (Table 9-2)
Nutrient Management	17%	11%	14%
Tillage Practices	38%	30%	19%
Filter Strips*	22%	22%	14%
Wetland*	5%	40%	25%

*Literature value utilized for estimation

We note particularly the great difference in the estimates for the potential reductions from wetlands both in the two TMDLs prepared by CDM and the Charleston Side Channel Reservoir TMDL. But CDM also has taken contradictory positions on the effectiveness of wetlands in the two TMDLs we have reviewed. In the Altamont New Reservoir TMDL (Section 9.1, page 9-6), CDM states: "The lower bound of the literature value for wetlands (i.e. 5%) was used due to studies that have shown the long-term effectiveness of phosphorus removal in wetlands is negligible." But in the Washington County Lake TMDL, CDM has used a value of 40%. As quoted by CDM (Altamont New Reservoir TMDL, Section 9.1.1, page 9.2 and Washington County Lake TMDL Section 10.2.1.2, page 10.9), "Over the long term, it is generally thought that wetlands are neither sources nor sinks of phosphorus (Kovasic et al. 2000)". We believe that most of the scientific literature supports Dr. Kovacic's statement.

Response: The inconsistencies for potential percent reduction of management measures in each report prepared by CDM was done in error and will be corrected in the final published reports. The correct values for each management measure are shown below. This change does not impact the degree of implementation recommended for each watershed.

Summary of Total Phosphorus Load Reductions

Management Measure	Potential Percent Reduction
Nutrient Management	10%
Conservation Tillage Practices	11%
Filter Strips*	22%
Wetland*	5%

***Literature value utilized for estimation**

30. The only site in the watershed actually visited by the project team was the Mt. Joy boat ramp, which is in no way representative of the 38,535-acre watershed.

Response: This was the only area shown in pictures in the report. The team visited other areas of the watershed not shown in the report. The extent of the TMDL scope for the study did include field investigations.

31. The TMDL and the implementation plan are derived from a computer model and not from hands-on data collection from the watershed. While this is saving of time and money, it may not realistically reflect conditions in the watershed and may not lead to practical solutions for the impairments which exist.

Response: This TMDL was developed based on readily available data. The water quality data used in the modeling were based on data collected by Illinois EPA from Kinkaid Lake. While the amount of and types of data were lacking in some areas, the Implementation Plan suggests practices that are known to control pollutant loadings that lead to pH impairment. As the report suggests, an adaptive management approach to implementation should be taken, and future monitoring will provide more data, which local stakeholders can use for implementation decision making.

32. The Kinkaid watershed is arguably the steepest watershed in Illinois. One-third of the watershed is in excess of 15% slope and 25,000 acres are in excess of 5% slope. The highest point in the watershed is more than 400 feet above the base of the dam. The headwaters of the original creek are 254 feet higher than the base of the dam.

Response: The slope of this watershed was taken into account during the analysis. Slope length and slope steepness are factors used in the USLE equation, which is a component of the GWLF model that was used during TMDL development.

33. Stream flow into the lake was not measured, but was estimated from stream flow at Casey Fork (Mt. Vernon). One can question the similarity of the two watersheds. (p. 5-2)

Response: Flow data from the Casey Fork watershed were used in the absence of a gauge in the Kinkaid Lake watershed. The drainage area ratio method was used to estimate flows entering the lake. An explanation of this method can be found in Section 5.1.3 of the report.

34. Average monthly rainfall data were used in the model. While these data are probably accurate, there is no accounting for the rate of precipitation. In a steeply sloping watershed, three inches of rain falling over three days is entirely different from three inches over 2 hours (a heavy rain in the Kinkaid watershed is comparable to flushing a toilet).

Response: TMDLs are supposed to account for all seasonal conditions within a watershed, not specific events. Use of monthly precipitation takes into account that requirement of TMDL development.

35. How was water volume calculated for segment RNC4 (upper lake)? This appears to have a major bearing on total phosphorus entering the lake if total Phosphorus = mg Phos./L. x water volume. IEPA has not established specific boundaries for the lake segment represented by each sampling site, but has assigned a surface area to the lake

segments. When these areas were added together, it resulted in their estimate of total lake surface area being approximately 50% more than it actually is. (p. 5-15)

Response: The entire volume of the lake was calculated based on historic depth and surface area. Specific segment volumes were not calculated separately.

36. On p.5-6 and 5-7, it is stated that the correlation between pH and chlorophyll a is expected to indicate a direct relationship between the two constituents. In fact Table 5-5 (p.6) shows that segment RNC4 has some of the lowest pH values for the lake and the text indicates no individual samples with a pH impairment. Yet Table 5-7 shows segment RNC4 with chlorophyll a levels more than double those of any other portion of the lake. The actual data contradicts the hypothesis.

Response: TMDLs are supposed to account for all seasonal conditions within a watershed, not specific events. Use of monthly precipitation takes into account that requirement of TMDL development.

37. On page 5-7, it is stated that these relationships would suggest that controlling phosphorus will in turn control pH. Table 5-6 (page 5-7) shows RNC4 with by far the highest phosphorus levels for the lake, but Table 5-5 shows that segment to be in compliance for pH. In fact it is the sampling segments which are well within the standards for Phosphorus that have shown a few individual violations for pH. The actual data again disproves the hypothesis.

Response: See response to question 21.

38. The computer model assumes that all cropland is immediately adjacent to streams. That is definitely not the case in the Kinkaid watershed.

Response: See response to question 5.

39. The TMDL report states that there are no terraces in the Kinkaid Watershed. KAWP 2000 (page 11) reports more than 24,000 linear feet of terraces in the watershed (source – Jackson County Soil and Water Conservation District).

Response: This statement has been deleted from the report.

40. In 1991, 1995, and 1996, the text (page 5-6) reports a total of three individual samples slightly below the lower pH limit in the discharge below the spillway. Table 5-4 (page 5-5) reports a total of 70 samples from this location over a seven year period. In 1991, 1994, and 2000 the text reports a total of 4 individual samples testing slightly above the upper limit for pH in segments RNC1 and RNC3. Table 5-4 reports a total of 77 samples taken from these locations over an 11 year period. Do these data indicate any consistent trend toward pH violations? Is it possible to question the accuracy of the instrumentation or readings for pH?

Response: The data indicate that pH impairments are infrequent, however IEPA has determined that 1 violation in a 3 period indicates impairment. All data are shown in Appendix A

41. What is the location of the gauge at which the discharge from the lake was sampled? If it is, as we surmise, located at the Highway 149 bridge, that location is approximately one mile downstream from the spillway. That portion of the creek has it's own watershed and is, at times, actually supplied by the Big Muddy River.

Resonse: Downstream discharge was not analyzed for the Kinkaid Lake TMDL. Water quality data used for TMDL development were taken from the four water quality stations located within the lake.

42. Why does passing over the spillway cause a pH drop of 3 (9.1 in RNC 1 to 6.1 in the "discharge")?

Response: The only water quality data analyzed for Kinkaid Lake were from stations sampled within the lake. No water quality data were analyzed from water that passed over the spillway for this TMDL.

43. A 1983 erosion study of the Kinkaid watershed determined that there was almost 5 times the amount of sheet and rill erosion from cropland as was determined by the 2000 study (KAWP 2000, page 40). Some of the decrease in erosion is attributed to conversion to conservation tillage on cropland. In addition, land use changes have resulted in 1,100 acres of cropland being converted to hay or pasture lands and 2,200 acres of cropland have been enrolled into CRP and seeded to permanent grass cover.

Response: The land use coverage used in the modeling was obtained from Illinois Department of Natural Resource's Critical Trends Assessment database, and was supplemented by the National Agricultural Statistics Service's Cropland Data Layer. Cropland taken out of production would be reflected in these data. Current tillage practices were obtained from the most recent Soil Transect Survey conducted by the Illinois Department of Agriculture. These data were reviewed and verified to be applicable to the Kinkaid Lake watershed by local NRCS staff.

44. The KAWP 2000 erosion study (page 43) reports that sheet and rill erosion from cropland accounts for approximately 25% of the sediment delivered annually into Kinkaid Lake. Sheet and rill erosion from woodlands and grasslands account for 45% of the sediment delivered annually. The remaining sediment delivered annually comes from gully, stream bank and shoreline erosion.

Response: Although gully, stream bank and shoreline erosion are not accounted for in GWLF, they do contain as much phosphorus as the other sources. The source of phosphorus they do contain is accounted for in the Margin of Safety for the TMDL.

45. Sediment from woodlands, grasslands, stream banks and shoreline is not devoid of phosphorus even though none has been applied.

Response: Sediment loading and associated phosphorus loading from woodlands and grasslands was accounted for in the model. Loadings from stream banks and shoreline erosion would be accounted for in the margin of safety.

46. On page 4-5, it is stated that phosphorus is commonly released from sediment into the water when anoxic conditions exist. There is good potential in the upper lake (RNC4) for anoxic conditions to exist, especially during the warm season and especially west of Highway 151. Anoxic conditions occur all over the lake below the thermocline. How much of the soluble phosphorus in the lake comes from sediment deposited over the past 30 years?

Response: The data do not show that this portion of the lake stratifies so as to cause anoxic conditions. Further study would need to occur to determine the amount of phosphorus entering the lake via sediment.

47. The text on page 7-14 states that the model assumes internal cycling is not occurring in Kinkaid Lake. The shallow upper end, especially since significant siltation has occurred, does indeed qualify as a shallow reservoir.

Response: See response to 46.

48. Conservation tillage practices should be continued and encouraged as stated on page 9-2. Voluntary conversion of cropland into conservation programs should be continued and encouraged. Nutrient management is an economical and sensible practice and is already probably followed by most farmers.

Response: The Agency concurs with this statement, and these practices are discussed in the report's Implementation Plan.

49. KAWP 2000 page 30 reports that only 5% of the land adjacent to streams is in cropland. This refutes the assumption in the model that all cropland in the watershed is immediately adjacent to streams. 81% of land adjacent to streams is forested for a width of at least 200 feet from the stream and 14% is in grassland for a width of at least 200 feet.

Response: The model does not assume all cropland is adjacent to streams. It groups all land use within a sub-basin together and predicts loading from a given area. A detailed model which would require more extensive data than is available for the watershed would be needed to account for the spatially varying land use.

50. The implementation plan appears to assume that storm water runoff would flow slowly and evenly across the length of the filter strips. In a watershed as steep as Kinkaid, this will not be the case.

Response: Design of filter strips would have to take into account local conditions.

51. A map showing the intended location of the filter strips would be helpful. Further study may well indicate it would not be possible to filter strip 1900 feet of the two streams mentioned without tearing out existing riparian corridor (trees) or existing grasslands (some on steeply sloping land). Political considerations have been ignored. Much of those two streams are on U.S. Forest Service land. In the past they have not been eager to allow such alterations on their lands.

Response: The total potential length of filter strip installation was based on land use coverage used in the GIS analysis. Only land that is farmed to the edge of streams were considered as potential locations for filter strips. Land use currently in grassland or woodland was not considered, and the agency in no way is condoning such land being replaced by filter strips. The installation of filter strips is strictly voluntary. We encourage local stakeholders to further study filter strip placement in the watershed.

52. The text states that over the long term wetlands are not thought to have an effect on phosphorus entering the lake (page 9.3). Why then is it recommended to construct 134 acres of wetlands?

Response: The text states that there are varying results from wetlands. Consideration of wetlands would need to take this into account as well as site-specific design considerations.

53. Hedging statements such as those at the bottom of page 7-13, pointing out deficiencies in data plus lack of on-the-ground experience in the watershed, lead one to question the validity of both the TMDL and implementation procedures. There is a reasonable possibility that if the implementation plan is completely carried out, the TMDL will still not be in compliance.

Response: This TMDL was developed based on readily available data. We noted in the report where data gaps exist, and suggest additional data that could be collected to strengthen the correlations attempted in the report. The purpose of the Implementation Plan is to suggest practices that may help reduce phosphorus loads to the lake, which should help control pH. We recommend using an adaptive management approach in concert with future monitoring. Data from future monitoring-collected after some BMPs are installed-will determine whether or not the lake is fully supporting its designated uses and if and where additional BMPs are needed.

54. Since 1983 many improvements have been made in the watershed and efforts are on-going to do more. There is also a reasonable probability that if nothing is done to carry out the implementation plan, the lake will show compliance (unless, of course, we continue to use data from the last century).

Response: Land use data, cropping and tillage practices in the watershed were based on the most recent data and verified by county NRCS staff, which would reflect improvements made since 1983. Future assessments of Lake Kinkaid will be based on future data taken through the Ambient Lake Monitoring Program. These monitoring data will be assessed according to methodologies explained in the state's 305(b) Report. The lake will only show compliance when future data show that it is fully supporting all of it's designated uses.

55. On the basis of the TMDL report, it is difficult to see justification for expenditure of public and private funds to create the wetlands and filter strips recommended in the implementation plan.

Response: The report's Implementation Plan recommends that an adaptive management approach be taken. Not all of the recommended practices need to be installed all at once, but rather interested landowners can voluntarily enroll land in programs that provide financial assistance for implementing these practices. Landowners are free to install these practices regardless of whether or not a TMDL has been developed in their watershed. Filter strips and wetlands are recommended based on their ability to reduce the amount of nutrient-laden sediments from entering waterways.

56. Most local citizens perceive sedimentation and siltation to be the major problems at Kinkaid Lake. If we continue existing efforts to prevent sedimentation through erosion control and to manage siltation, the TMDL as perceived by the EPA will come into compliance.

Response: The goal of the TMDL is for Kinkaid Lake to fully support all of its designated uses. Future data assessments will be based on samples taken through the Clean Lake Study and the Ambient Lake Monitoring Program. The target for this TMDL is based on the numeric standard for pH, which can be achieved by reducing phosphorus loads to the lake. Much of this phosphorus enters the lake through sediment. By decreasing the amount of sediment entering the lake through implementation of the recommended BMPs, the phosphorus loads should decrease as well.

57. The only impairment the contractor addressed in the TMDL was pH due to four minor excursions over a ten-year period. The hypothesis used by the consultant is based on a hypothesis by Wetzel who asserts that photosynthesis and respiration are major influences on pH. That hypothesis would not work in RNC-4 because the light column is too short for chlorophyll-a due to the sediment in suspension. I would prefer data from Kinkaid Lake be applied to prove their hypothesis before making an assumption based on a previous study from another situation and location to suggest a relationship between phosphorus and chlorophyll-a to pH in Kinkaid Lake

Response: The TMDL takes into account the entire lake column not just segment RNC-4. It is likely that the algae activity that could be associated with pH impairments occur in different portions of the lake. . In fact, none of the pH excursions were measured in RNC-4-there were two each in RNC-1 and RNC-3.

58. Why did CDM not conclude the paucity of infractions from as large a number of samples should remove the impairment concern from Kinakid Lake? Is it a federal mandate that once a resource is placed on an impaired list, it cannot be found to be an insignificant impairment to warrant removal from the 303(d) List?

Response: pH is listed as a cause of impairment in lakes when at least one violation of the applicable standard for pH (<6.5 or >9.0) occurs during the monitoring year. The Clean Water Act mandates that TMDLs should be developed for waters listed on the State's 303(d) List. The only way a cause of impairment can be de-listed is if: 1. a TMDL is developed for that cause; 2. new data show the water body is no longer impaired for that cause; or 3. the cause is found to be "pollution" (e.g., flow reduction or habitat modification) and not a "pollutant" (e.g., pH).

59. During the final public meeting, the consultant was provided with a copy of "Kinkaid Lake Watershed Investigation" conducted July 11, 2000, by R. D. Windhorn, which arrived at figures for deposition of materials from the watershed to Kinkaid Lake. The BATHTUB model used the wrong assumption that all materials from crop fields and the watershed were deposited directly into Kinkaid Lake. That assumption is not scientifically sound and taints the model's findings. Perhaps Mr. Windhorn's data could be inserted into the model and the load form the watershed to the lake recalculated for a more accurate assessment.

Response: See response to 49.

60. Presently, the Kinkaid-Reed's Creek Conservancy District is in the middle of a Phase I Clean Lakes Study that should provide fresh data for a review on the validity and the necessity of this impairment at Kinkaid Lake. The new data should be reviewed to ascertain if the present condition of Kinkaid Lake warrants the Illinois EPA impairment concern.

Response: We concur with this statement. As new data are taken from the lake, through the Clean Lakes Study as well as the Agency's Ambient Lake Monitoring Program, the data will be used in future assessments to determine if the lake is supporting all of it's designated uses. If not, the most recent data will be assessed to determine causes of impairment. The Implementation Plan for this report includes a continued monitoring plan and an adaptive management approach for monitoring BMP effectiveness.

DISTRIBUTION OF RESPONSIVENESS SUMMARY

Additional copies of this responsiveness summary are available from Mark Britton, Illinois EPA Office of Community Relations, phone 217-524-7342 or email Mark.Britton@epa.state.il.us

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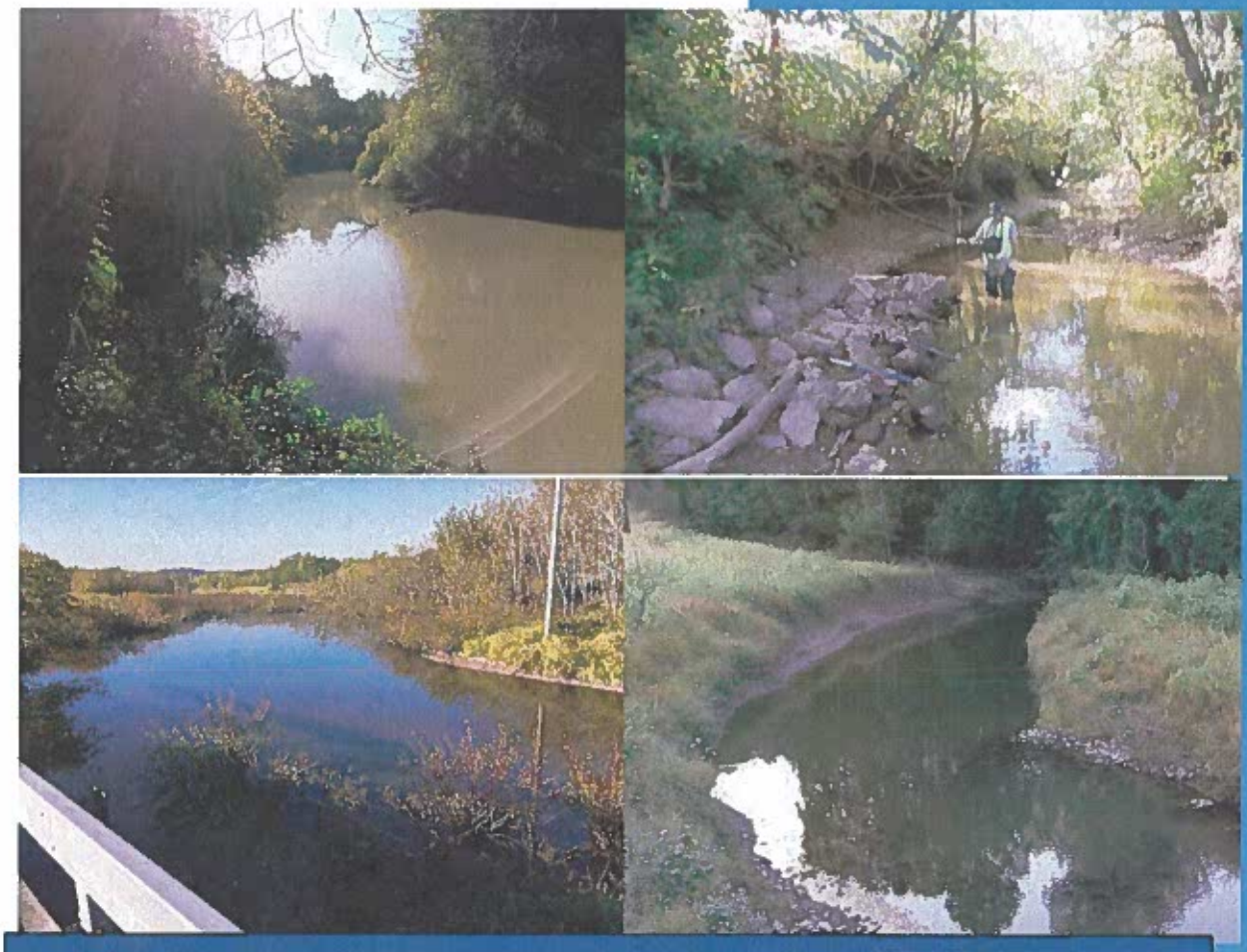
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R02254



Stage 3 TMDL Report

Upper Big Muddy Watershed

Prepared for:
Illinois EPA

DRAFT for Public Comment
October 15, 2018

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Upper Big Muddy River Watershed
Total Maximum Daily Load

Stage 3 Report

Prepared for:
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Draft for Public Comment
October 15, 2018

Prepared by:
LimnoTech

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Executive Summary

Section 303(d) of the 1972 Clean Water Act requires States to define impaired waters and identify them on a list, which is called the 303(d) list. The State of Illinois 303(d) lists are published every two years and are available at: http://www.epa.state.il.us/water/tmdl/303d-list.html. This report focuses on assessments based on the 2012 303(d) list (IEPA, 2012), which was the version that was final at the start of this project. Section 303(d) of the Clean Water Act and USEPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting designated uses under technology-based controls. The TMDL process establishes the allowable loading of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and instream conditions. This allowable loading represents the maximum quantity of the pollutant that the waterbody can receive without exceeding water quality standards. The TMDL also takes into account a margin of safety, which reflects scientific uncertainty, as well as the effects of seasonal variation. By following the TMDL process, States can establish water quality-based controls to reduce pollution from both point and nonpoint sources, and restore and maintain the quality of their water resources (USEPA, 1991).

Load Reduction Strategies (LRSs) are being completed for causes that do not have numeric standards. LRSs for causes of impairment with target criteria will consist of loading capacity and the percent reduction needed to meet the target criteria.

The following waterbodies in the Upper Big Muddy River watershed are listed on the 2012 Illinois Section 303(d) List of Impaired Waters (IEPA, 2012) as not meeting their designated uses. IEPA conducted additional sampling in 2015 on 6 of the waterbodies to support the modeling presented in this report. This document presents TMDLs for the following segments and reservoirs to allow these waterbodies to fully support their designated uses:

- Upper Big Muddy River (IL_N-11)
- Andy Cr. (IL_NZN-13)
- Lake Cr. (IL_NGA-02)
- Beaver Cr. (IL_NGAZ-JC-D1)
- Middle Fork Big Muddy (IL_NH-06)
- Arrowhead (Williamson) Lake (IL_RNZX)
- Herrin Old Reservoir (IL_RNZD)
- Johnston City Lake (IL_RNZE)
- West Frankfort Old Lake (IL_RNP)
- West Frankfort New Lake (IL_RNQ)

LRSs for the following water bodies are also presented:

- Upper Big Muddy River (IL_N-06, IL_N-11, IL_N-17)
- Pond Cr. (IL_NG-02)
- Middle Fork Big Muddy (IL_NH-07)

This report covers each step of the TMDL process and is organized as follows:

- Problem Identification

- Stage 2 Sampling
- Development of Numeric Targets
- Development of Water Quality Models
- TMDL Development
- LRS Development
- Public Participation and Involvement
- Adaptive Implementation Process
- Clean Water Act Section 319

Illinois EPA conducts TMDLs following a three-stage process. Stage 1 includes watershed characterization, data analysis and model selection. Stage 2 involves data collection, and is conducted if necessary. Stage 3 includes model calibration and application, and TMDL and implementation plan development. Upper Big Muddy River Watershed Stage 1 work began in September, 2013. A public meeting to present the Stage 1 findings and the draft Stage 1 report was held in December 2013. The final Stage 1 report was completed in January, 2014, and recommended additional monitoring for dissolved oxygen modeling, and the delisting of the following stream segments for the noted impairments:

- Andy Cr. / IL_NZN-13 – Manganese
- Hurricane Creek / IL_NF-01 – Lindane
- M. Fk. Big Muddy / IL_NH-06 – Manganese
- M. Fk. Big Muddy / IL_NH-07 – Manganese
- Prairie Cr. / IL_NZM-01 – Sulfates

Stage 2 low flow sampling was conducted in 2015 to support dissolved oxygen modeling on several stream segments in the Upper Big Muddy River watershed. As a result of this sampling and data analysis, the following stream segments are recommended for delisting based on either the waters meeting the water quality standards during the sampling period, or the low dissolved ozygen conditions were flow related:

- Big Muddy R. / IL_N-17 - Dissolved Oxygen (Sampling met WQS)
- M. Fk. Big Muddy / IL_NH-06 - Dissolved Oxygen (Low DO is due to high sediment oxygen demand / low flow)
- M. Fk. Big Muddy / IL_NH-07 - Dissolved Oxygen (Low DO is due to high sediment oxygen demand / low flow)
- Pond Cr. / IL_NG-02 - Dissolved Oxygen (Sampling met WQS)

Further data analysis as a part of the Stage 3 TMDL/LRS preparation on the following segments has indicated that the listed impairment may not currently exist:

- Hurricane Creek / IL_NF-01 - Sedimentation/Siltation
- Herrin Old / IL_RNZD - Total Suspended Solids (TSS)
- Johnston City / IL_RNZE - Total Suspended Solids (TSS)
- West Frankfort Old / IL_RNP - Total Suspended Solids (TSS)
- West Frankfort New/ IL_RNQ - Total Suspended Solids (TSS)
- Lake Cr. / IL_NGA-02 - Phosphorus (Total)
- Big Muddy R. / IL_N-11 - Sulfates

The results of these data alayses will be reevaluated during the next 303(d) listing cycle to determine if these stream segments should continue to be listed as impaired.

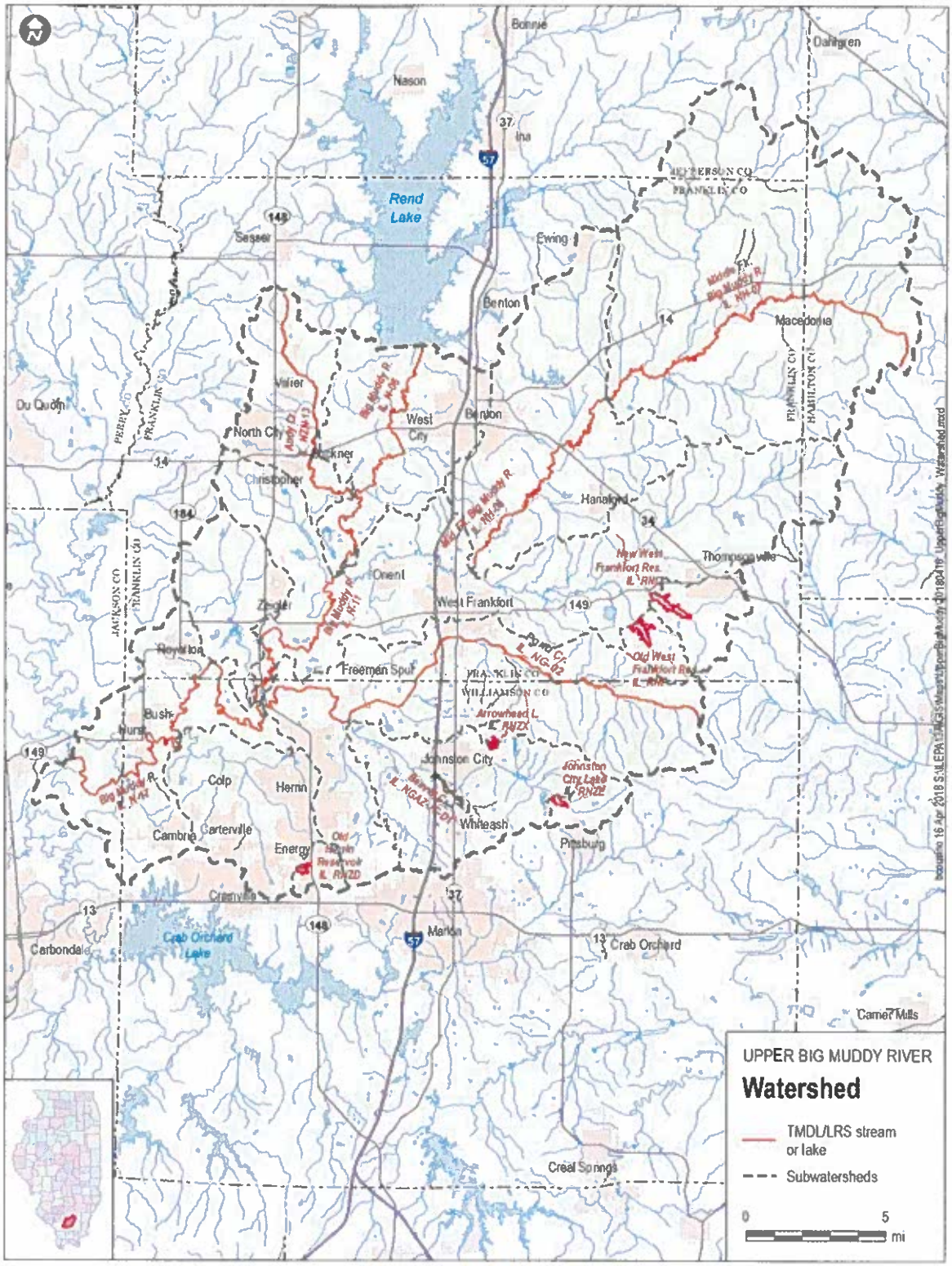


Figure 1-1. Upper Big Muddy River Watershed

1 Problem Identification

The impaired waterbodies within the Upper Big Muddy River watershed listed by the IEPA are listed below (Table 1-1), with the parameters (causes) they are listed for, and the impairment status of each designated use. The waterbodies that are proposed for delisting in the Table below are based on one of the following reasons:

1. Analysis of the data provided under Stage 1 that the existing data did not support the listed impairments.
2. Analysis of the data collected during the Stage 2 sampling performed for IEPA indicated that the impairments may not currently exist.
3. Analysis of the data collected during the Stage 2 sampling performed for IEPA indicated that the impairments are due to low flow conditions, not pollutant loading.
4. Based on a comparison of TSS data to the LRS target concentration developed by IEPA, it was determined that TSS reduction is not needed.
5. Based on a comparison of TP data to the LRS target concentration developed by IEPA, it was determined that TP reduction is not needed.

Table 1-1. Impaired Waterbody Summary

Waterbody/ Segment ID	Size (mile/ac)	Impaired Designated Use	Impairment Cause	Proposed Action
Big Muddy R. / IL_N-06	15.13 mi	Aquatic life	Sedimentation/Siltation	Prepare LRS
Big Muddy R. / IL_N-11	11.48 mi	Aquatic life	Sulfates	**Delist (1)**
		Primary contact recreation	Fecal Coliform	Prepare TMDL
		Aquatic life	Sedimentation/Siltation, TSS	Prepare LRS
Big Muddy R. / IL_N-17	21.48 mi	Aquatic life	Dissolved Oxygen	**Delist (2)**
		Aquatic life	Sedimentation/Siltation, TSS	Prepare LRS
Hurricane Creek / IL_NF-01	10.6 mi	Aquatic life	Lindane	**Delist (1)**
		Aquatic life	Sedimentation/Siltation	**Delist (4)**
Prairie Cr. / IL_NZM-01	9.06 mi	Aquatic life	Sulfates	**Delist (1)**
Andy Cr. / IL_NZN-13	11.7 mi	Aquatic life	Iron	Prepare TMDL
		Aquatic life	Manganese	Delist (1)
		Aquatic life	Dissolved Oxygen	Delist (3)
Herrin Old / IL_RNZD	51.3 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
		Aesthetic Quality	Total Suspended Solids (TSS)	**Delist (4)**
Pond Cr. / IL_NG-02	23.53 mi	Aquatic life	Chloride	Delist (1)
		Aquatic life	Dissolved Oxygen	**Delist (2)**

Waterbody/ Segment ID	Size (mile/ac)	Impaired Designated Use	Impairment Cause	Proposed Action
		Aquatic life	Sedimentation/Siltation	Prepare LRS
Lake Cr. / IL_NGA-02	12.33 mi	Aquatic life	Dissolved Oxygen	Prepare TMDL
		Aquatic life	Phosphorus (Total)	**Delist (5)**
Beaver Cr. / IL_NGAZ-JC-D1	1.7 mi	Aquatic life	Manganese	Prepare TMDL
Johnston City / IL_RNZE	64 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
		Aesthetic Quality	Total Suspended Solids (TSS)	**Delist (4)**
Arrowhead (Williamson) / IL_RNZX	30 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
M. Fk. Big Muddy / IL_NH-06	12.52 mi	Primary contact recreation	Fecal Coliform	Prepare TMDL
		Aquatic life	Dissolved Oxygen	**Delist (3)**
		Aquatic life	Manganese	**Delist (1)**
M. Fk. Big Muddy / IL_NH-07	19.74 mi	Aquatic life	Dissolved Oxygen	**Delist (3)**
		Aquatic life	Manganese	**Delist (1)**
		Aquatic life	Sedimentation/Siltation	Prepare LRS
West Frankfort Old / IL_RNP	146 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
		Aesthetic Quality	Total Suspended Solids (TSS)	**Delist (4)**
West Frankfort New/ IL_RNQ	214 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
		Aesthetic Quality	Total Suspended Solids (TSS)	**Delist (4)**

Delisting of the stream segments identified in the table able will occur as a part of a future 303(d) listing process based on the reasons noted above. TMDLs are currently only being developed for pollutants that have numerical water quality standards. Load Reduction Strategies (LRSs) are being developed for pollutants that do not have numerical water quality standards. All of the waterbodies that are being addressed in this Stage 3 report and the implementation plan are summarized in Table 1-2 below.

Table 1-2. TMDL & LRS Waterbody Summary

Waterbody/ Segment ID	Size (mile/ac)	Impaired Designated Use	Impairment Cause	Proposed Action
Big Muddy R. / IL_N-06	15.13 mi	Aquatic life	Sedimentation/Siltation	Prepare LRS
Big Muddy R. / IL_N-11	11.48 mi	Primary contact recreation	Fecal Coliform	Prepare TMDL
		Aquatic life	Sedimentation/Siltation, TSS	Prepare LRS
Big Muddy R. / IL_N-17	21.48 mi	Aquatic life	Sedimentation/Siltation, TSS	Prepare LRS
Andy Cr. / IL_NZN-13	11.7 mi	Aquatic life	Iron	Prepare TMDL
		Aquatic life	Dissolved Oxygen	Prepare TMDL
Herrin Old / IL_RNZD	51.3 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
Pond Cr. / IL_NG-02	23.53 mi	Aquatic life	Chloride	Prepare TMDL
		Aquatic life	Sedimentation/Siltation	Prepare LRS

Waterbody/ Segment ID	Size (mile/ac)	Impaired Designated Use	Impairment Cause	Proposed Action
Lake Cr. / IL_NGA-02	12.33 mi	Aquatic life	Dissolved Oxygen	Prepare TMDL
Beaver Cr. / IL_NGAZ-JC-D1	1.7 mi	Aquatic life	Manganese	Prepare TMDL
Johnston City / IL_RNZE	64 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
Arrowhead (Williamson) / IL_RNZX	30 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
M. Fk. Big Muddy / IL_NH-06	12.52 mi	Primary contact recreation	Fecal Coliform	Prepare TMDL
M. Fk. Big Muddy / IL_NH-07	19.74 mi	Aquatic life	Sedimentation/Siltation	Prepare LRS
West Frankfort Old / IL_RNP	146 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL
West Frankfort New/ IL_RNQ	214 ac	Aesthetic Quality	Phosphorus (Total)	Prepare TMDL

2 Stage 2 Sampling

The Stage 1 report recommended additional sampling be conducted during low flow conditions to support dissolved oxygen modeling in support of TMDL development. In 2015, IEPA conducted Stage 2 sampling to support dissolved oxygen TMDL modeling. Samples were collected in September and October of 2015, and data were reported for CBOD5, BOD5, Nitrite-Nitrate Nitrogen, Ammonia, total kjeldahl nitrogen (TKN), total phosphorus, dissolved phosphorus, chlorophyll a, total suspended solids and volatile suspended solids, and sediment oxygen demand (SOD). Flow, velocity and channel morphometry were also recorded during sampling.

Figure 2-1 shows the locations sampled in 2015. The data collected at these locations were used in the dissolved oxygen modeling described in this report. TMDLs and LRSs for other parameters were based on existing data, previously collected by IEPA and described in the Stage 1 report (Attachment 1).

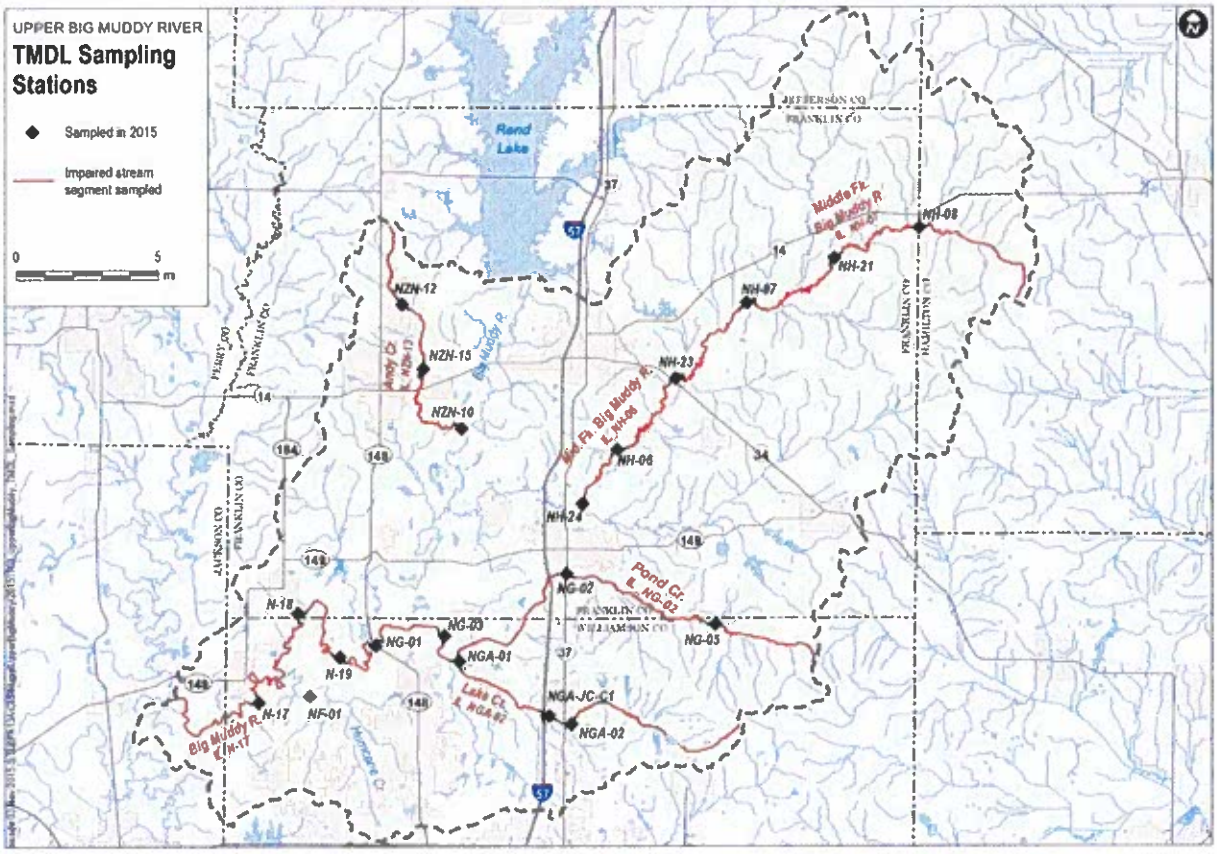


Figure 2-1. 2015 Sampling Locations in the Upper Big Muddy River Watershed









3 Development of Numeric Targets

Designated use, use support and water quality criteria for waterbodies in the Upper Big Muddy River watershed have been previously described in the Stage 1 Report (Attachment 1). This section describes the development of numeric TMDL and LRS targets.

3.1 Development of TMDL and LRS Targets

The TMDL target is a numeric endpoint specified to represent the level of acceptable water quality that is to be achieved by implementing the TMDL. Where possible, the water quality criterion for the pollutant of concern is used as the numeric endpoint.

3.1.1 Phosphorus (Total)

The General Use standards for phosphorus are in Section 302.205 of Title 35. For the phosphorus TMDLs in the lakes within the Upper Big Muddy River watershed, the target is set at the water quality criterion for total phosphorus of 0.05 mg/L.

When appropriate numeric standards do not exist, surrogate parameters must be selected to represent protection of the designated use. For streams and rivers in the Upper Big Muddy River watershed, IEPA has developed a total phosphorus LRS target of 0.217 mg/L (IEPA, 2016). This target is based on an average of validated, real-world data (1999-2013) for the nearby Upper Kaskaskia watershed, which contains several streams that are in full support of aquatic life. This LRS target was ultimately not used to develop a total phosphorus LRS because the average phosphorus concentrations measured in the stream segments listed for TP impairment were below this LRS target concentration.

3.1.2 Dissolved Oxygen

The General Use standards for dissolved oxygen are in Section 302.206 of Title 35. For the Upper Big Muddy River watershed dissolved oxygen TMDLs in streams, the target is set at the water quality criterion for daily minimum dissolved oxygen of 5.0 mg/L recognizing that this is the more conservative of the seasonal minimal dissolved oxygen criteria (recall that between August and February, the minimum is 3.5 mg/L). The QUAL2E models used to calculate the TMDLs predicts a daily average dissolved oxygen concentration and does not directly predict daily minimum values. QUAL2E results can be translated into a form comparable to a daily minimum, by subtracting the observed difference between daily average and daily minimum dissolved oxygen from the model output.

3.1.3 Iron

The General Use standards for iron are in Section 302.208 of Title 35. A single-value standard of 1.0 mg/L applies to dissolved iron, and this is the target used for TMDL development for the Andy Creek (IL_NZN-13) segment.

3.1.4 Manganese

The General Use standards for manganese are in Section 302.208 of Title 35. The water quality standards for dissolved manganese are given by the following equations:

Acute Standard:

$WQS = e^{A+Bln(H)} \times 0.9812$

where A = 4.9187 and B = 0.7467;

and ln(H) is the natural logarithm of the hardness in mg/L.

Chronic Standard:

$WQS = e^{A+Bln(H)} \times 0.9812$

where A = 4.0635 and B = 0.7467;

and ln(H) is the natural logarithm of the hardness in mg/L.

The chronic standard was used to develop the manganese TMDL for Beaver Cr. (IL_NGAZ-JC-D) in the Upper Big Muddy River watershed. The calculated target for this stream segment is shown in section 4.2.6.

3.1.5 Fecal Coliform

The General Use standards for fecal coliform bacteria are in Section 302.209 of Title 35. During the months May through October (swimming-season), based on a minimum of five samples taken over not more than a 30 day period, fecal coliform bacteria shall not exceed a geometric mean of 200 per 100 mL, nor shall more than 10% of the samples during any 30 day period exceed 400 per 100 mL. For fecal coliform TMDLs in the Upper Big Muddy River watershed, the target is conservatively set at the water quality criterion of 200 colony forming units (cfu)/100 mL.

3.1.6 Total Suspended Solids (TSS)

When appropriate numeric standards do not exist, surrogate parameters must be selected to represent protection of the designated use. For all streams and rivers in the Upper Big Muddy River watershed, IEPA has developed a LRS target of 32.2 mg/L TSS (IEPA, 2016). This target is based on an average of validated, real-world data (1999-2013) for the nearby Upper Kaskaskia watershed, which contains several streams that are in full support of aquatic life.

Based on an average of validated, real-world data for these streams over a period from 1999 to 2013, the load reduction targets for all streams in this watershed are as follows:

- Total Suspended Solids: 32.2 milligrams/liter

For all lakes in the watershed, the load reduction targets are as follows:

- Total Suspended Solids: 23 milligrams/liter

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4 Development of Water Quality Models

Water quality models are used to define the relationship between pollutant loading and the resulting water quality. This section describes the modeling to support TMDL and LRS development, and is divided into the following sections:

- QUAL2E modeling for dissolved oxygen TMDL
- Load Duration Curve approach for fecal coliform, sulfate, iron, manganese, and chloride TMDLs
- BATHTUB modeling for total phosphorus TMDLs for reservoirs.

The remainder of this section describes the TSS modeling to support the TSS LRS.

4.1 QUAL2E Model for the Dissolved Oxygen TMDLs

The QUAL2E water quality model was used to define the relationship between external oxygen-demanding loads and the resulting concentrations of dissolved oxygen in the Lake Cr. (IL_NGA-02) stream segment in the Upper Big Muddy River watershed.

In addition, QUAL2E to was used to model the the dissolved oxygen in Pond Creek (IL_) and Andy Creek (IL_NZN-) to determine if the observed low dissolved oxygen was based on pollutant loads, or low flow conditions. Based on the results of those models, no TMDLs were developed for those stream segments.

QUAL2E is a one-dimensional stream water quality model applicable to dendritic, well-mixed streams. It assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the main direction of flow. The model allows for multiple waste discharges, water withdrawals, tributary flows, and incremental inflows and outflows.

4.1.1 Model Selection

A discussion of the model selection process for the Upper Big Muddy River watershed is provided in the Stage 1 report (Attachment 1).

The QUAL2E model (Brown and Barnwell, 1987) was selected to address dissolved oxygen impairments in the Upper Big Muddy River watershed. QUAL2E is the most commonly used water quality model for addressing low flow conditions.

4.1.2 Modeling Approach

The approach selected for the dissolved oxygen TMDL consists of using data collected during 2015 low flow season surveys to define the current water quality of the river, and using the QUAL2E model to define the extent to which loads must be reduced to meet water quality standards. This is the recommended approach presented in the Stage 1 report.

4.1.3 QUAL2E Model Inputs

This section gives an overview of the model inputs required for QUAL2E application, and how they were derived. The following categories of inputs are required for QUAL2E:

- Model options (title data)
- Model segmentation

- Hydraulic characteristics
- Reach kinetic coefficients
- Initial conditions
- Incremental inflow conditions
- Headwater characteristics
- Point source flows and loads

4.1.3.a Model Options

This portion of the model input parameters defines the specific water quality constituents to be simulated. QUAL2E was set up to simulate temperature, biochemical oxygen demand, the nitrogen series, phosphorus, algae and dissolved oxygen.

4.1.4 Andy Cr. (IL_NZN-13) QUAL2E Model Application

This sections described the application of the QUAL2E model to the above noted stream segment.

4.1.4.a Model Segmentation

The QUAL2E model divides the river being simulated into discrete segments (called "reaches") that are considered to have constant channel geometry and hydraulic characteristics. Reaches are further divided into "computational elements", which define the interval at which results are provided. Andy Creek QUAL2E model consists of two reaches, which are comprised of a varying number of computational elements. Computational elements were specified to have a fixed length of 0.20 miles. Reaches are defined with respect to water quality monitoring stations and tributaries. Model segmentation is presented below in Table 4-1 and Figure 4-1.

Table 4-1. Andy Creek QUAL2E Segmentation

Reach	River miles	Number of computational elements	Other features
1	8.25 – 5.0	13	NZN-12, Valier STP, NZN-15
2	5.0 – 0.0	20	NZN-10

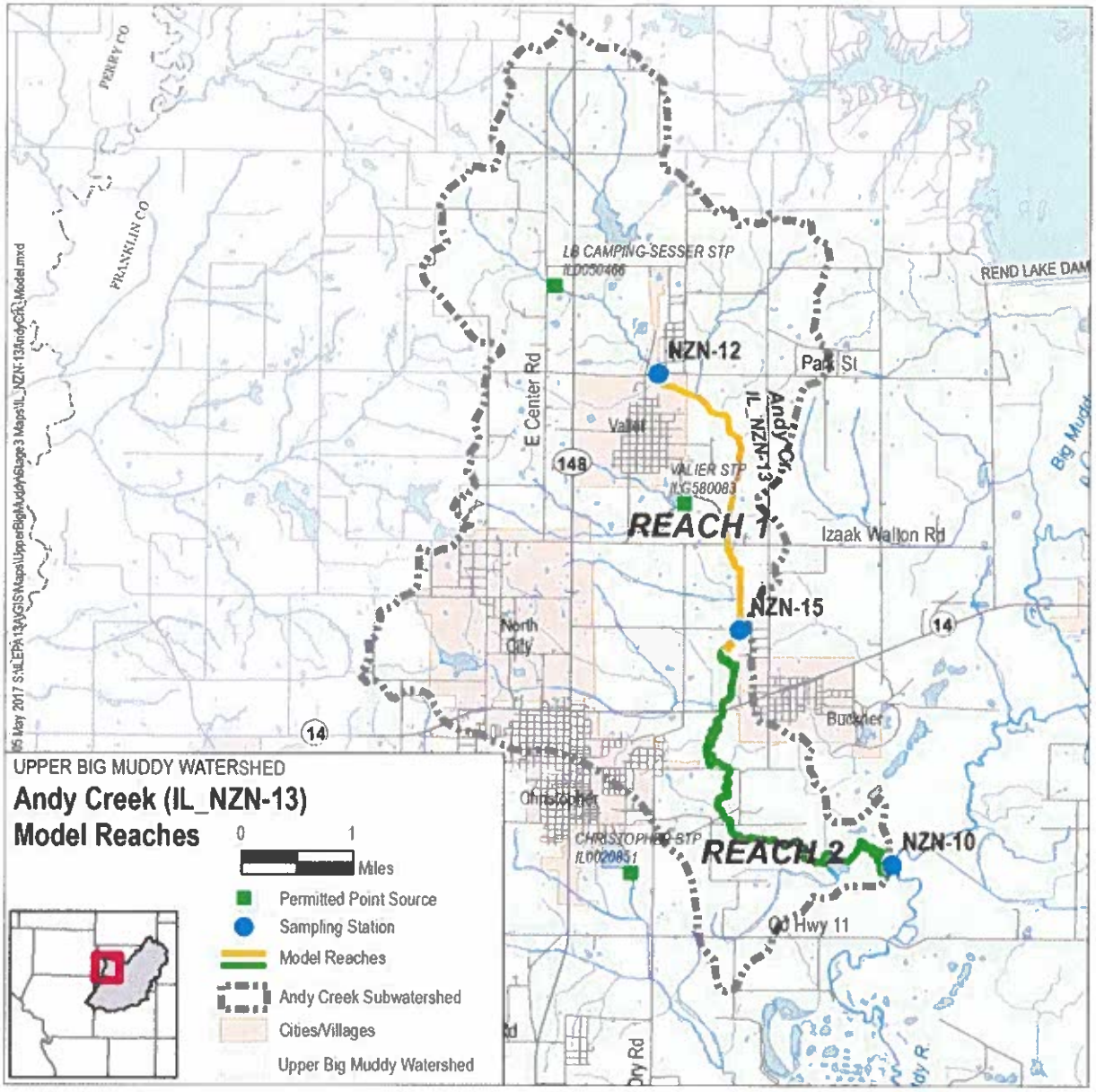


Figure 4-1. Andy Creek QUAL2E Segmentation

4.1.4.b Hydraulic characteristics

A functional representation was used to describe the hydraulic characteristics of the system. For each reach, velocity and depth were specified, based on measurements taken during the September 23, 2015 field survey.

4.1.4.c Reach Kinetic Coefficients

Kinetic coefficients were initially set at values commonly used in past QUAL2E applications from Illinois. The appropriateness of these initial values were assessed during the model calibration process, where these coefficients were refined as necessary (within accepted ranges taken from the scientific literature) to allow model results to best describe observed water quality data.

4.1.4.d Initial Conditions

Initial model conditions were based on field observations, flow measurements, and water quality data collected during 2015. Specifically, observed concentrations of ammonia, phosphorus, organic nitrogen, nitrate and chlorophyll a were used to specify initial conditions.

4.1.4.e Incremental Inflow Conditions

Incremental inflows were calculated using a drainage area ratio and field measured flows. Increases in flows were added to each reach incrementally to represent non-monitored tributaries (flows were increasing from upstream to downstream). Concentrations for these incremental inflows were considered to have concentrations at typical background levels, and temperatures consistent with the mainstem. Other flows came from the headwater and point sources.

4.1.4.f Headwater Characteristics

Headwater characteristics were based on the flow/water quality measurements collected at the more upstream IEPA station (NZN-12).

4.1.4.g Point Source Flows and Loads

There are two permitted NPDES discharges from sewage treatment plants in the Andy Creek watershed. The NPDES permits are for the LB Camping Sesser STP (IL0050466) and the Valier STP (ILG580083). (Attachment 1, Section 2.9).

The model considers one permitted point source that discharges to Andy Creek via a small tributary. The upsrtream point source (LB Camping Sesser STP) is assumed to contribute no load or small loads (based on discharge monitoring report (DMR) data and some assumptions where data was not available), and any impacts on the DO impairments to Andy Creek at the downstream stations would be incorporated into the model by using the sampling data collected at station NZN-12 as the upstream boundary conditions. See Table 4-2 for details of when data were used, and when assumptions were made.

Table 4-2. Andy Creek (IL_NZN-13) Concentrations of QUAL2E model inputs

Model input point	Flow (cfs)	Temp. (Deg F)	DO (mg/L)	CBOD5 (mg/L)	Ammonia (mg/L)	Source
Headwater	0.10	63.7	4.47	1	0.05	Data collected at NZN-12
Valier STP discharge to Reach 1	0.06	70	8.70	10.90	5.80	DMR data (flow, CBOD5, DO, Ammonia)
Incremental inflow to Reach 1	0.145	65.0	4.5	1	0.00	Calculated from flow balance. Water quality specified based on typical background levels.

4.1.4.h QUAL2E Model Calibration

QUAL2E model calibration consisted of:

- Applying the model with all inputs specified as above
- Comparing model results to observed dissolved oxygen, BOD, ammonia, and chlorophyll data
- Adjusting model coefficients to provide the best comparison between model predictions and observed dissolved oxygen data.

The QUAL2E dissolved oxygen calibration for Andy Creek is discussed below. The model was initially applied with the model inputs as specified above. Observed data for the low flow survey conducted on September 23, 2015 was used for calibration purposes.

QUAL2E was calibrated to match the observed average dissolved oxygen concentrations measured at two locations (NZN-15 and NZN-10) on the mainstem of the creek. The data collected at NZN-12 was used to define the upstream boundary conditions. The initial BOD calibration was deemed successful, albeit not totally conclusive, as the majority of observed data (as well as model predictions) for both parameters were below laboratory detection limits. Similarly, the initial coefficients used to describe chlorophyll a correctly replicated observed low observed field concentrations and confirmed that algal productivity was not an important component of the dissolved oxygen budget.

Model results initially over-predicted observed dissolved oxygen data. Model calibration was attained by adjusting reach-specific sediment oxygen demand, with calibration values ranging from 0.054 to 0.065 mg/sq. ft./day. Those values were initially based on the SOD measurement taken at NZN-15 of 0.065 mg/sq. ft./day. The resulting dissolved oxygen predictions compared well to the measured concentrations as shown in Figure 4-2. The QUAL2E model output files from the calibration runs are included in Attachment 3.

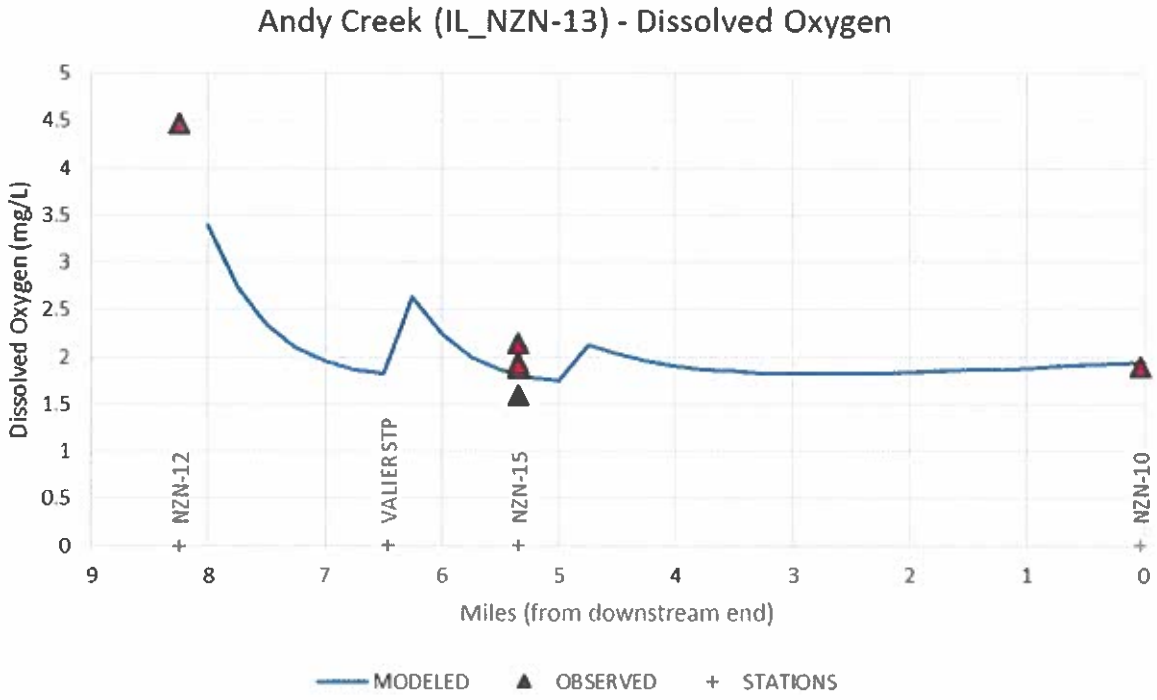


Figure 4-2. QUAL2E DO Calibration for Andy Creek for 9/23/2015 Sampling Survey

4.1.5 Lake Cr. (IL_NGA-02) QUAL2E Model Application

This sections described the application of the QUAL2E model to the above noted stream segment.

4.1.5.a Model Segmentation

The QUAL2E model divides the river being simulated into discrete segments (called "reaches") that are considered to have constant channel geometry and hydraulic characteristics. Reaches are further divided into "computational elements", which define the interval at which results are provided. The Lake Creek QUAL2E model consists of two reaches, which are comprised of a varying number of computational elements. Computational elements were specified to have a fixed length of 0.25 miles. Reaches are defined with respect to water quality monitoring stations and tributaries. Model segmentation is

presented below in Table 4-3 and Figure 4-3. The division between reaches 1 and 2 was determined based on the location of additional tributaries that contribute additional flow to the stream which would be expected to change the hydraulic characteristics of the reach.

Table 4-3. Lake Creek QUAL2E Segmentation

Reach	River miles	Number of computational elements	Other features
1	3.25 – 5.25	8	NGA-02, Johnston City STP, NGA-JC-C1
2	0 – 3.25	14	NGA-01

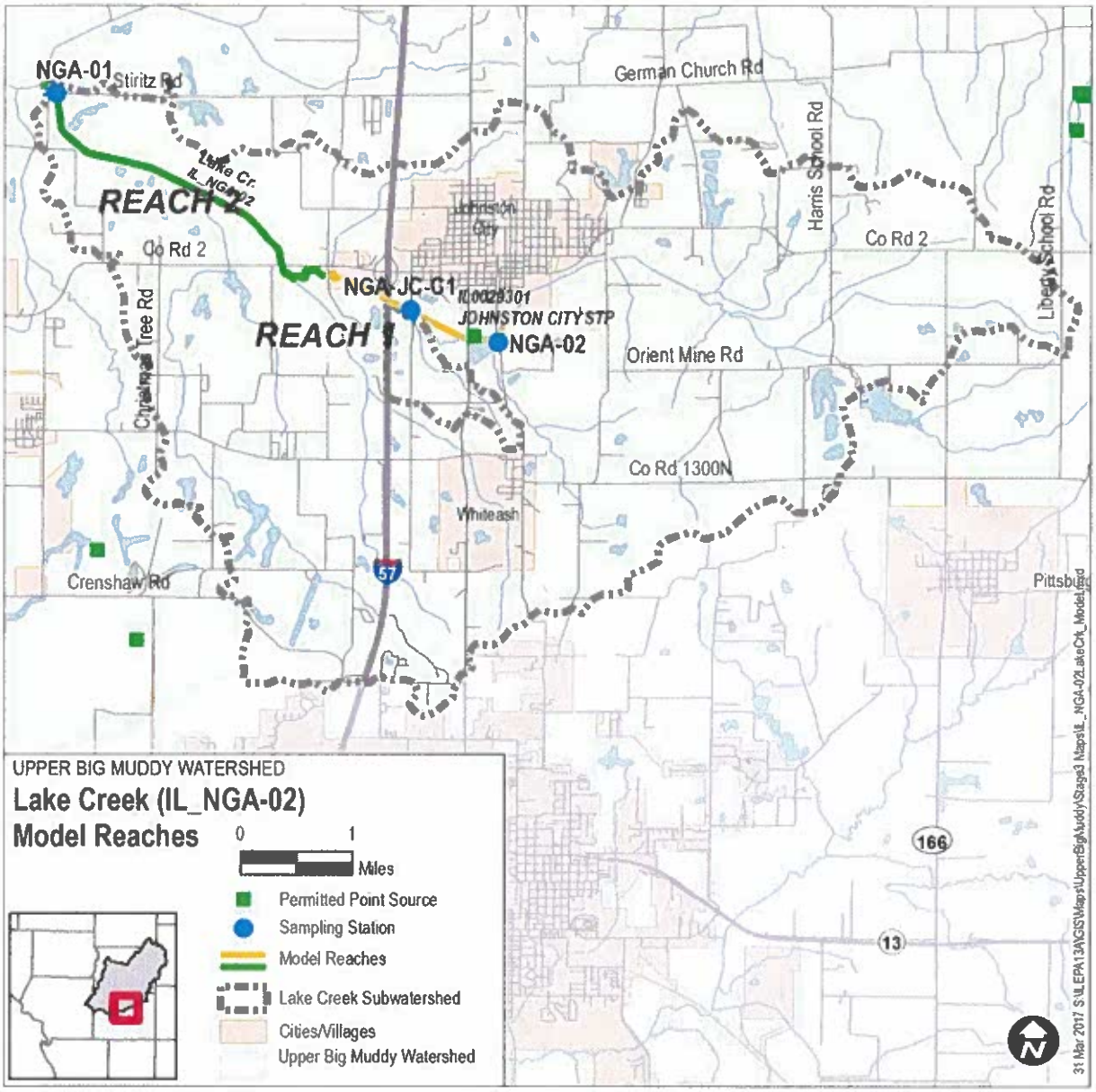


Figure 4-3. Lake Creek (IL_NGA-02) QUAL2E Model Segmentation

4.1.5.b Hydraulic characteristics

A functional representation was used to describe the hydraulic characteristics of the system. For each reach, velocity and depth were specified, based on measurements taken during the August, September and October 2015 field surveys.

4.1.5.c Reach Kinetic Coefficients

Kinetic coefficients were initially set at values commonly used in past QUAL2E applications from Illinois. The appropriateness of these initial values were assessed during the model calibration process, where these coefficients were refined as necessary (within accepted ranges taken from the scientific literature) to allow model results to best describe observed water quality data.

4.1.5.d Initial Conditions

Initial model conditions were based on field observations taken during 2015 and USGS flow measurements. Specifically, observed concentrations of ammonia, phosphorus, organic nitrogen, nitrate and chlorophyll a were used to specify initial conditions.

4.1.5.e Incremental Inflow Conditions

Incremental inflows were calculated using a drainage area ratio and measured USGS flows. Increases in flows were added to each reach incrementally to represent non-monitored tributaries (flows were increasing from upstream to downstream). Concentrations for these incremental inflows were considered to have concentrations at typical background levels, and temperatures consistent with the mainstem. Other flows came from the headwater and point sources.

4.1.5.f Headwater Characteristics

Headwater characteristics were based on the flow/water quality measurements collected at the more upstream IEPA station (NGA-02).

4.1.5.g Point Source Flows and Loads

There is one permitted NPDES discharges in the Lake Creek watershed. It is for the Johnston City STP (IL0029301), a municipal sewage treatment plant. See Table 4-4 for details of when data were used, and when assumptions were made.

Table 4-4. Lake Creek (IL_NGA-02) Concentrations of QUAL2e model inputs

Model input point	Flow (cfs)	Temp. (Deg F)	DO (mg/L)	$CBOD_5$ (mg/L)	Ammonia (mg/L)	Source
Headwater	0.10	63.7	4.47	1	0.05	Data collected at NGA-02, or calculated from flow balance.
Johnston City STP discharge to Reach 1	0.75	70	7.6	14.2	8.90	DMR data (flow, CBOD5, DO), data from NGA-JC-C1 (Ammonia).
Incremental inflow to Reach 2	4.69	65.0	9.0	1	0.00	Calculated from flow balance. Water quality specified based on typical background levels.

It is noted that DMR data from the September 2015 for Johnston City STP indicate that the monthly average CBOD5 concentration (14.2 mg/l) exceeded the permit limit of 10 mg/L, along with effluent violations of daily maximum and monthly average ammonia nitrogen concentrations, although it is uncertain whether the effluent limit violations were occurring specifically during the time of the survey. The of $CBOD_5$ in the Johnston City STP were based on the September 2015 DMR for that facility. The $CBOD_5$ and DO concentrations used to characterize the point load in the QUAL2E model were the monthly averages. The daily maximum $CBOD_5$ was 17 mg/L, but there is no information on whether that occurred on the date of the sampling. The ammonia nitrogen concentration used in the model to characterize the point load was based on the observed concentration at station NGA-JC-C1, which is higher than the reported daily maximum value for ammonia nitrogen in the DMR. The effluent sampling frequency for ammonia nitrogen required in the NPDES permit for the Johnston City STP is only two days per month, so it is possible that higher concentrations could occur between samples. The flow used was the daily average flow for the month reported in the DMR of 0.488 MGD, which is lower than the design average flow for the facility of 0.55 MGD.

4.1.5.h QUAL2E Model Calibration

QUAL2E model calibration consisted of:

- Applying the model with all inputs specified as above
- Comparing model results to observed dissolved oxygen, BOD, ammonia, and chlorophyll data
- Adjusting model coefficients to provide the best comparison between model predictions and observed dissolved oxygen data.

The QUAL2E dissolved oxygen calibration for Lake Creek (IL_NGA-02) is discussed below. The model was initially applied with the model inputs as specified above. Observed data for the low flow survey conducted in 2015 was used for calibration purposes.

QUAL2E was calibrated to match the observed average dissolved oxygen concentrations measured at two locations (NGA-01, and NGA-JC-C1) on the mainstem of the creek. Data collected at station NGA-02 was used to characterize the upstream boundary conditions. The initial DO and ammonia calibration was deemed successful. Similarly, the initial coefficients used to describe chlorophyll a correctly replicated observed low observed field concentrations and confirmed that algal productivity was not an important component of the dissolved oxygen budget in the area downstream of the Johnston City STP discharge.

The reach-specific sediment oxygen demand values entered in the model for Reach 1 of 0.079 g/sq. ft./day was based on an SOD test run at NGA-02. The sediment oxygen demand values entered in the model for Reach 2 of 0.06 g/sq. ft./day was adjusted to match the observed downstream data. The resulting dissolved oxygen predictions compared well to the measured concentrations during the survey, as shown in Figure 4-4. The QUAL2E model output files from the calibration runs are included in Attachment 3.

Based on the components of dissolved oxygen mass balance in the QUAL2E model output files, the largest components of the oxygen deficit in the stream immediately downstream of the Johnston City STP were due to the sediment oxygen demand, and the oxygen consumed for nitrification of ammonia and nitrite. Although SOD is one of the dominant sources of the oxygen deficit, the true cause is a lack of base flow (which greatly exacerbates the effect of SOD).

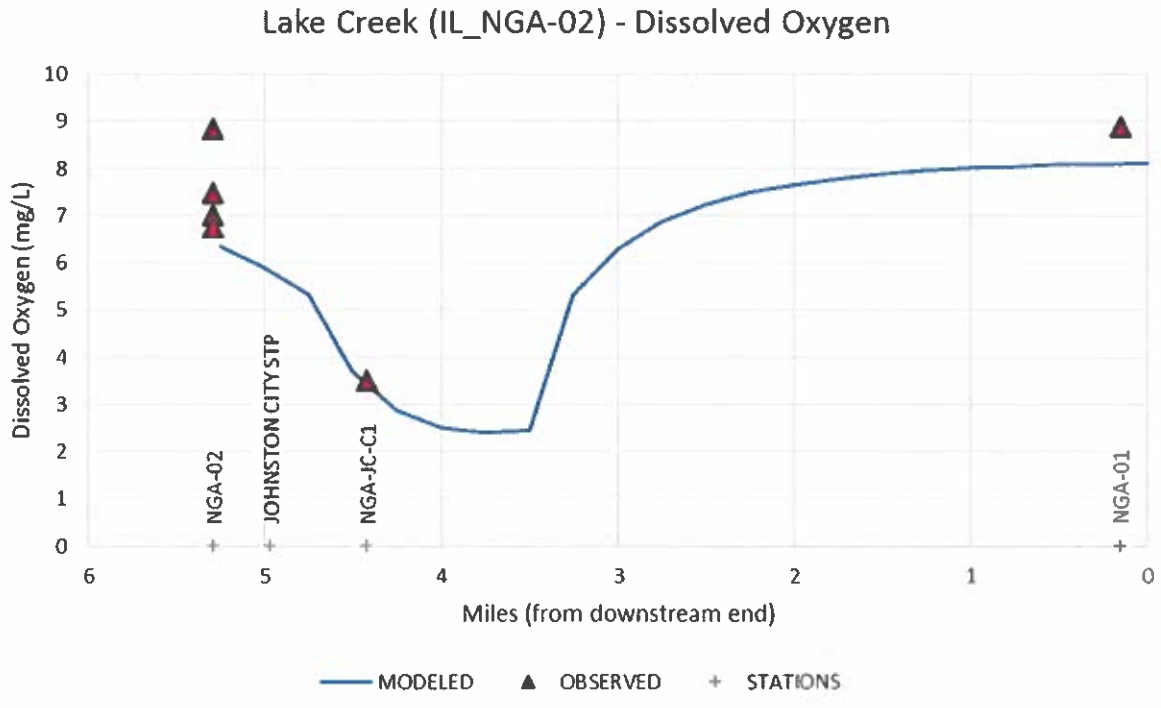


Figure 4-4. QUAL2E DO Calibration for Lake Creek for 9/24/2015 Sampling Survey

4.2 Load Duration Curve Approach

A load duration curve approach was used in the fecal coliform, sulfate, iron, chloride, and manganese analyses for streams in the Upper Big Muddy watershed. A load-duration curve is a graphical representation of observed pollutant load compared to maximum allowable load over the entire range of flow conditions. The load duration curve provides information to:

- Help identify the issues surrounding the problem and differentiate between point and nonpoint source problems, as discussed immediately below;
- Address frequency of deviations (how many samples lie above the curve vs. those that plot below); and
- Aid in establishing the level of implementation needed, by showing the magnitude by which existing loads exceed standards for different flow conditions.

4.2.1 Model Selection

A detailed discussion of the model selection process for TMDL development in the Upper Big Muddy River watershed is provided in the Stage 1 Report. The load-duration curve approach was selected because it is a simpler approach that can be supported with the available data and still support the selected level of TMDL implementation for this TMDL. The load-duration curve approach identifies broad categories of pollutant sources and the extent of control required from these source categories to attain water quality standards.

4.2.2 Approach

The load duration curve approach uses stream flows for the period of record to gain insight into the flow conditions under which exceedances of the water quality standard occur. A load-duration curve is developed by: 1) ranking the daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results; 2) translating the flow duration curve (produced in step 1) into a load duration curve by multiplying the flows by the water quality standard; and 3) plotting observed pollutant loads (measured concentrations times stream flow) on the same graph. Observed loads that fall above the load duration curve exceed the maximum allowable load, while those that fall on or below the line do not exceed the maximum allowable load. An analysis of the observed loads relative to the load duration curve provides information on whether the pollutant source is point or nonpoint in nature. A more complete description of the load duration curve approach is provided in the Stage 1 Report.

4.2.3 Big Muddy R. / IL_N-11 – Fecal Coliform Load Duration Curve

This section describes the flow and water quality data used to support development of the load duration curve for fecal coliform bacteria on the above noted stream segment.

4.2.3.a Flow Data

Segment IL_N-11 of the Big Muddy River is located downstream of Rend Lake, so the flows in the river at that point are impacted by the reservoir storage and dam operations. When developing the load-duration curve, the reservoir storage can reduce the peak flows, and maintain a higher baseflow, making distinction between dry and wet weather related sources difficult to distinguish. To remedy that problem, daily flow measurements were used from the USGS gage on Casey Fork near Mount Vernon, IL (USGS gage number 05595820) for the period from 1999 through 2015.

Casey Fork is a tributary to the Big Muddy River upstream of Rend Lake, so flows at that location are not impacted by the reservior. This gage is located approximately 28.6 miles north of station N-11, where the water quality data was collected. This gage has a drainage area of 76.9 square miles, so all flow data from

the gage are adjusted based on the drainage area ratio (DAR) to the stream segment under consideration. The drainage area within the Upper Big Muddy River watershed for segment IL-N-11 is 312.3 square miles, which does not include areas upstream of Rend Lake. The Casey Fork gage was selected based on the proximity to the stream segment under consideration, and that it is located within the same watershed, the fact that it is upstream of Rend Lake, so it is not impacted by the reservoir.

4.2.3.b Water Quality Data

Fecal coliform data collected at station N-11 by IEPA between 1999 and 2010 were used in the analysis. The data were collected as part of IEPA's ambient water quality monitoring program. Only data for the months of May-October were used because the water quality standard applies only during this period.

4.2.3.c Analysis

A flow duration curve was generated by ranking daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results. The load duration curve for fecal coliform were generated by multiplying the flows in the duration curve by the water quality standard of 200 cfu/100 mL for fecal coliform bacteria. The load duration curve for fecal coliform is shown with a solid line in Figure 4-5. Observed pollutant loads of fecal coliform were calculated using available concentration data paired with corresponding flows, and were plotted on the same graph. The fecal coliform data used only measurements collected between May and October, since that is the period specified under Section 302.209 of Title 35.

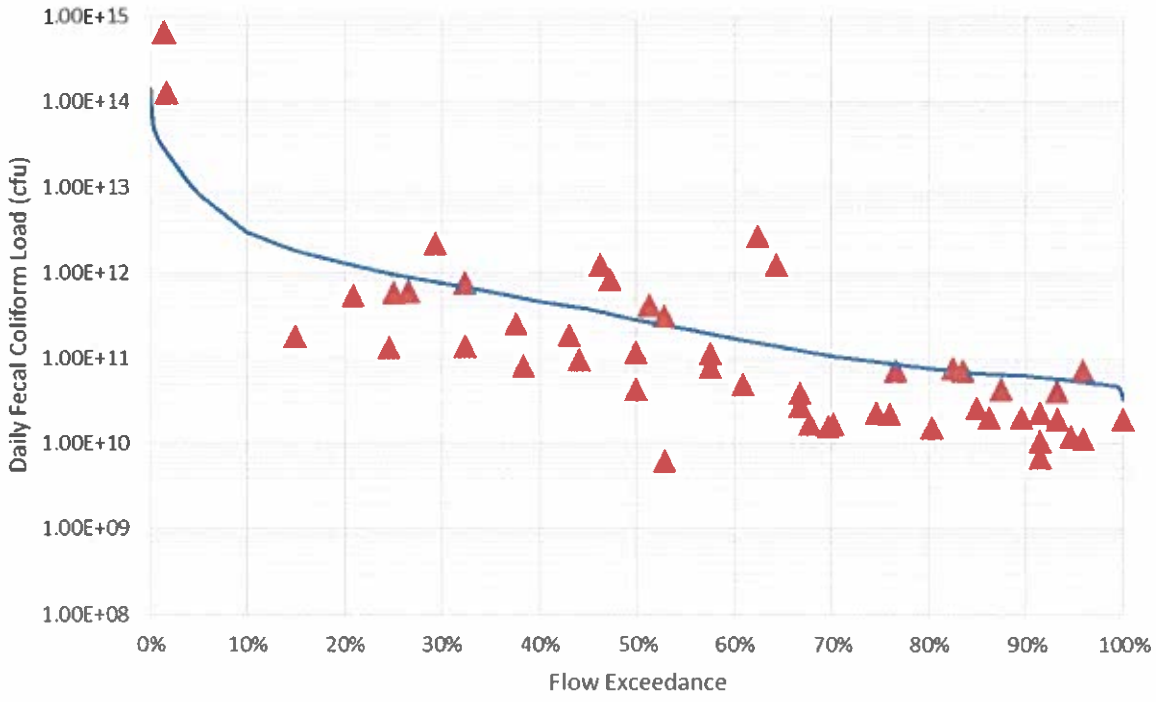


Figure 4-5. Fecal Coliform Load Duration Curve for Upper Big Muddy River (IL_N-11) with Observed Loads (triangles)

In Figure 4-5, the data show exceedances of the fecal coliform target occur over all ranges of flows, but with more exceedances (as a fraction of the samples) occuring in the higher range of flows. This indicates that wet weather sources contribute to the observed violations of the water quality standard.

4.2.4 Andy Cr. / IL_NZN-13 – Iron Load Duration Curve

This section describes the flow and water quality data used to support development of the load duration curve for dissolved iron on the above noted stream segment.

4.2.4.a Flow Data

There is no stream gage on Andy Creek that can be used to estimate the daily flows and loadings. Daily flow measurements are available for the USGS gage on Crab Orchard Creek near Marion, IL (USGS gage number 05597500) for the period from 1999 through 2015. This gage is located approximately 20.2 miles southeast of the Andy Creek watershed. This gage has a drainage area of 31.7 square miles, so all flow data from the gage are adjusted based on the drainage area ratio (DAR) to the stream segment under consideration. The stream segment under consideration has a drainage area of 20.4 square miles at its outlet. The Crab Orchard Creek gage was selected for consideration based on the drainage areas being similar in size, the proximity to the stream segment under consideration, with similar watershed land uses and topography.

4.2.4.b Water Quality Data

Dissolved iron data collected by IEPA in 2008 were used in the analysis. The data were collected as part of IEPA's ambient water quality monitoring program. There were three samples analyzed, and all three exceeded the water quality standards.

4.2.4.c Analysis

A flow duration curve was generated by ranking daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results. A load duration curve for iron was generated by multiplying the flows in the duration curve by the water quality standard of 1.0 mg/L for dissolved iron. The load duration curve for iron is shown with a solid line in Figure 4-6. Observed pollutant loads of dissolved iron were calculated using available concentration data paired with corresponding flows, and were plotted on the same graph.

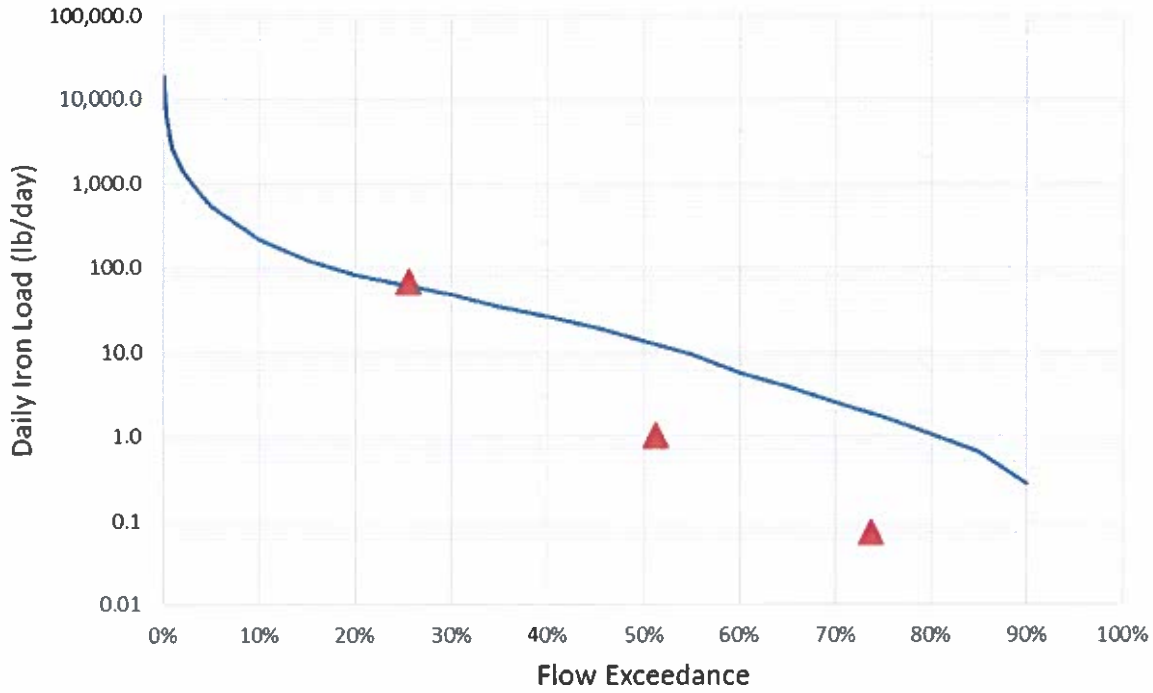


Figure 4-6: Dissolved Iron Load Duration Curve for Andy Creek (IL_NZN-13) with Observed Loads (triangles)

In Figure 4-6, the data show that the sampled data points only exceeded the dissolved iron target at the highest sampled flow. This indicates that wet weather sources or runoff contribute to the observed violation of the water quality standard.

4.2.5 Pond Cr. / IL_NG-02 – Chloride Load Duration Curve

This section describes the flow and water quality data used to support development of the load duration curve for fecal coliform bacteria on the above noted stream segment.

4.2.5.a Flow Data

Daily flow measurements are available for the USGS gage on Crab Orchard Creek near Marion, IL (USGS gage number 05597500) for the period from 1999 through 2015. This gage has a drainage area of 31.7 square miles, so all flow data from the gage are adjusted based on the drainage area ratio (DAR) to the stream segment under consideration.

4.2.5.b Water Quality Data

Fecal coliform data collected by IEPA between 1999 and 2006 were used in the analysis. The data were collected as part of IEPA's ambient water quality monitoring program. Only data for the months of May-October were used because the water quality standard applies only during this period.

4.2.5.c Analysis

A flow duration curve was generated by ranking daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results. The load duration curve for chloride was generated by multiplying the flows in the duration curve by the water quality standard 500 mg/L for chloride. The load duration curve for chloride is shown with a solid line in Figure 4-7. Observed pollutant loads of chloride were calculated using available concentration data paired with corresponding flows, and were plotted on the same graph.

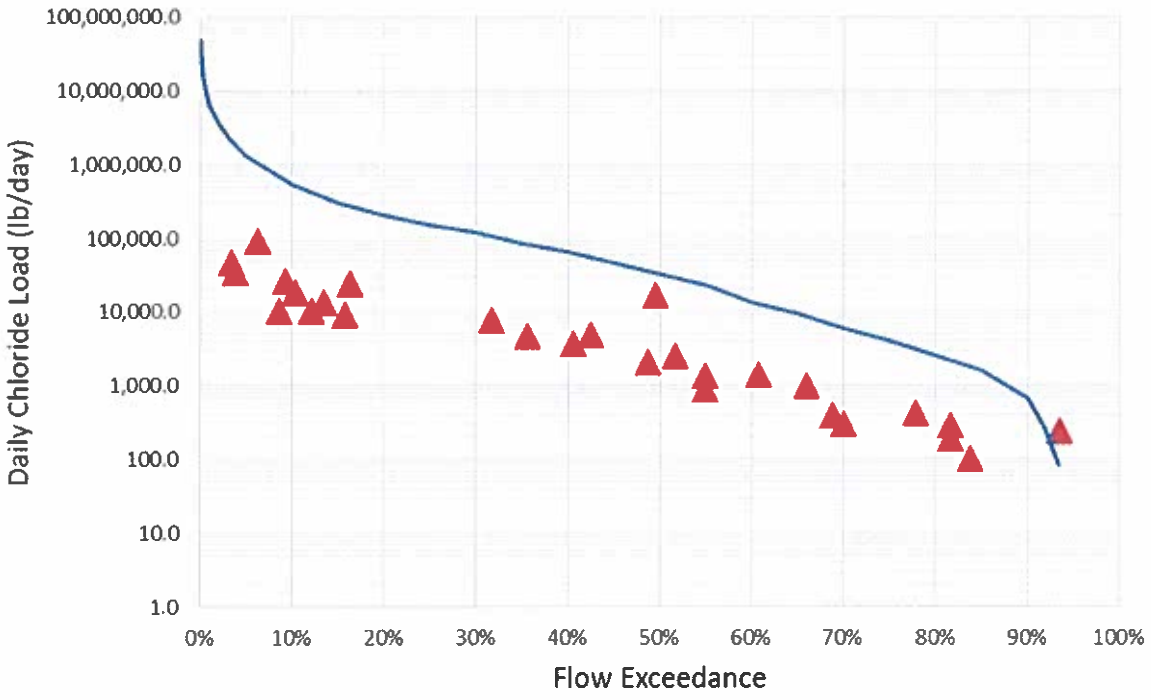


Figure 4-7: Chloride Load Duration Curve for Pond Creek (IL_NG-02) with Observed Loads (triangles)

In Figure 4-7, the data show that the single exceedance of the chloride target occurs at the lowest sampled flow. This indicates that wet weather sources do not contribute to the observed violation of the water quality standard. With the single data point showing an exceedance of the water quality standard for Chloride occurring at the very lowest flows, this indicates that the impairment may be flow related. Before implementing a TMDL for this stream segment, additional monitoring is recommended to confirm that the impairment is related to a pollutant load source, and is not only related to very low flow conditions in the stream. Additional monitoring recommendations are contained in the Watershed Implementation Plan to achieve the TMDLs and Load Reduction Strategy in the Upper Big Muddy River watershed.

4.2.6 Beaver Cr. / IL_NGAZ-JC-D1 – Manganese Load Duration Curve

This section describes the flow and water quality data used to support development of the load duration curve for manganese on the above noted stream segment.

4.2.6.a Flow Data

Daily flow measurements are available for the USGS gage on Crab Orchard Creek near Marion, IL (USGS gage number 05597500) for the period from 1999 through 2015. This gage has a drainage area of 31.7 square miles, so all flow data from the gage are adjusted based on the drainage area ratio (DAR) to the stream segment under consideration.

The stream gage data shows that there are periods where there is no flow in the stream, This does not necessarily mean that the stream dries up, but the flows are below the threshold for stream measurement. This causes the load-duration curve to be equal to zero during these time periods.

4.2.6.b Water Quality Data

Manganese data collected by IEPA in 2008 were used in the analysis. There is only a single data point available for this analysis.

4.2.6.c Analysis

A flow duration curve was generated by ranking daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results. The load duration curve for manganese was generated by multiplying the flows in the duration curve by the chronic water quality standard of 4.85 mg/L, which was calculated based on a hardness measurement of 383 mg/L that was field measured at the same time at the manganese measurement in this stream segment. The load duration curve for manganese is shown with a solid line in Figure 4-8. Observed pollutant loads were calculated using available concentration data paired with corresponding flows, and were plotted on the same graph.

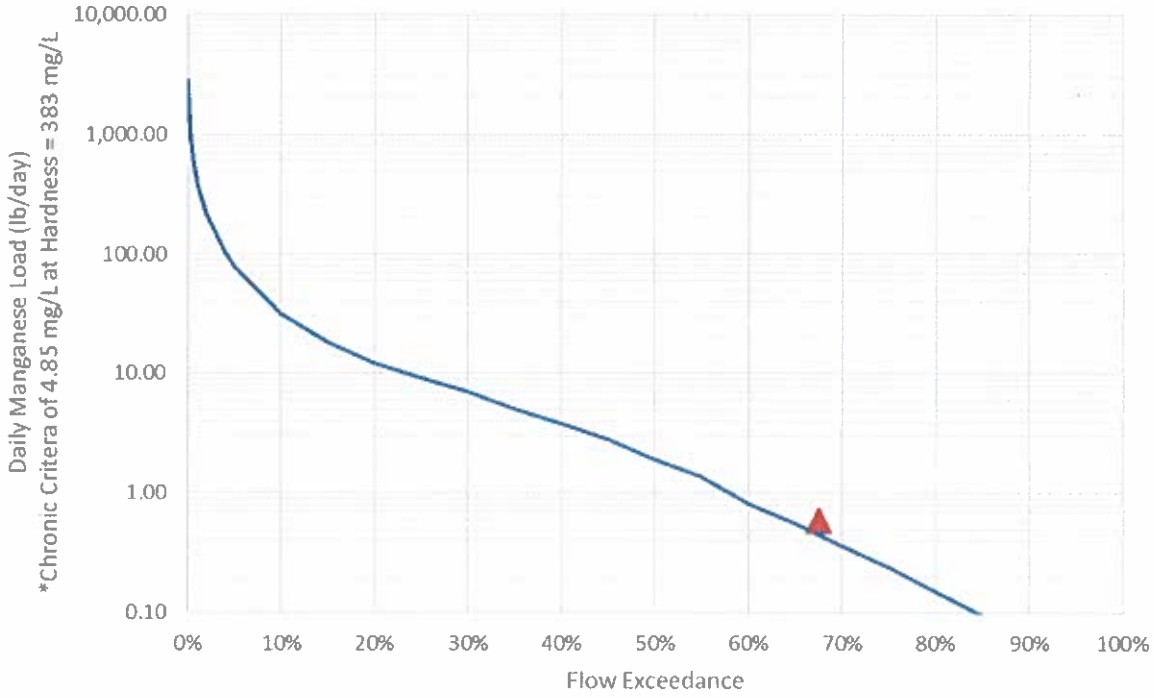


Figure 4-8: Manganese Load Duration Curve for Beaver Creek (IL_NGAZ-JC-D1 with Observed Loads (triangles)

In Figure 4-8, the data show that the single exceedance of the manganese target occurs at the lower end of the normally encountered flows (30% to 70%).

4.2.7 M. Fk. Big Muddy / IL_NH-06 – Fecal Coliform Load Duration Curve

This section describes the flow and water quality data used to support development of the load duration curve for fecal coliform bacteria on the above noted stream segment.

4.2.7.a Flow Data

There is no stream gage on this segment of the Middle Fork of the Big Muddy River that can be used to estimate the daily flows and loadings. Daily flow measurements are available for the USGS gage on Casey Fork near Mount Vernon, IL (USGS gage number 05595820) for the period from 1999 through 2015. Casey Fork is a tributary to the Big Muddy River upstream of Rend Lake, so flows at that location are not impacted by the reservoir storage and dam operations. This gage is located approximately 23.3 miles north of station NH-06, where the water quality data was collected. This gage has a drainage area of 76.9 square miles, so all flow data from the gage are adjusted based on the drainage area ratio (DAR) to the

stream segment under consideration. The stream segment under consideration has a drainage area of 160.6 square miles at its outlet.

4.2.7.b Water Quality Data

Fecal coliform data collected at station NH-06 by IEPA between 1999 and 2010 were used in the analysis. The data were collected as part of IEPA's ambient water quality monitoring program. Only data for the months of May-October were used because the water quality standard applies only during this period.

4.2.7.c Analysis

A flow duration curve was generated by ranking daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results. The load duration curve for fecal coliform were generated by multiplying the flows in the duration curve by the water quality standard of 200 cfu/100 mL for fecal coliform bacteria. The load duration curve for fecal coliform is shown with a solid line in Figure 4-9. Observed pollutant loads of fecal coliform were calculated using available concentration data paired with corresponding flows, and were plotted on the same graph. The fecal coliform data used only measurements collected between May and October, since that is the period specified under Section 302.209 of Title 35.

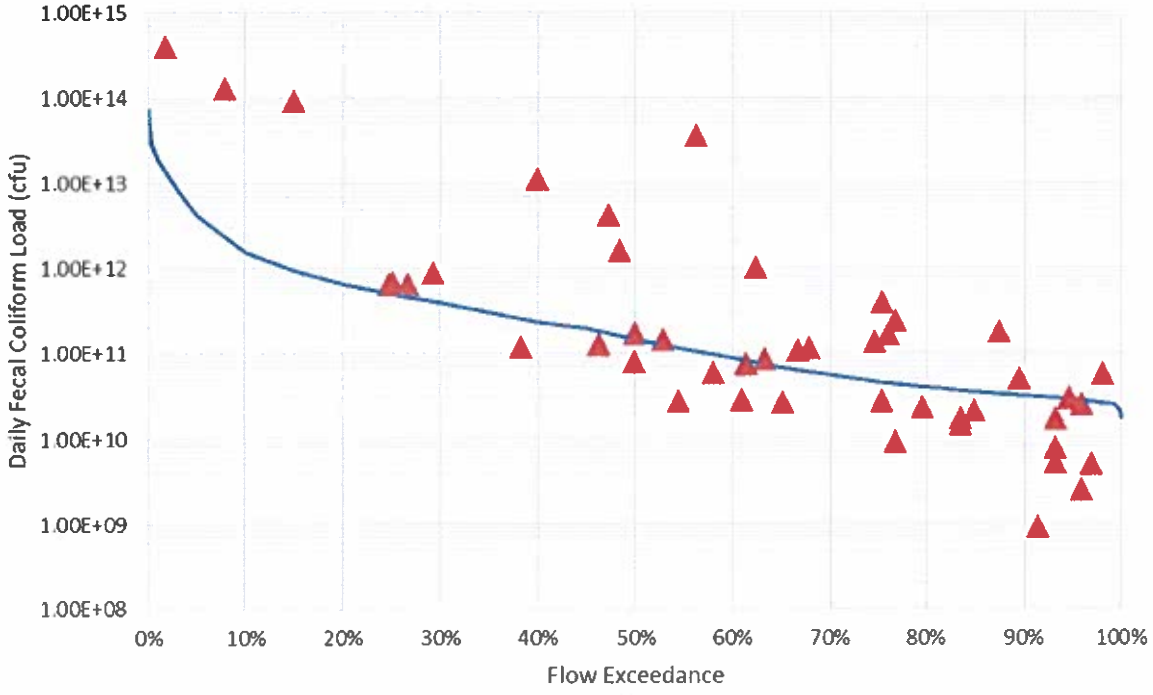


Figure 4-9. Fecal Coliform Load Duration Curve for Middle Fork Big Muddy River (IL_N-11) with Observed Loads (triangles)

In Figure 4-9, exceedances of the fecal coliform target occur over all ranges of flows, but with more exceedances in the higher range of flows. This indicates that wet weather sources are a contributing factor to the observed violations of the water quality standard, but that significant dry weather reductions are necessary as well.

4.3 BATHTUB Model

The BATHTUB model (Walker, 1986) was selected as the tool to define load reduction necessary to attain phosphorus targets in the following lakes/reservoirs located in the Upper Big Muddy River watershed:

- Herrin Old / IL_RNZD
- Johnston City / IL_RNZE
- Arrowhead (Williamson) / IL_RNZX
- West Frankfort Old / IL_RNP
- West Frankfort New/ IL_RNQ

4.3.1 Model Selection

A detailed discussion of the model selection process is provided in the Stage 1 report (Attachment 1). BATHTUB is a simple modeling tool that can predict the relationship between phosphorus load and resulting in-lake phosphorus concentrations. The BATHTUB model was selected because it does not have extensive data requirements (and can therefore be applied with existing data), yet still provides the capability for calibration to observed lake data. BATHTUB has been used previously for several reservoir TMDLs in Illinois, and has been cited as an effective tool for lake and reservoir water quality assessment and management, particularly where data are limited (Ernst et al., 1994).

BATHTUB is a software program for predicting the lake/reservoir response to nutrient loading. Because reservoir ecosystems typically have different characteristics than many natural lakes, BATHTUB was developed to specifically account for some of these differences, including the effects of non-algal turbidity on transparency and algae responses to phosphorus.

BATHTUB contains a number of empirical regression equations that have been calibrated using a wide range of lake and reservoir data sets. It can treat the lake or reservoir as a continuously stirred, mixed reactor, or it can predict longitudinal gradients in trophic state variables in a reservoir or narrow lake. These trophic state variables include in-lake total and ortho-phosphorus, organic nitrogen, hypolimnetic dissolved oxygen, metalimnetic dissolved oxygen, chlorophyll concentrations, and Secchi depth (transparency). Both tabular and graphical displays are available from the program.

4.3.2 Modeling Approach

The approach taken for the total phosphorus TMDLs consisted of using existing empirical data to define current loads to each of the lakes, and using the BATHTUB model to define the extent to which these loads must be reduced to meet water quality standards. This approach was taken because phosphorus concentrations exceed the water quality standards, often by significant amounts. Phosphorus loads will need to be reduced to a fraction of existing load in order to attain water quality standards.

4.3.3 BATHTUB Model Inputs

This section gives an overview of the model inputs required for BATHTUB application, and how they were derived for application to the reservoirs on this project. The following categories of inputs are required for BATHTUB:

- Model Options
- Global Variables
- Reservoir Segmentation
- Tributary Loads

  The model options and global variables applied universally across the 5 lakes that were modeled in BATHTUB for this this project. Those are discussed below, with the descriptions of the reservoir segmentation and tributary loads in each model contained in separate sections of this report.

4.3.3.a Model Options

BATHTUB provides a multitude of model options to estimate nutrient concentrations in a reservoir. Model options were entered as shown in Table 4-5, and the rationale for these options discussed below. No conservative substance was being simulated, so this option was not needed. The Canfield and Bachman phosphorus option was selected for phosphorus, as this is a commonly used formulation for Midwestern phosphorus TMDLs (e.g. MPCA, 2007; https://www.pca.state.mn.us/sites/default/files/wq-iw8-03e.pdf) Nitrogen was not simulated because phosphorus is the nutrient of concern.

Chlorophyll a and transparency were not simulated because the water quality target is specified as total phosphorus. The Fischer numeric dispersion model was selected, which is the default approach in BATHTUB for defining mixing between lake segments. Phosphorus calibrations were based on lake concentrations. No nitrogen calibration was required. The use of availability factors was not required and estimated concentrations were used to generate mass balance Tables.

Table 4-5. BATHTUB Model Options

Model	Model Option
Conservative substance	Not computed
Total phosphorus	Canfield and Bachman
Total nitrogen	Not computed
Chlorophyll-a	Not computed
Transparency	Not computed
Longitudinal dispersion	Fischer-numeric
Phosphorus calibration	Concentrations
Nitrogen calibration	None
Error analysis	Model and Data
Availability factors	Ignored
Mass-balance Tables	Use estimated concentrations

4.3.3.b Global Variables

The global variables required by BATHTUB consist of:

- The averaging period for the analysis
- Precipitation, evaporation, and change in lake levels
- Atmospheric phosphorus loads

BATHTUB is a steady state model, whose predictions represent concentrations averaged over a period of time. One decision in the application of BATHTUB is the selection of length of time over which inputs and outputs should be modeled. An annual averaging period was used for all lakes in the Upper Big Muddy watershed, consistent with the fact that tributary loading estimates represented annual average conditions.

There was no assumed increase in storage during the modeling period, to represent steady state conditions. The values selected for precipitation and change in lake levels have little influence on model predictions. Atmospheric phosphorus loads were specified using default values provided by BATHTUB.

4.3.3.c Reservoir Segmentation

BATHTUB provides the capability to divide the reservoir under study into a number of individual segments, allowing prediction of the change in phosphorus concentrations over the length of each segment. The segmentation scheme selected for the lakes modeled was designed to provide at least two

segments per lake, to include segment representing the deeper conditions near the dam, and at least one upstream segment, depending on the lake and the conficuration of the primary lake sampling stations.

Table 4-6. BATHTUB Model Segmentation

Lake / Reservoir	Total Size (ac)	Model Segments
Herrin Old / IL_RNZD	51.3	2
Johnston City / IL_RNZE	64	2
Arrowhead (Williamson) / IL_RNZX	30	3
West Frankfort Old / IL_RNP	146	2
West Frankfort New/ IL_RNQ	214	3

The areas of the segments and the watersheds for the segments were determined by Geographic Information System (GIS), and maps are provided for each of the lakes provided below.

BATHTUB requires that a range of inputs be specified for each segment. These include segment surface area, length, total water depth, and depth of thermocline and mixed layer. Segment-specific values for segment depths (total, thermocline and mixed layer) were calculated from the lake monitoring data, while segment lengths and surface areas were calculated via GIS.

4.3.3.d Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Tributary and direct drainage flows to each segment were estimated using observed flows at the USGS gaging station at on Crab Orchard Creek near Marion, IL (USGS gage number 05597500), adjusted through the use of drainage area ratios as follows:

Flow into segment = Flow at USGS gage * Segment-specific drainage area ratio

Drainage area ratio = Drainage area of watershed contributing to model segment

Drainage area of watershed contributing to USGS gage

Segment-specific drainage area ratios were calculated via GIS information.

Total phosphorus concentrations for each tributary and direct drainage inflow were estimated by dividing the watershed phosphorus load (calculated based on land use and literature phosphorus loading rates) by the tributary flow.

Average total phosphorus concentrations = Annual watershed phosphorus loads / Annual tributary flow

A complete listing of all segment-specific flows and tributary concentrations is provided in Attachment 4.

4.3.4 BATHTUB Calibration

BATHTUB model calibration consists of:

1. Applying the model with all inputs specified as above
2. Comparing model results to observed phosphorus data
3. Adjusting model coefficients to provide the best comparison between model predictions and observed phosphorus data.

Additional site-sprecific information on the calibration of the BATHTUB model application for each reservoir in the Upper Big Muddy River watershed is given in the sections below.

4.3.5 Herrin Old / IL_RNZD BATHTUB Model Application

Herrin Old Reservoir is a 51 acre lake located in Williamson County, Illinois. It is approximately 21 feet deep at its deepest point near the dam at the downstream side of the lake. Herrin Old Lake requires a TMDL for total phosphorus.

The listing and recommendation of a TMDL for total phosphorus in the Stage 1 report was based on a single water quality sample taken in 2011 that exceeded the water quality standard of 0.05 mg/L. Additional data from 2012 and 2013 was provided by IEPA for the modeling and TMDL preparation. The new data shows that the water quality sampled at the upstream stations (RNZD02 & RNZD-3) all met the water quality standards. These were all sampled at a depth of 1 ft. The only samples taken during this period that exceeded the water quality standard we taken at station RNZD-1 at depths near the bottom of the reservoir. This indicates that the internal phosphorus loading from sedimants is the primary source contributing to the impairment of the water body.

4.3.5.a Reservoir Segmentation

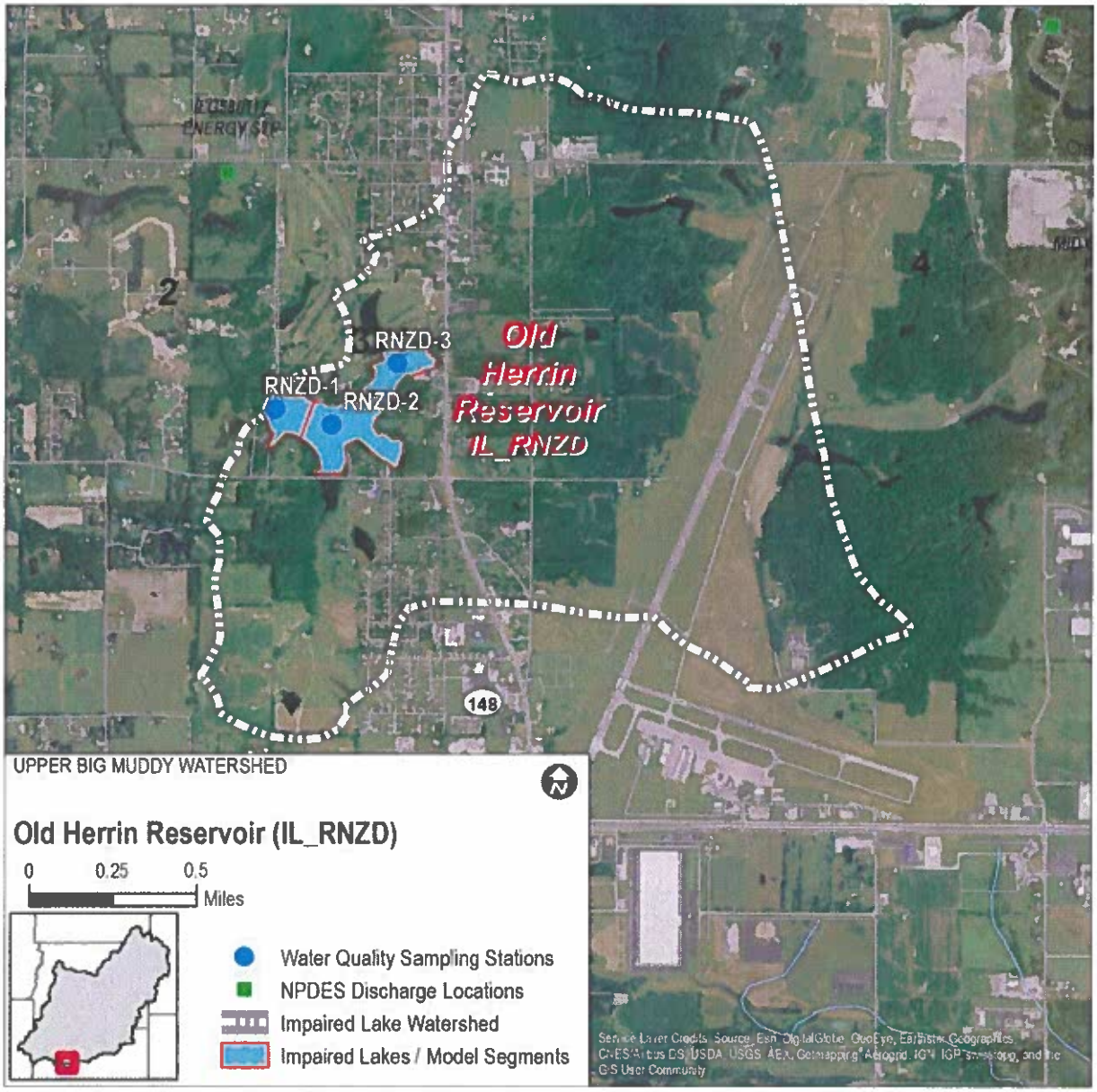


Figure 4-10. Old Herrin Reservoir (IL_RNZD) Segmentation Used in BATHTUB Model

4.3.5.b Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Tributary and direct drainage flows to each segment were estimated using observed flows at the USGS gaging station at on Crab Orchard Creek near Marion, IL (USGS gage number 05597500), adjusted through the use of drainage area ratios as described in section 4.3.3.d above.

Annual average flow from the contributing watershed calculated using the above method was 3.2 cfs, and the annual average total phosphorus concentrations (calculated based on land use and literature phosphorus loading rates) 0.029 mg/L. This correlated well with the observed total phosphorus

concentrations at the upstream sampling stations (RNZD-2 and RNZD-3). The total estimated annual watershed load is 84.3 kg/yr of total phosphorus.

A complete listing of all segment-specific flows and tributary concentrations is provided in Attachment 4.

4.3.5.c BATHTUB Calibration

The BATHTUB model was initially applied with the model inputs as specified above. Observed lake data for the year 2012 were used for calibration purposes.

BATHTUB was calibrated to match the observed reservoir-average phosphorus concentrations. Model results using default model parameters initially under-predicted the observed phosphorus, i.e. model predictions were lower than observed concentrations. Phosphorus loss rates in BATHTUB reflect a typical "net settling rate" (i.e. settling minus sediment release) observed in a range of reservoirs. Under-prediction of observed phosphorus concentrations can occur in cases of elevated phosphorus release from lake sediments. The mismatch between model and data was corrected via the addition of an internal phosphorus load of 12 mg/m²/day in the downstream model segment (Segment 1). This internal load estimate was adjusted during the model calibration to match th observed data. The resulting modeled and observed total phosphorus concentrations are shown in Figure 4-11. BATHTUB output files are provided in Attachment 4.

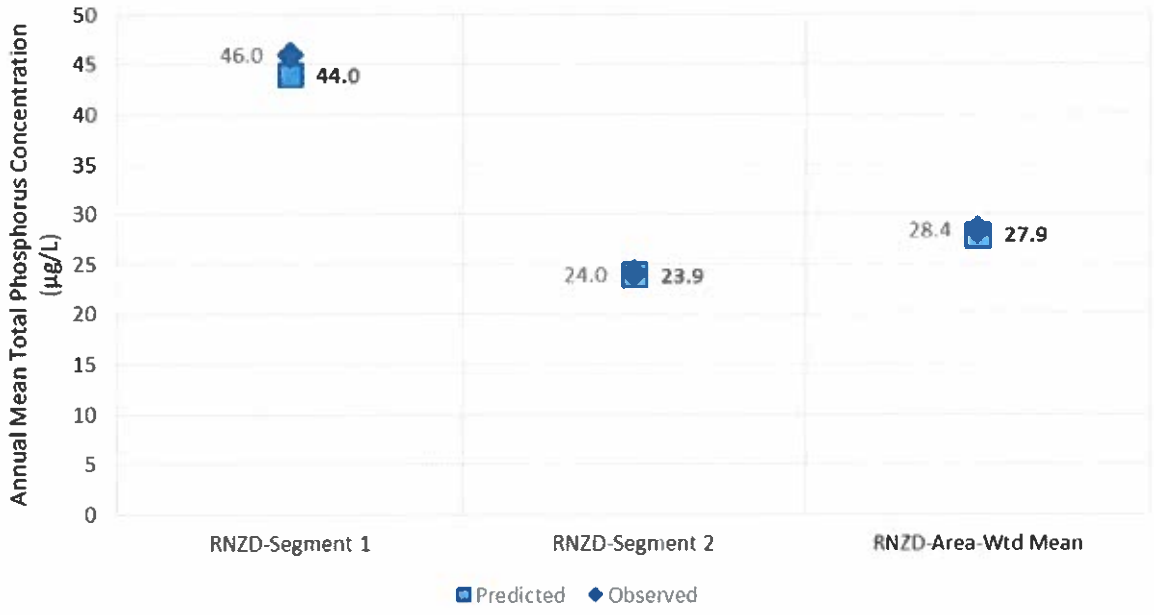


Figure 4-11. Herrin Old (IL_RNZD) BATHTUB Segment Modeled vs. Observed Total Phosphorus Concentration

4.3.6 Johnston City / IL_RNZE BATHTUB Model Application

Johnston City Lake / IL_RNZE is an impoundment of Lake Creek; it is just east of Freeman No. 4 Mine. The lake requires a TMDL for total phosphoru. The most recent water quality data for Johnston City Lake is from 2002. There are three sampling stations located within the lake, as shown in Figure 4-12 below.

4.3.6.a Reservoir Segmentation

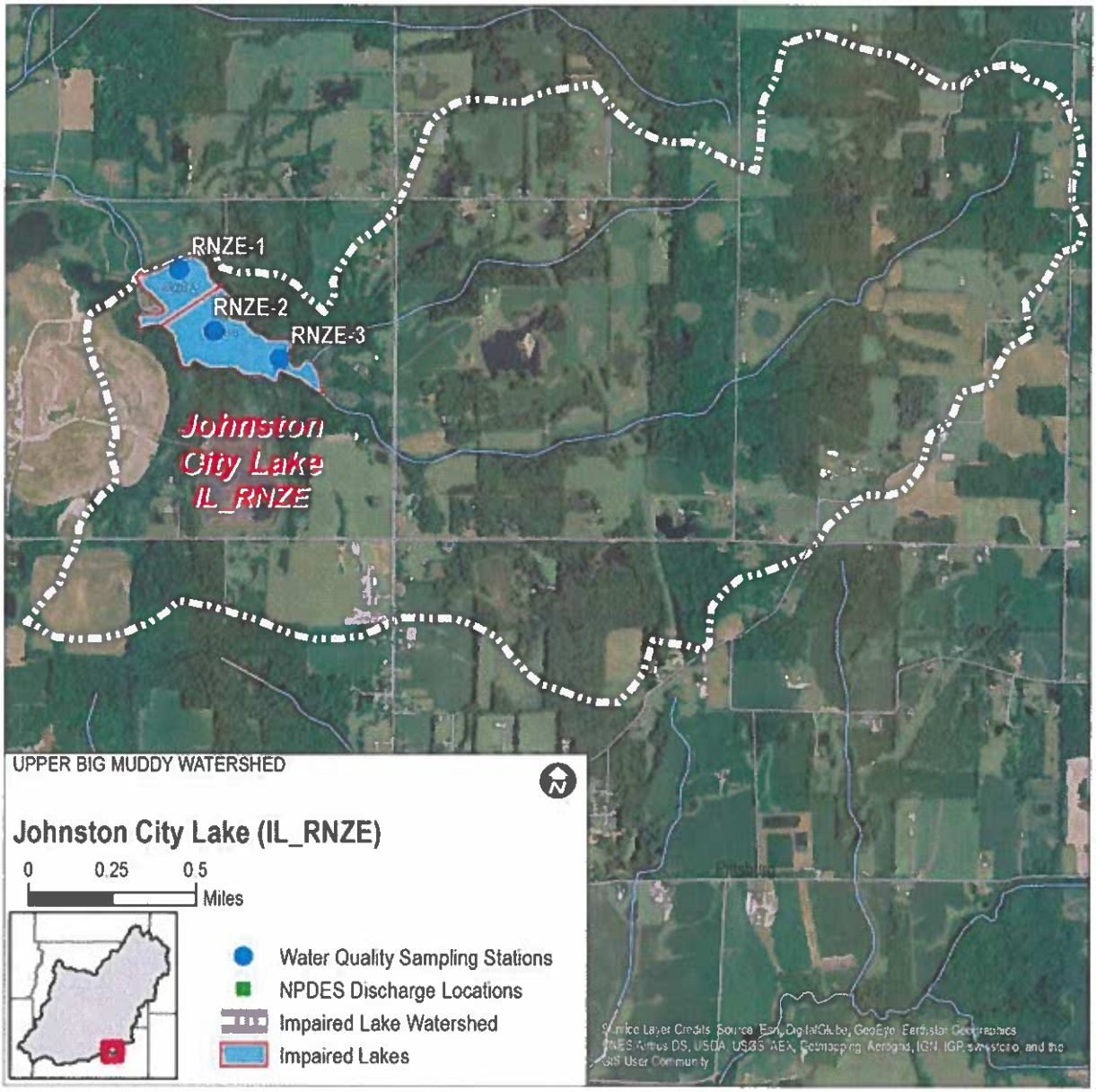


Figure 4-12. Johnston City Lake (IL_RNZE) Segmentation Used in BATHTUB Model

4.3.6.b Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Tributary and direct drainage flows to each segment were estimated using observed flows at the USGS gaging station at on Crab Orchard Creek near Marion, IL (USGS gage number 05597500), adjusted through the use of drainage area ratios as described in section 4.3.3.d above.

Annual average flow from the contributing watershed calculated using the above method was 4.9 cfs, and the annual average total phosphorus concentrations (calculated based on land use and literature phosphorus loading rates) 0.040 mg/L. The total estimated annual watershed load is 175.5 kg/yr of total phosphorus.

A complete listing of all segment-specific flows and tributary concentrations is provided in Attachment 4.

4.3.6.c BATHTUB Calibration

The BATHTUB model was initially applied with the model inputs as specified above. Observed lake data for the year 2002 were used for calibration purposes.

BATHTUB was calibrated to match the observed reservoir-average phosphorus concentrations. Model results using default model parameters initially under-predicted the observed phosphorus, i.e. model predictions were lower than observed concentrations. Phosphorus loss rates in BATHTUB reflect a typical "net settling rate" (i.e. settling minus sediment release) observed in a range of reservoirs. Under-prediction of observed phosphorus concentrations can occur in cases of elevated phosphorus release from lake sediments. The mismatch between model and data was corrected via the addition of an internal phosphorus load of 2 mg/m²/day in the upstream model segment (Segment 2). The resulting modeled and observed total phosphorus concentrations are shown in Figure 4-13. BATHTUB output files are provided in Attachment 4.

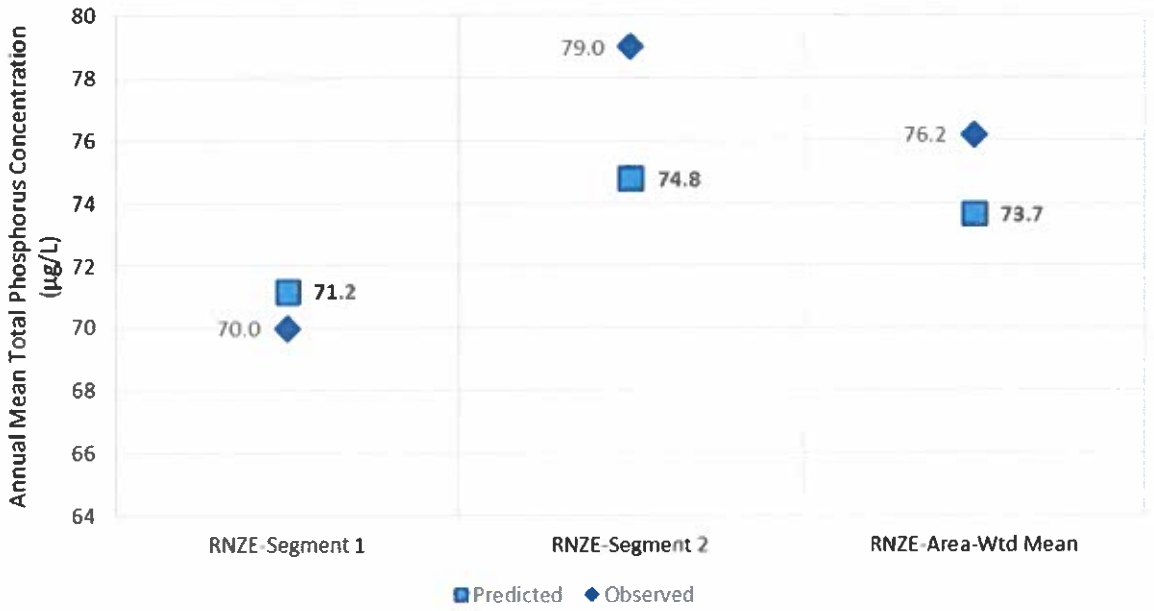


Figure 4-13. Johnston City Lake (IL_RNZE) BATHTUB Segment Modeled vs. Observed Total Phosphorus Concentration

4.3.7 Arrowhead (Williamson) / IL_RNZX BATHTUB Model Application

Arrowhead Lake (Williamson) / IL_RNZX is located just northeast of Johnston City, near Shakerag, IL. Arrowhead requires a TMDL for total phosphorus.

4.3.7.a Reservoir Segmentation

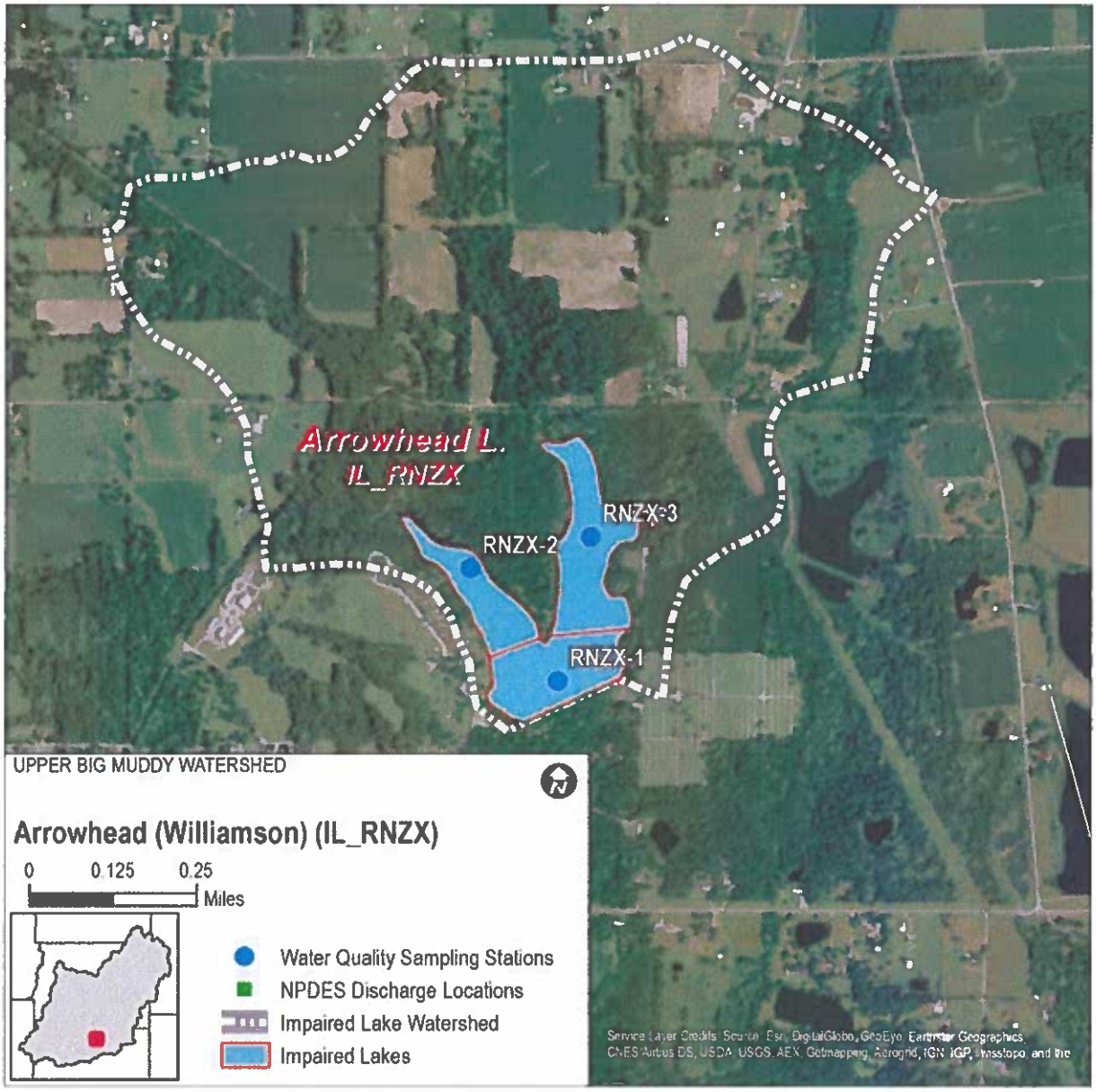


Figure 4-14. Arrowhead (Williamson) (IL_RNZX) Segmentation Used in BATHTUB Model

4.3.7.b Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Tributary and direct drainage flows to each segment were estimated using observed flows at the USGS gaging station at on Crab Orchard Creek near Marion, IL (USGS gage number 05597500), adjusted through the use of drainage area ratios as described in section 4.3.3.d above.

Annual average flow from the contributing watershed calculated using the above method was 1.0 cfs, and the annual average total phosphorus concentration (calculated based on land use and literature

phosphorus loading rates) was 0.046 mg/L. The total estimated annual watershed load is 39.7 kg/yr of total phosphorus.

A complete listing of all segment-specific flows and tributary concentrations is provided in Attachment 4.

4.3.7.c BATHTUB Calibration

The BATHTUB model was initially applied with the model inputs as specified above. Observed lake data for the year 2013 were used for calibration purposes.

BATHTUB was calibrated to match the observed reservoir-average phosphorus concentrations. Model results using default model parameters initially under-predicted the observed phosphorus, i.e. model predictions were lower than observed concentrations. Phosphorus loss rates in BATHTUB reflect a typical "net settling rate" (i.e. settling minus sediment release) observed in a range of reservoirs. Under-prediction of observed phosphorus concentrations can occur in cases of elevated phosphorus release from lake sediments. The mismatch between model and data was corrected via the addition of an internal phosphorus load of 12 mg/m²/day. The resulting modeled and observed total phosphorus concentrations are shown in Figure 4-15. BATHTUB output files are provided in Attachment 4.

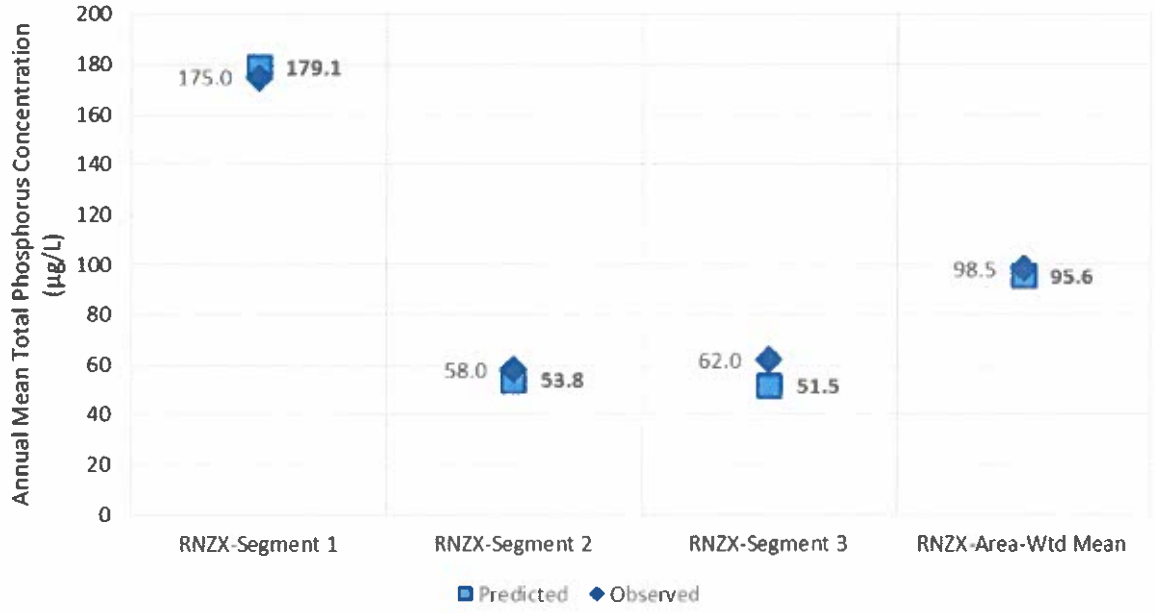


Figure 4-15. Arrowhead (Williamson) (IL_RNZX) BATHTUB Segment Modeled vs. Observed Total Phosphorus Concentration

4.3.8 West Frankfort Old / IL_RNP BATHTUB Model Application

West Frankfort Old City Lake is a 147 acre impoundment located approcimately 6 miles east of the West Frankfort in Franklin County that requires a TMDL for total phosphorus. The water quality data used to develop the BATHTUB model was collected in 2008 and 2013.

4.3.8.a Reservoir Segmentation

The BATHTUB model for the West Franklin Old Reservior, was developed with two model segments as shown in Figure 4-16, one representing the upstream monitoring stations (RNP-2 & RNP-3), and one representing the downstream station at the deepest portion of the lake (RNP-1).

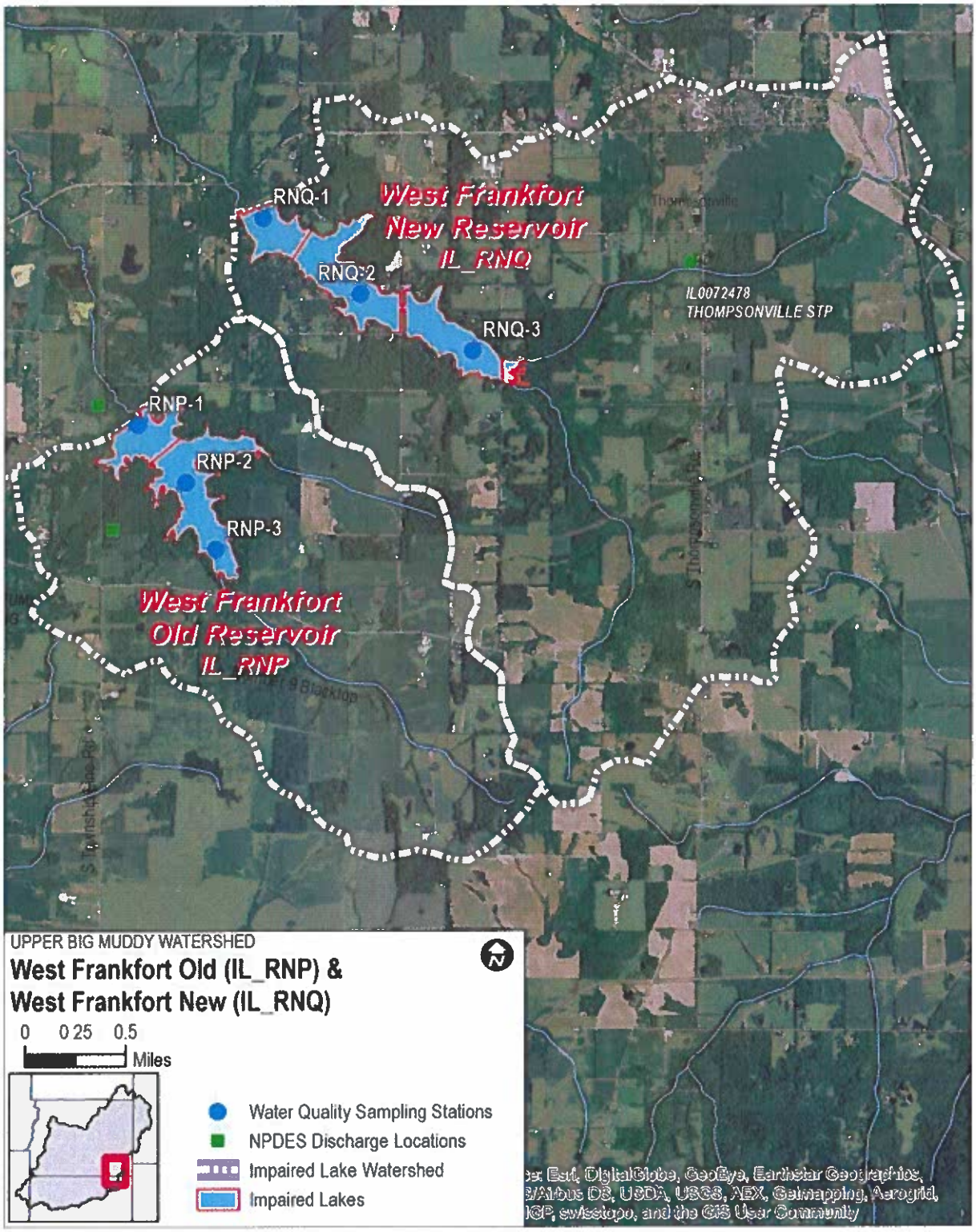


Figure 4-16. West Frankfort Old (IL_RNP) and West Frankfort New (IL_RNQ) Lake Segmentation Used in BATHTUB

4.3.8.b Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Tributary and direct drainage flows to each segment were estimated using observed flows at the USGS gaging station at on Crab Orchard Creek near Marion, IL (USGS gage number 05597500), adjusted through the use of drainage area ratios as described in section 4.3.3.d above.

Annual average flow from the contributing watershed calculated using the above method was 5.0 cfs, and the annual average total phosphorus concentration (calculated based on land use and literature phosphorus loading rates) was 0.164 mg/L. The total estimated annual watershed load is 725.5 kg/yr (1599.5 lb/year) of total phosphorus.

4.3.8.c BATHTUB Calibration

The BATHTUB model was initially applied with the model inputs as specified above. Observed lake data for the years 2008 and 2013 were used for calibration purposes.

BATHTUB was calibrated to match the observed reservoir-average phosphorus concentrations. Model results using default model parameters initially under-predicted the observed phosphorus, i.e. model predictions were lower than observed concentrations. Phosphorus loss rates in BATHTUB reflect a typical "net settling rate" (i.e. settling minus sediment release) observed in a range of reservoirs. Under-prediction of observed phosphorus concentrations can occur in cases of elevated phosphorus release from lake sediments. The mismatch between model and data was corrected via the addition of an internal phosphorus load of 40 mg/m²/day in the downstream segment (Segment 1). The resulting modeled and observed total phosphorus concentrations are shown in Figure 4-17. BATHTUB output files are provided in Attachment 4.

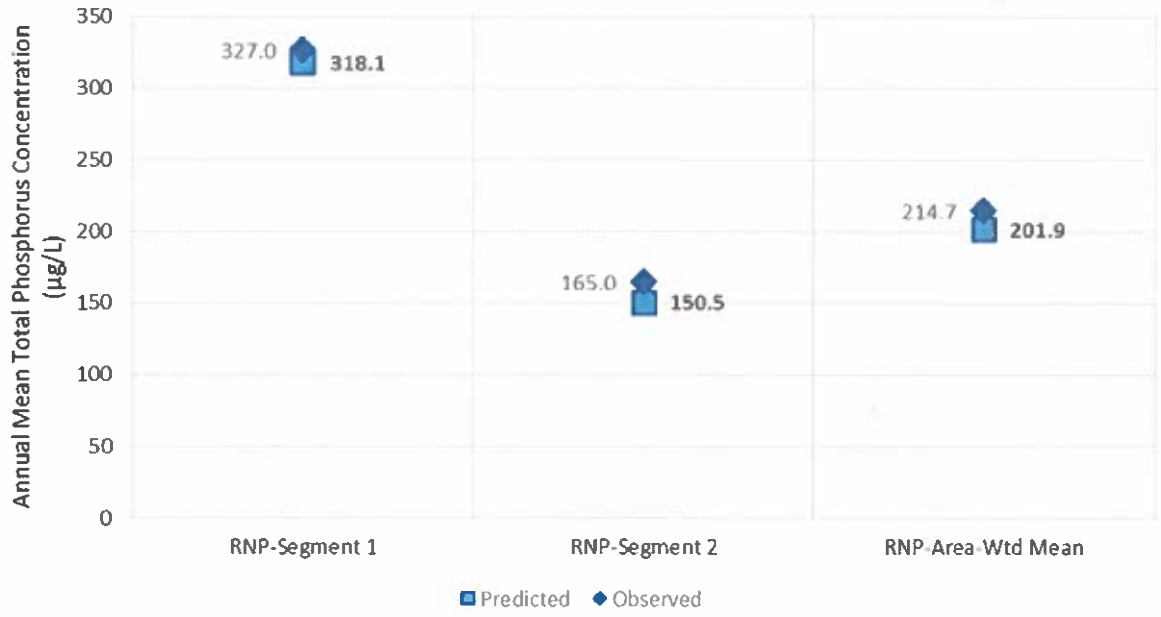


Figure 4-17. West Frankfort Old (IL_RNP) BATHTUB Segment Modeled vs. Observed Total Phosphorus Concentration

4.3.9 West Frankfort New/ IL_RNQ BATHTUB Model Application

4.3.9.a Reservoir Segmentation

West Frankfort New reservoir is located northeast of West Franklin Old Reservior, as shown in Figure 4-16. The BATHTUB model was developed with three model segments, one for each of the primary monitoring station in the lake.

4.3.9.b Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Tributary and direct drainage flows to each segment were estimated using observed flows at the USGS gaging station at on Crab Orchard Creek near Marion, IL (USGS gage number 05597500), adjusted through the use of drainage area ratios as described in section 4.3.3.d above.

Annual average flow from the contributing watershed calculated using the above method was 10.0 cfs, and the annual average total phosphorus concentration (calculated based on land use and literature phosphorus loading rates) was 0.101 mg/L. The total estimated annual watershed load is 906.2 kg/yr of total phosphorus.

In addition to the watershed loads, there is a point source load from the Thompsonville STP (IL0072478). The design average flow (DAF) for the facility is 0.08 million gallons per day (MGD) and the design maximum flow (DMF) for the facility is 0.20 MGD. Treatment consists of two cell aerated lagoon and rock filter.

The average daily flows from this STP reported in the DMRs from 2008 through 2016 0.087 MGD. There is no water quality data for total phosphorus from this point source to use for model calibration. The total phosphorus concentration in the STP effluent was assumed to be 3.66 mg/L. With the monthly average flows reported on the DMRs for that facility, the annual average loading is 437.4 kg/yr.

Based on the combined flow and loads from the sources identified above, the total annual average concentration into the reservoir is 0.148 mg/L, with a total annual loading of 1343.6 kg/yr.

4.3.9.c BATHTUB Calibration

The BATHTUB model was initially applied with the model inputs as specified above. Observed lake data for the year 2013 were used for calibration purposes.

BATHTUB was calibrated to match the observed reservoir-average phosphorus concentrations. Model results using default model parameters initially under-predicted the observed phosphorus, i.e. model predictions were lower than observed concentrations. Phosphorus loss rates in BATHTUB reflect a typical "net settling rate" (i.e. settling minus sediment release) observed in a range of reservoirs. Under-prediction of observed phosphorus concentrations can occur in cases of elevated phosphorus release from lake sediments. The mismatch between model and data was corrected via the addition of internal phosphorus loads of 25 mg/m^2/day in Segment 3 (upstream), 35 mg/m^2/day in Segment 2, and 90 mg/m^2/day in Segment 1 (downstream). The resulting modeled and observed total phosphorus concentrations are shown in Figure 4-18. BATHTUB output files are provided in Attachment 4.



Figure 4-18. West Frankfort New (IL_RNQ) BATHTUB Segment Modeled vs. Observed Total Phosphorus Concentration

4.4 Total Suspended Solids Model for Load Reduction Strategy Development

This section describes the model selection and modeling approach for the total suspended solids load reduction strategy for the following waterbodies in the Upper Big Muddy River watershed, identified by IEPA as being impaired due to elevated total suspended solids concentrations:

- Herrin Old / IL_RNZD
- Johnston City / IL_RNZE
- West Frankfort Old / IL_RNP
- West Frankfort New/ IL_RNQ
- Big Muddy R. / IL_N-06
- Big Muddy R. / IL_N-11
- Big Muddy R. / IL_N-17
- Hurricane Creek / IL_NF-01
- Pond Cr. / IL_NG-02
- M. Fk. Big Muddy / IL_NH-07

4.4.1 Modeling Approach

The total suspended solids load reduction strategy is based on a simple empirical model using the average of all available TSS data on each waterbody, and comparing it with the LRS endpoint concentration identified in Section 3.1.

The load reduction target concentration for TSS for all streams in this watershed is 27.75 mg/L. For all lakes in the watershed, the load reduction targets concentration is 23 mg/L.

After reviewing the water quality data available, it was found that the following waterbodies have average TSS concentrations already below the target for the watershed, and therefore will not have LRSs prepared.

- Herrin Old / IL_RNZD
- Johnston City / IL_RNZE
- West Frankfort Old / IL_RNP
- West Frankfort New/ IL_RNQ
- Hurricane Creek / IL_NF-01

5 TMDL Development for the Upper Big Muddy River Watershed

This section presents the development of the TMDLs for the following waterbodies in the Upper Big Muddy River watershed:

- Upper Big Muddy River (IL_N-11) for fecal coliform
- Andy Cr. (IL_NZN-13) for iron.
- Lake Cr. (IL_NGA-02) for dissolved oxygen.
- Beaver Cr. (IL_NGAZ-JC-D1) for manganese.
- Middle Fork Big Muddy (IL_NH-06) for fecal coliform.
- Arrowhead (Williamson) (IL_RNZX) for total phosphorus.
- Herrin Old (IL_RNZD) for total phosphorus.
- Johnston City (IL_RNZE) for total phosphorus.
- West Frankfort Old (IL_RNP) for total phosphorus.
- West Frankfort New (IL_RNQ) for total phosphorus.

In addition, a dissolved oxygen TMDL was planned for Andy Creek (IL_NZN-13), but after reviewing the field data and developing the QUAL2E model, it was determined that the low flows and high sediment oxygen demand were the primary causes of the low dissolved oxygen in this stream, not external pollutant loadings.

5.1 Andy Creek (IL_NZN-13) Dissolved Oxygen TMDL

A dissolved oxygen assessment was conducted for Andy Creek segment IL_NZN-13. The result of this assessment indicates that low stream flows preclude attainment of dissolved oxygen standards, even in the complete absence of external pollutant loads. For this reason, a TMDL is not being developed for dissolved oxygen. Details of the assessments are discussed below.

Two lines of assessment were used to make the determination that it is low stream flows, rather than external pollutant loads, that precludes attainment of dissolved oxygen standards:

1. Sediment oxygen demand is the dominant component of the dissolved oxygen mass balance provided by QUAL2E.
2. Setting all external loading sources to zero in the QUAL2E model does not result in attainment in dissolved oxygen standards.
3. Leaving all external loads at currently specified values, but increasing base stream flow, does result in attainment with dissolved oxygen standards.

5.1.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards.

The first step in determining the loading capacity was to reduce external sources of oxygen-demanding substances to determine whether these reductions would result in the river attaining the dissolved oxygen target.

QUAL2E simulations showed that, even with incremental inflow and permitted BOD loads set to zero, compliance with the dissolved oxygen standards was not attained. Examination of model results showed that sediment oxygen demand was the dominant source of the oxygen deficit, and that DO standards could only be attained during critical periods via reduction of SOD[1].

5.2 Lake Creek (IL_NGA-02) Dissolved Oxygen TMDL

A dissolved oxygen assessment was conducted for Lake Creek segment IL_NGA-02 utilizing the data collected in September 2015 and a QUAL2E model. The QUAL2E model was calibrated to the data available, which occurred during a month when there were effluent limit violations from the Johnston City STP for both CBOD5 and ammonia nitrogen.

To determine if the effluent violations were causing the observed DO impairments, the QUAL2E model was run with modifying the input loads from the Johnston City STP to the current permit limits of 10 mg/L $CBOD_5$ (monthly average effluent limit) and 1.5 mg/L ammonia nitrogen (monthly average effluent limit), and 6.0 mg/L of dissolved oxygen (monthly average minimum) at the design average flow for the facility of 0.55 MGD.

The result of this assessment shows that if the Johnston City STP effluent meets the above noted limits. The dissolved oxygen concentration in the stream reaches a minimum level of 5.37 mg/L, which is above the 5.0 mg/L endpoint selected for the TMDL based on the State of Illinois water quality standards.

5.2.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards.

The first step in determining the loading capacity was to reduce external sources of oxygen-demanding substances to determine whether these reductions would result in the river attaining the dissolved oxygen target.

QUAL2E simulations showed that with the point load $CBOD_5$ and ammonia nitrogen loads set to zero, compliance with the dissolved oxygen standards was attained with a minimum dissolved oxygen concentration of 5.38 mg/L.

Further QUAL2E simulations with adjusted BOD, dissolved oxygen, and ammonia nitrogen loads from the Johnston City STP were performed to determine the loading capacity. As noted above, QUAL2E model simulations with the input loads from the Johnston City STP set ther current permit limits of 10 mg/L $CBOD_5$ (monthly average effluent limit) and 1.5 mg/L ammonia nitrogen (monthly average effluent limit), and 6.0 mg/L of dissolved oxygen (monthly average minimum) at the design average flow for the facility of 0.55 MGD resulted in a minimum dissolved oxygen concentration of 5.37 mg/L, which is above the 5.0 mg/L endpoint selected for the TMDL based on the State of Illinois water quality standards.

Additional QUAL2E simulations were performed with the input loads from the Johnston City STP adjusted until the minimum dissolved oxygen concentration was 5.0 mg/L to determine the maximum loading capacity of the stream. The loading capacity of the stream for ammonia nitrogen was determined

[1] Although SOD is the dominant source of the oxygen deficit, the true cause of low dissolved oxygen is a lack of base flow (which greatly exacerbates the effect of SOD). Because TMDLs cannot be written to control flow, no TMDL was developed for this stream segment.

to be 1.80 mg/L, with a $CBOD_5$ load of 11 mg/L, and 5.45 mg/L of dissolved oxygen at the design average flow for the facility. The total loading capacity for Lake Creek segment IL_NGA-02 for ammonia nitrogen is 8.25 lb/day.

5.2.2 Allocation

A TMDL consists of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

The WLA for the Johnston City STP into Lake Creek segment IL_NGA-02 was calculated based on the permitted design average flow for the facility, and the current NPDES effluent limit concentration for ammonia nitrogen of 1.5 mg/L (monthly average limitation). The WLA for Lake Creek is presented in Table 5-1.

Table 5-1. Lake Creek Segment IL_NGA-02 Watershed Permitted Dischargers and WLAs

NPDES ID	Facility Name	Ammonia Nitrogen Effluent Concentration (mg/L)	Design average flow (MGD)	WLA (lb/day)
ILG0029301	Johnston City STP	1.50	0.55	6.88

The remaining loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The load allocation for nonpoint sources is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall phosphorus load. Given a total loading capacity of 8.25 lbs/day of ammonia nitrogen, a WLA for the Johnston City STP of 6.88 lbs/day, and an explicit margin of safety of 10% (discussed below), the load allocation for Lake Creek segment IL_NGA-02 is 0.54 lbs/day.

5.2.3 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The QUAL2E model and the sampling were performed during a low flow period, which is critical for determining loads associated with low dissolved oxygen.

5.2.4 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the QUAL2E water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the stream, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit total ammonia nitrogen load allocated to the margin of safety is 0.825 lbs/day for Lake Creek.

5.2.5 Reserve Capacity

Lake Creek is located in Williamson County, the population of which has increased by 8.3% between 2000 and 2010 (Stage 1 Report Section 2.6). In 2010, the U.S. Census Bureau estimated the Franklin County population at 66,357.

The Illinois Department of Public Health population projections (Shahidullah 2015) for Williamson County shows a slight population increase to 69,246 in the year 2025. Further, the Greater Egypt Regional Planning and Development Commission, referencing US Census Bureau projections, states that the population in the Greater Egypt 5-county area which includes Williamson County will be relatively steady (or slightly declining) through 2030 (GERPDC 2010).

A reserve capacity is not needed, due to the slight projected increase in population, and because, at this time IEPA is not aware of any increases in discharges from the existing point sources, or the establishment of future municipal or industrial point sources.

5.2.6 TMDL Summary

The dissolved oxygen (ammonia) TMDL for Lake Creek segment IL_NGA-02, is presented in Table 5-2.

Table 5-2. Lake Creek IL_NGA-02 TMDL Summary

Allocation	Total Ammonia Nitrogen Load (lbs/day)
Load Capacity (LC)	8.25
Wasteload Allocation (WLA)	6.88
Load Allocation (LA)	0.54
Margin of safety (10% of LC)	0.83

5.3 Upper Big Muddy River (IL_N-11) Fecal Coliform TMDL

A load capacity calculation approach was applied to support development of a fecal coliform TMDL for Upper Big Muddy River segment IL_N-11.

5.3.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards.

The loading capacity for Upper Big Muddy River segment IL_N-11 was defined over a range of specified flows based on expected Upper Big Muddy River flows at the mouth of the creek. The allowable loading capacity was computed by multiplying flow by the TMDL target (200 cfu/100 mL). The fecal coliform loading capacity for IL_N-11 is presented in Table 5-3.

Table 5-3. Fecal Coliform Load Capacity (IL_N-11)

Flow Exceedance Percentile from the LDC	Upper Big Muddy River Flow (cfs)	Allowable Load (cfu/day)
99%	9.7	4.8E+10
95%	11	5.6E+10
90%	13	6.2E+10
80%	16	7.7E+10
70%	22	1.1E+11
60%	35	1.7E+11
50%	57	2.8E+11
40%	93	4.6E+11
30%	150	7.6E+11
20%	260	1.3E+12
10%	610	3.0E+12
5%	1700	8.3E+12
1%	7200	3.5E+13

The maximum fecal coliform concentrations recorded between May and October were examined for each flow duration interval, as shown in Table 5-4, in order to estimate the percent reduction in existing loads required to meet the 200 cfu/100 mL target. As shown in Table 5-4, a greater reduction is needed at higher river flows to meet the target. During these higher flow periods, fecal coliform measurements were observed to exceed 200 cfu/100 mL more frequently.

Table 5-4. Required Reductions in Existing Loads under Different Flow Conditions (IL_N-11)

Flow Percentile Interval	Upper Big Muddy River Flow (cfs)	# samples > 200/ # samples (May-Oct)	Maximum fecal coliform concentration (cfu/100 ml)	Percent Reduction to Meet Target
0 - 30	28,875 - 154	3 / 8	4,500	95.6%
30 - 70	154 - 21.9	7 / 22	3,600	94.4%
70 - 100	21.9 - 6.9	1 / 15	210	4.8%

5.3.2 Allocation

A TMDL consists of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

The WLA for the 10 permitted sewage treatment plant discharges in the Upper Big Muddy River segment IL_N-11 watershed was calculated based on the permitted design average flow for these dischargers and a fecal coliform concentration that is consistent with meeting the TMDL target (200 cfu/100mL). Eight of the ten NPDES-permitted dischargers have disinfection exemptions, therefore, the WLA is based on the

dischargers meeting 200 cfu/100 mL at the downstream end of their exempted reach. WLAs are presented in Table 5-5.

Table 5-5. Segment IL_N-11 Watershed Permitted Dischargers and WLAs

NPDES ID	Facility Name	Disinfection exemption?	Design average flow (MGD)	WLA (cfu/day)
ILG580083	VALIER STP	Yes, year-round	0.08	6.06E+08
ILG580215	WEST CITY STP	Yes, year-round	0.1	7.57E+08
ILG580221	HANAFORD STP	Yes, year-round	0.042	3.18E+08
ILG580272	ORIENT STP	Yes, year-round	0.0752	5.69E+08
IL0050466	LB CAMPING-SESSER STP	No (400 cfu / 100 mL Daily Max)	0.0051	3.86E+07
IL0061760	HILL CITY APARTMENTS-BENTON	Yes, year-round	0.004	3.03E+07
IL0065111	REND LAKE CONS. DIST. STP	Yes, year-round	0.5	3.79E+09
IL0020851	CHRISTOPHER STP	Yes, year-round	0.768	5.81E+09
IL0022365	BENTON NORTHWEST STP	No (400 cfu / 100 mL Daily Max)	1.01	7.65E+09
IL0031704	WEST FRANKFORT STP	Yes, year-round	1.4	1.06E+10

The total WLA for the ten (10) point source dischargers in the IL_N-11 watershed is 3.02E+10 cfu/day. This does not include any dischargers in the areas upstream of Rend Lake. The significant retention time and settling capacity in the reservior are assumed to reduce fecal coliform loads from the upstream areas to be below the water quality standards.

The remainder of the loading capacity is given to the load allocation for nonpoint sources as an implicit MOS was used in this TMDL (Table 5-6). The load allocations are not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall fecal coliform load.

Table 5-6. Fecal Coliform TMDL for Segment IL_N-11 Upper Big Muddy River[1]

Upper Big Muddy River Flow (cfs)	Allowable Load (cfu/day)	Wasteload Allocation (WLA) (cfu/day)	Load Allocation (LA) (cfu/day)
12.6	6.16E+10	3.02E+10	3.14E+10
15.8	7.75E+10	3.02E+10	4.73E+10
21.9	1.07E+11	3.02E+10	7.71E+10
34.9	1.71E+11	3.02E+10	1.41E+11
56.9	2.78E+11	3.02E+10	2.48E+11
93.4	4.57E+11	3.02E+10	4.27E+11
154	7.55E+11	3.02E+10	7.25E+11
260	1.27E+12	3.02E+10	1.24E+12
609	2.98E+12	3.02E+10	2.95E+12
7226	3.54E+13	3.02E+10	3.53E+13

[1]This TMDL has an implicit Margin of Safety, so MOS is not included in this table.

5.3.3 Critical Condition

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Figure 4-5 provides a graphical depiction of the data compared to the load capacity, showing that exceedances of the TMDL target occur over the full range of flow conditions. TMDL development utilizing the load-duration approach applies to the full range of flow conditions; therefore critical conditions were addressed during TMDL development.

5.3.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The load capacity calculation approach used for the TMDL evaluated seasonal loads because only May through October water quality data were used in the analysis, consistent with the specification that the standard only applies during this period. The fecal coliform standard will be met regardless of flow conditions in the applicable season because the load capacity calculations specify target loads for the entire range of flow conditions that are possible to occur in any given point in the season where the standard applies.

5.3.5 Margin of Safety

Total maximum daily loads are required to contain a Margin of Safety (MOS) to account for any uncertainty concerning the relationship between pollutant loading and receiving water quality. The MOS can be either implicit (e.g., incorporated into the TMDL analysis through conservative assumptions), or explicit (e.g., expressed in the TMDL as a portion of the loading), or expressed as a combination of both. The fecal coliform TMDL contains an implicit margin of safety, through the use of multiple conservative assumptions. First, the TMDL target (no more than 200 cfu/100 mL at any point in time) is more conservative than the more restrictive portion of the fecal coliform water quality standard (geometric mean of 200 cfu/100 mL for all samples collected May through October). An additional implicit Margin of Safety is provided via the use of a conservative model to define load capacity. The model assumes no decay of bacteria that enter the river, and therefore represents an upper bound of expected concentrations for a given pollutant load. This margin of safety can be reviewed in the future as new data are developed.

5.4 Middle Fork Big Muddy (IL_NH-06) Fecal Coliform TMDL

A load capacity calculation approach was applied to support development of a fecal coliform TMDL for Middle Fork Big Muddy River segment IL_NH-06.

5.4.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards.

The loading capacity for the Middle Fork Big Muddy River segment IL_NH-06 was defined over a range of specified flows based on expected flows at the outlet of the segment. The allowable loading capacity was computed by multiplying flow by the TMDL target (200 cfu/100 mL). The fecal coliform loading capacity for IL_NH-06 is presented in Table 5-7.

Table 5-7. Fecal Coliform Load Capacity (IL_NH-06)

Flow Exceedance Percentile from the LDC	Middle Fork Big Muddy River Flow (cfs)	Allowable Load (cfu/day)
99%	5.0	2.5E+10
95%	5.8	2.9E+10
90%	6.5	3.2E+10
80%	8.1	4.0E+10
70%	11	5.5E+10
60%	18	8.8E+10
50%	29	1.4E+11
40%	48	2.4E+11
30%	79	3.9E+11
20%	130	6.5E+11
10%	310	1.5E+12
5%	870	4.2E+12
1%	3700	1.8E+13

The maximum fecal coliform concentrations recorded between May and October were examined for each flow duration interval, as shown in Table 5-8, in order to estimate the percent reduction in existing loads required to meet the 200 cfu/100 mL target. As shown in Table 5-8, the greatest reduction is needed at normally encountered river flows to meet the target. During these higher flow periods, fecal coliform measurements were observed to exceed 200 cfu/100 mL more frequently (as a fraction of the samples taken).

Table 5-8. Required Reductions in Existing Loads under Different Flow Conditions (IL_NH-06)

Flow Percentile Interval	Upper Big Muddy River Flow (cfs)	# samples > 200/ # samples (May-Oct)	Maximum fecal coliform concentration (cfu/100 ml)	Percent Reduction to Meet Target
0 - 30	14,849 - 79	7 / 7	20,000	99.0%
30 - 70	79 - 11.3	10 / 18	63,600	99.7%
70 - 100	11.3 - 3.55	7 / 21	1,760	88.6%

5.4.2 Allocation

A TMDL consists of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

The WLA for the 3 permitted sewage treatment plant discharges in the Middle Fork Big Muddy River segment IL_NH-06 watershed was calculated based on the permitted design average flow for these dischargers and a fecal coliform concentration that is consistent with meeting the TMDL target (200 cfu/100mL). All three of these NPDES-permitted dischargers have disinfection exemptions, therefore, the WLA is based on the dischargers meeting 200 cfu/100 mL at the downstream end of their exempted reach. WLAs are presented in Table 5-9.

Table 5-9. Segment IL_NH-06 Permitted Dischargers and WLAs

NPDES ID	Facility Name	Disinfection exemption?	Design average flow (MGD)	WLA (cfu/day)
ILG580221	HANAFORD STP	Yes, year-round	0.042	3.18E+08
IL0061760	HILL CITY APARTMENTS-BENTON	Yes, year-round	0.004	3.03E+07
IL0065111	REND LAKE CONS. DIST. STP	Yes, year-round	0.5	3.79E+09

The total WLA for the three (3) point source dischargers in the IL_NH-06 watershed is 4.13E+09 cfu/day.

The remainder of the loading capacity is given to the load allocation for nonpoint sources as an implicit MOS was used in this TMDL (Table 5-10). The load allocations are not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall fecal coliform load.

Table 5-10. Fecal Coliform TMDL for Segment IL_NH-06 Upper Big Muddy River[1]

Upper Big Muddy River Flow (cfs)	Allowable Load (cfu/day)	Wasteload Allocation (WLA) (cfu/day)	Load Allocation (LA) (cfu/day)
6.5	3.17E+10	4.13E+09	2.75E+10
8.1	3.99E+10	4.13E+09	3.57E+10
11.3	5.52E+10	4.13E+09	5.10E+10
18.0	8.79E+10	4.13E+09	8.38E+10
29.2	1.43E+11	4.13E+09	1.39E+11
48.0	2.35E+11	4.13E+09	2.31E+11
79.4	3.88E+11	4.13E+09	3.84E+11
134	6.54E+11	4.13E+09	6.50E+11
313	1.53E+12	4.13E+09	1.53E+12
3716	1.82E+13	4.13E+09	1.82E+13

[1]This TMDL has an implicit Margin of Safety, so MOS is not included in this table.

5.4.3 Critical Condition

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Figure 4-9 provides a graphical depiction of the data compared to the load capacity, showing that exceedances of the TMDL target occur over the full range of flow conditions. TMDL development utilizing the load-duration approach applies to the full range of flow conditions; therefore critical conditions were addressed during TMDL development.

5.4.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The load capacity calculation approach used for the TMDL evaluated seasonal loads because only May through October water quality data were used in the analysis, consistent with the specification that the standard only applies during this period. The fecal coliform standard will be met regardless of flow conditions in the applicable season because the load capacity calculations specify target loads for the entire range of flow conditions that are possible to occur in any given point in the season where the standard applies.

5.4.5 Margin of Safety

Total maximum daily loads are required to contain a Margin of Safety (MOS) to account for any uncertainty concerning the relationship between pollutant loading and receiving water quality. The MOS can be either implicit (e.g., incorporated into the TMDL analysis through conservative assumptions), or explicit (e.g., expressed in the TMDL as a portion of the loading), or expressed as a combination of both. The fecal coliform TMDL contains an implicit margin of safety, through the use of multiple conservative assumptions. First, the TMDL target (no more than 200 cfu/100 mL at any point in time) is more conservative than the more restrictive portion of the fecal coliform water quality standard (geometric mean of 200 cfu/100 mL for all samples collected May through October). An additional implicit Margin of Safety is provided via the use of a conservative model to define load capacity. The model assumes no decay of bacteria that enter the river, and therefore represents an upper bound of expected concentrations for a given pollutant load. This margin of safety can be reviewed in the future as new data are developed.

5.5 Andy Creek (IL_NZN-13) Iron TMDL

A load capacity calculation approach was applied to support development of dissolved iron TMDL for Andy Creek segment IL_NZN-13.

5.5.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards. The loading capacity was defined over a range of specified flows based on expected flows. The allowable loading capacity was computed by multiplying the estimated flow in Andy Creek by the TMDL target concentration of 1 mg/l (Table 5-11).

Table 5-11. Iron Load Capacity (IL_NZN-13)

Flow Exceedance Percentile from the LDC	Stream Flow (cfs)	Allowable Load (lbs/day)
90%	0.1	0.27
80%	0.2	1.0
70%	0	2.5
60%	1	5.5
50%	2	1.3
40%	5	2.6
30%	9	4.8
20%	15	8.3
10%	40	2.1
5%	99	5.4

The maximum dissolved iron concentrations were examined for each flow duration interval, as shown in Table 5-12, in order to estimate the percent reduction in existing loads required to meet the 1 mg/l target. Reductions of up to 9.9% in current loads are needed at higher river flows to meet the target. No reductions are needed at lower flows.

Table 5-12. Required Reductions in Existing Loads under Different Flow Conditions (IL_NZN-13)

Flow Percentile Interval	Stream Flow (cfs)	# samples > 1 mg/L / # samples	Maximum Dissolved Iron concentration (mg/L)	Percent Reduction to Meet Target
0 - 30	3,572 - 9	1 / 1	1.11	9.9%
30 - 70	9 - 0.46	0 / 1	0.081	-
70 - 100	0.46 - 0	0 / 1	0.038	-

5.5.2 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There are no permitted dischargers of iron in the Andy Creek segment IL_NZN-13 watershed, and therefore the wasteload allocation did not need to be calculated.

The remainder of the loading capacity is given to the load allocation for nonpoint sources and the MOS (Table 5-13). The load allocations are not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall iron load.

Table 5-13. Iron TMDL for Andy Creek (Segment IL_NZN-13)

Stream Flow (cfs)	Allowable Load (lbs/day)	MOS (10%) (lbs/day)	Wasteload Allocation (WLA) (lbs/day)	Load Allocation (LA) (lbs/day)
0.05	0.27	0.03	0	0.24
0.19	1.04	0.10	0	0.94
0.46	2.46	0.25	0	2.2
1.0	5.54	0.55	0	5.0
2.4	13.2	1.3	0	11.9
4.8	26.0	2.6	0	23.4
9.0	48.5	4.9	0	43.7
15	83.1	8.3	0	74.8
40	215	22	0	194
472	2541	254	0	2287

5.5.3 Critical Condition

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Figure 4-6 provides a graphical depiction of the data compared to the load capacity, showing that the TMDL target is exceeded during higher flow conditions. TMDL development utilizing the load-duration approach applies to the full range of flow conditions, including high flows; therefore critical conditions were addressed during TMDL development.

5.5.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The iron standard will be met regardless of flow conditions in any season because the load capacity calculations specify target loads for the entire range of flow conditions that are possible to occur in the stream.

5.5.5 Margin of Safety

Total maximum daily loads are required to contain a Margin of Safety (MOS) to account for any uncertainty concerning the relationship between pollutant loading and receiving water quality. The iron TMDL contains an explicit margin of safety of 10%. This 10% margin of safety was included to address potential uncertainty in the effectiveness of load reduction alternatives. This margin of safety can be reviewed in the future as new data are developed.

5.6 Beaver Creek (IL_NGAZ-JC-D1) Manganese TMDL

A load capacity calculation approach was applied to support development of an atrazine TMDL for Beaver Creek segment IL_NGAZ-JC-D1.

5.6.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards. The loading capacity was defined over a range of specified flows based on expected flows. The allowable loading capacity was computed by multiplying the estimated Beaver Creek flow by the TMDL target concentration of 4.85 mg/l (Table 5-14).

Table 5-14. Manganese Load Capacity (IL_NGAZ-JC-D1)

Flow Exceedance Percentile from the LDC	Beaver Creek Flow (cfs)	Allowable Load (lbs/day)
80%	0.006	0.15
70%	0.01	0.36
60%	0.03	0.81
50%	0.07	1.93
40%	0.15	3.80
30%	0.27	7.10
20%	0.47	12.16
10%	1.2	31.42
5%	3.0	78.36
1%	14	371.98

The maximum manganese concentrations were examined for each flow duration interval, as shown in Table 5-15, in order to estimate the percent reduction in existing loads required to meet the 4.85 mg/L target. Reductions of 24.4% of current loads are needed based on the single water quality sample data point sampled in the normally occurring flows interval. No reductions are are able to be calculated at lower or higher flows based on the data available.

Table 5-15. Required Reductions in Existing Loads under Different Flow Conditions (IL_NGAZ-JC-D1)

Flow Percentile Interval	Beaver Creek Flow (cfs)	# samples > 4.85 mg/l samples	Maximum Manganese concentration (mg/L)	Percent Reduction to Meet Target
0 - 30	108 - 0.27	0 / 0	-	-
30 - 70	0.27 - 0.01	1 / 1	6.41	24.4%
70 - 100	0.01 - 0	0 / 0	-	-

5.6.2 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There are no permitted dischargers of manganese in the Beaver Creer segment IL_NGAZ-JC-D1 watershed, and therefore the wasteload allocation did not need to be calculated.

The remainder of the loading capacity is given to the load allocation for nonpoint sources and the MOS (Table 5-16). The load allocations are not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall manganese load.

Table 5-16. Manganese TMDL for Beaver Creek (Segment IL_NGAZ-JC-D1)

Flow (cfs)	Allowable Load (lbs/day)	MOS (10%) (lbs/day)	Wasteload Allocation (WLA) (lbs/day)	Load Allocation (LA) (lbs/day)
0.01	0.36	0.04	0	0.32
0.03	0.81	0.08	0	0.73
0.07	1.9	0.2	0	1.7
0.15	3.8	0.4	0	3.4
0.27	7.1	0.7	0	6.4
0.5	12.2	1.2	0	11.0
1.2	31.3	3.1	0	28.2

5.6.3 Critical Condition

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Figure 4-8 provides a graphical depiction of the data compared to the load capacity, showing that the TMDL target is exceeded during higher flow conditions. TMDL development utilizing the load-duration approach applies to the full range of flow conditions, including high flows; therefore critical conditions were addressed during TMDL development.

5.6.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The atrazine standard will be met regardless of flow conditions in any season because the load capacity calculations specify target loads for the entire range of flow conditions that are possible to occur in the river.

5.6.5 Margin of Safety

Total maximum daily loads are required to contain a Margin of Safety (MOS) to account for any uncertainty concerning the relationship between pollutant loading and receiving water quality. The manganese TMDL contains an explicit margin of safety of 10%. This 10% margin of safety was included to address potential uncertainty in the effectiveness of load reduction alternatives. This margin of safety can be reviewed in the future as new data are developed.

5.7 Herrin Old (IL_RNZD) Total Phosphorus TMDL

5.7.1 Calculation of the Loading Capacity

The loading capacity for Herrin Old Reservoir was determined by running the BATHTUB model repeatedly, reducing the tributary nutrient concentrations and/or internal phosphorus loadings for each simulation until model results demonstrated attainment of the water quality objective.

The maximum tributary concentration that results in compliance with water quality standards was used as the basis for determining the loading capacity. The tributary concentration was then converted into a loading rate through multiplication with the tributary flow.

The initial BATHTUB simulations and the sampling data from 2013 indicated that Herrin Old Reservoir phosphorus concentrations would meet the the water quality standards using the lake-averaged

phosphorus concentrations. The sampling data indicated that the only exceedances of the water quality standard were at the deepest parts of the lake, which indicates that the internal phosphorus source needs to be reduced by either capping the sediments (e.g. alum treatment or similar), or by dredging any organic sediments from the lake. The resulting load, with calibrated tributary concentrations and no additional sediment phosphorus load yields an average phosphorus load of 0.23 kg/day (0.51 lbs/day) and a concentration of 0.029 mg/L. This is below the phosphorus target of 0.05 mg/L, so reductions in the tributary loads are not necessary.

5.7.2 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There are no point sources in the watershed, and therefore there is no wasteload allocation given for Herrin Old Reservoir. The entire loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The loading capacity is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall phosphorus load. Given a loading capacity of 0.23 kg/day (0.51 lbs/day), and an explicit margin of safety of 10% (discussed below), the load allocation for Herrin Old Reservoir of 0.21 kg/day (0.46 lbs/day).

5.7.3 Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events can transport significant quantities of nonpoint source loads to lake. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. This TMDL is based upon an annual period that takes into account both spring loads and summer water quality in order to effectively consider these critical conditions.

5.7.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The BATHTUB model used for this TMDL is designed to evaluate loads over a seasonal to annual averaging period. The annual loading analysis that was used is appropriate due to the facts that:

1. The analysis demonstrated that the TMDL could only attain water quality targets if a significant reduction was achieved in sediment phosphorus release.
2. There is a long response time between phosphorus loading and sediment response, typically on the order of several years (e.g. Chapra and Canale, 1991).

5.7.5 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the BATHTUB water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the watershed, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit total phosphorus load allocated to the margin of safety is 0.02 kg/day (0.04 lbs/day) for Herrin Old Reservoir.

5.7.6 Reserve Capacity

This watershed is located in Williamson County, the population of which has increased by 8.3% between 2000 and 2010 (Stage 1 Report Section 2.6). In 2010, the U.S. Census Bureau estimated the Franklin County population at 66,357.

The Illinois Department of Public Health population projections (Shahidullah 2015) for Williamson County shows a slight population increase to 69,246 in the year 2025. Further, the Greater Egypt Regional Planning and Development Commission, referencing US Census Bureau projections, states that the population in the Greater Egypt 5-county area which includes Williamson County will be relatively steady (or slightly declining) through 2030 (GERPDC 2010).

A reserve capacity is not needed, due to the slight projected increase in population, and because, at this time IEPA is not aware of any increases in discharges from the existing point sources, or the establishment of future municipal or industrial point sources.

5.7.7 TMDL Summary

The total phosphorus TMDL for Herrin Old Reservoir, segment IL_RNZD, is presented in Table 5-17.

Table 5-17. Herrin Old Reservior IL_RNZD TMDL Summary

Allocation	Total Phosphorus Load kg/day (lbs/day)
Load Capacity (LC)	0.23 (0.51)
Wasteload Allocation (WLA)	Not applicable. There are no permitted dischargers in this watershed
Load Allocation (LA)	0.21 (0.46)
Margin of safety (10% of LC)	0.02 (0.05)

5.8 Johnston City (IL_RNZE) Total Phosphorus TMDL

5.8.1 Calculation of the Loading Capacity

The loading capacity for Johnston City Reservoir was determined by running the BATHTUB model repeatedly, reducing the tributary nutrient concentrations for each simulation until model results demonstrated attainment of the water quality objective. The maximum tributary concentration that results in compliance with water quality standards was used as the basis for determining the loading

capacity. The tributary concentration was then converted into a loading rate through multiplication with the tributary flow.

Initial BATHTUB load reduction simulations indicated that Johnston City Reservoir phosphorus concentrations would exceed the water quality standard regardless of the level of tributary load reduction, due to the elevated internal phosphorus loads from lake sediments. This internal phosphorus flux is expected to decrease in the future in response to external phosphorus load reductions, or in response to management actions to remove organic sediments from the lake, reverting back to more typical conditions. This reduction in future sediment phosphorus release was represented in the model by eliminating the additional internal sediment phosphorus source for future scenarios. The resulting load, with calibrated tributary concentrations and no additional sediment phosphorus load yields an average phosphorus load of 0.43 kg/day (0.95 lbs/day) and a concentration of 0.048 mg/L. This meets the phosphorus target of 0.05 mg/L, so reductions in the tributary loads are not necessary. Therefore, the loading capacity is equal to the current incoming loads of 0.43 kg/day (0.95 lbs/day).

5.8.2 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There are no point sources in the watershed, and therefore there is no wasteload allocation given for Johnston City Reservoir. The entire loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The loading capacity is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall phosphorus load. Given a loading capacity of 0.2 kg/day (0.44 lbs/day), and an explicit margin of safety of 10% (discussed below), the load allocation for Johnston City Reservoir of 0.18 kg/day (0.40 lbs/day).

5.8.3 Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events can transport significant quantities of nonpoint source loads to lake. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. This TMDL is based upon an annual period that takes into account both spring loads and summer water quality in order to effectively consider these critical conditions.

5.8.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The BATHTUB model used for this TMDL is designed to evaluate loads over a seasonal to annual averaging period. The annual loading analysis that was used is appropriate due to the facts that:

1. The analysis demonstrated that the TMDL could only attain water quality targets if a significant reduction was achieved in sediment phosphorus release.
2. There is a long response time between phosphorus loading and sediment response, typically on the order of several years (e.g. Chapra and Canale, 1991).

5.8.5 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the BATHTUB water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the watershed, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit total phosphorus load allocated to the margin of safety is 0.02 kg/day (0.04 lbs/day) for Johnston City Lake.

5.8.6 Reserve Capacity

This watershed is located in Williamson County, the population of which has increased by 8.3% between 2000 and 2010 (Stage 1 Report Section 2.6). In 2010, the U.S. Census Bureau estimated the Franklin County population at 66,357.

The Illinois Department of Public Health population projections (Shahidullah 2015) for Williamson County shows a slight population increase to 69,246 in the year 2025. Further, the Greater Egypt Regional Planning and Development Commission, referencing US Census Bureau projections, states that the population in the Greater Egypt 5-county area which includes Williamson County will be relatively steady (or slightly declining) through 2030 (GERPDC 2010).

A reserve capacity is not needed, due to the slight projected increase in population, and because, at this time IEPA is not aware of any increases in discharges from the existing point sources, or the establishment of future municipal or industrial point sources.

5.8.7 TMDL Summary

The total phosphorus TMDL for Johnston City Lake, segment IL_RNZE, is presented in Table 5-18.

Table 5-18. Johnston City Lake IL_RNZE TMDL Summary

Allocation	Total Phosphorus Load kg/day (lbs/day)
Load Capacity (LC)	0.48 (1.06)
Wasteload Allocation (WLA)	Not applicable. There are no permitted dischargers in this watershed
Load Allocation (LA)	0.43 (0.95)
Margin of safety (10% of LC)	0.05 (0.11)

5.9 Arrowhead (Williamson) (IL_RNZX) Total Phosphorus TMDL

5.9.1 Calculation of the Loading Capacity

The loading capacity for the Arrowhead (Williamson) Reservoir was determined by running the BATHTUB model repeatedly, reducing the tributary nutrient concentrations for each simulation until model results demonstrated attainment of the water quality objective. The maximum tributary concentration that results in compliance with water quality standards was used as the basis for determining the loading capacity. The tributary concentration was then converted into a loading rate through multiplication with the tributary flow.

Initial BATHTUB load reduction simulations indicated that Arrowhead (Williamson) Reservoir phosphorus concentrations would exceed the water quality standard regardless of the level of tributary load reduction, due to the elevated internal phosphorus loads from lake sediments. This internal phosphorus flux is expected to decrease in the future in response to external phosphorus load reductions and/or potential management actions (e.g. dredging organic sediments, alum treatment), reverting back to more typical conditions. This reduction in future sediment phosphorus release was represented in the model by eliminating the additional internal sediment phosphorus source for future scenarios. The resulting load, with calibrated tributary concentrations and no additional sediment phosphorus load yields an average phosphorus load of 0.11 kg/day (0.24 lbs/day) and a lake-wide average concentration of 0.049 mg/L. The predicted lake concentrations in the upstream model segments (Segment 2 and Segment 3) are 0.05 and 0.06 mg/l respectively. Therefore reductions in the tributary loads are necessary to meets the phosphorus target of 0.05 mg/L across the entire waterbody. The loading capacity was an average of 0.085 kg/day (0.19 lbs/day). This allowable load corresponds to an approximately 30% reduction from existing tributary loads.

5.9.2 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There are no point sources in the watershed, and therefore there is no wasteload allocation given for Arrowhead (Williamson) Reservoir. The entire loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The loading capacity is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall phosphorus load. Given a loading capacity of 0.085 kg/day (0.19 lbs/day), and an explicit margin of safety of 10% (discussed below), the load allocation for Arrowhead (Williamson) Reservoir of 0.076 kg/day (0.17 lbs/day).

5.9.3 Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events can transport significant quantities of nonpoint source loads to lake. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. This TMDL is based upon an annual period that takes into account both spring loads and summer water quality in order to effectively consider these critical conditions.

5.9.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The BATHTUB model used for this TMDL is designed to evaluate loads over a seasonal to annual averaging period. The annual loading analysis that was used is appropriate due to the facts that:

3. The analysis demonstrated that the TMDL could only attain water quality targets if a significant reduction was achieved in sediment phosphorus release.
4. There is a long response time between phosphorus loading and sediment response, typically on the order of several years (e.g. Chapra and Canale, 1991).

5.9.5 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the BATHTUB water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the watershed, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit total phosphorus load allocated to the margin of safety is 0.008 kg/day (0.02 lbs/day) for Arrowhead (Williamson) Reservoir.

5.9.6 Reserve Capacity

The Arrowhead (Williamson) Reservoir watershed is located in Williamson County, the population of which has increased by 8.3% between 2000 and 2010 (Stage 1 Report Section 2.6). In 2010, the U.S. Census Bureau estimated the Franklin County population at 66,357.

The Illinois Department of Public Health population projections (Shahidullah 2015) for Williamson County shows a slight population increase to 69,246 in the year 2025. Further, the Greater Egypt Regional Planning and Development Commission, referencing US Census Bureau projections, states that the population in the Greater Egypt 5-county area which includes Williamson County will be relatively steady (or slightly declining) through 2030 (GERPDC 2010).

A reserve capacity is not needed, due to the slight projected increase in population, and because, at this time IEPA is not aware of any increases in discharges from the existing point sources, or the establishment of future municipal or industrial point sources.

5.9.7 TMDL Summary

The total phosphorus TMDL for Arrowhead (Williamson) Reservoir, segment IL_RNZX, is presented in Table 5-19.

Table 5-19. Arrowhead (Williamson) IL_RNZX TMDL Summary

Allocation	Total Phosphorus Load kg/day (lbs/day)
Load Capacity (LC)	0.085 (0.19)
Wasteload Allocation (WLA)	Not applicable. There are no permitted dischargers in this watershed
Load Allocation (LA)	0.076 (0.17)
Margin of safety (10% of LC)	0.008 (0.02)

5.10 West Frankfort Old (IL_RNP) Total Phosphorus TMDL

Calculation of the Loading Capacity

The loading capacity for West Frankfort Old Reservoir was determined by running the BATHTUB model repeatedly, reducing the tributary nutrient concentrations for each simulation until model results demonstrated attainment of the water quality objective. The maximum tributary concentration that results in compliance with water quality standards was used as the basis for determining the loading capacity. The tributary concentration was then converted into a loading rate through multiplication with the tributary flow.

Initial BATHTUB load reduction simulations indicated that West Frankfort Old Reservoir phosphorus concentrations would exceed the water quality standard regardless of the level of tributary load reduction, due to the elevated internal phosphorus loads from lake sediments. This internal phosphorus flux is expected to decrease in the future in response to external phosphorus load reductions, reverting back to more typical conditions. This reduction in future sediment phosphorus release was represented in the model by eliminating the additional internal sediment phosphorus source for future scenarios. The resulting load, with calibrated tributary concentrations and no additional sediment phosphorus load yields an average phosphorus load of 1.99 kg/day (4.37 lbs/day) and a concentration of 0.11 mg/L. This exceeds the phosphorus target of 0.05 mg/L, so reductions in the tributary loads are necessary. The loading capacity was an average of 0.50 kg/day (1.09 lbs/day). This allowable load corresponds to an approximately 75% reduction from existing tributary loads.

5.10.1 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There are no point sources in the watershed, and therefore there is no wasteload allocation given for West Frankfort Old Reservoir. The entire loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The loading capacity is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall phosphorus load. Given a loading capacity of 0.50 kg/day (1.09 lbs/day), and an explicit margin of safety of 10% (discussed below), the load allocation for West Frankfort Old Reservoir of 0.45 kg/day (0.98 lbs/day).

5.10.2 Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events can transport significant quantities of nonpoint source loads to lake. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. This TMDL is based upon an annual period that takes into account both spring loads and summer water quality in order to effectively consider these critical conditions.

5.10.3 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The BATHTUB model used for this TMDL is designed to evaluate loads over a seasonal to annual averaging period. The annual loading analysis that was used is appropriate due to the facts that:

1. The analysis demonstrated that the TMDL could only attain water quality targets if a significant reduction was achieved in sediment phosphorus release.
2. There is a long response time between phosphorus loading and sediment response, typically on the order of several years (e.g. Chapra and Canale, 1991).

5.10.4 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the BATHTUB water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the watershed, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit total phosphorus load allocated to the margin of safety is 0.05 kg/day (0.11 lbs/day) for West Frankfort Old Reservoir.

5.10.5 Reserve Capacity

The West Frankfort Old Reservoir watershed is located in Franklin County, the population of which has increased by 1.4% between 2000 and 2010 (Stage 1 Report Section 2.6). In 2010, the U.S. Census Bureau estimated the Franklin County population at 39,570.

The Illinois Department of Public Health population projections (Shahidullah 2015) for Franklin County shows a slight population decline to 37,958 in the year 2025. Further, the Greater Egypt Regional Planning and Development Commission, referencing US Census Bureau projections, states that the population in the Greater Egypt 5-county area which includes Franklin County will be relatively steady (or slightly declining) through 2030 (GERPDC 2010).

A reserve capacity is not needed, due to the slight projected decrease in population, and because, at this time IEPA is not aware of any increases in discharges from the existing point sources, or the establishment of future municipal or industrial point sources.

5.10.6 TMDL Summary

The total phosphorus TMDL for West Frankfort Old Reservoir, segment IL_RNP, is presented in Table 5-20.

Table 5-20. West Frankfort Old IL_RNP TMDL Summary

Allocation	Total Phosphorus Load kg/day (lbs/day)
Load Capacity (LC)	0.50 (1.09)
Wasteload Allocation (WLA)	Not applicable. There are no permitted dischargers in this watershed
Load Allocation (LA)	0.45 (0.98)
Margin of safety (10% of LC)	0.05 (0.11)

5.11 West Frankfort New (IL_RNQ) Total Phosphorus TMDL

5.11.1 Calculation of the Loading Capacity

The loading capacity for West Frankfort New Reservoir was determined by running the BATHTUB model repeatedly, reducing the tributary nutrient concentrations for each simulation until model results demonstrated attainment of the water quality objective. The maximum tributary concentration that results in compliance with water quality standards was used as the basis for determining the loading capacity. The tributary concentration was then converted into a loading rate through multiplication with the tributary flow.

Initial BATHTUB load reduction simulations indicated that West Frankfort New Reservoir phosphorus concentrations would exceed the water quality standard regardless of the level of tributary load reduction, due to the elevated internal phosphorus loads from lake sediments. This internal phosphorus flux is expected to decrease in the future in response to external phosphorus load reductions or lake management actions, reverting back to more typical conditions. This reduction in future sediment phosphorus release was represented in the model by eliminating the additional internal sediment phosphorus source for future scenarios. The resulting load, with calibrated tributary and Thompsonville STP concentrations and no additional sediment phosphorus load yields an average phosphorus load of 3.63 kg/day (7.99 lbs/day) and a concentration of 0.104 mg/L. This exceeds the phosphorus target of 0.05 mg/L, so reductions in the tributary loads are necessary. The loading capacity calculated was an average of 0.91 kg/day (2.0 lbs/day). This allowable load corresponds to an approximately 75% reduction from existing loads, estimated as 3.68 kg/day (8.11 lbs/day).

5.11.2 Allocation

A TMDL consists of a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and a margin of safety (MOS). This definition is typically illustrated by the following equation:

$$TMDL = WLA + LA + MOS$$

There is a single point sources in the watershed from the Thompsonville STP (IL0072478). The current treatment at this facility consists of two cell aerated lagoon and a rock filter. These treatment processes are not capable of removing significant amount of total phosphorus from the effluent. The design average flow (DAF) for the facility is 0.08 million gallons per day (MGD) and the design maximum flow (DMF) for the facility is 0.20 MGD.

The average daily flows from this STP reported in the DMRs from 2008 through 2016 0.087 MGD. There is no water quality data for total phosphorus from this point source to use for model calibration. In estimating the existing phosphorus load from this facility, a total phosphorus concentration in the STP effluent was assumed to be 3.66 mg/L. The resulting average load from the Thompsonville STP is 1.20 kg/day (2.64 lb/day). This load along is higher than the loading capacity of the reservoir, so reductions will be necessary to meet the water quality standards. The WLA for this facility was developed based on the DAF, and a target effluent concentration of 1.0 mg/L. This results in an average WLA of 0.30 kg/day (0.67 lb/day), which represents a 74.6% reduction from the estimated current load.

The remaining loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The load allocation for nonpoint sources is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the

contributions of specific sources to the overall phosphorus load. Given a total loading capacity of 0.91 kg/day (2.0 lbs/day), a WLA for the Thompsonville STP of 0.30 kg/day (0.72 lb/day), and an explicit margin of safety of 10% (discussed below), the load allocation for West Frankfort New Reservoir is 0.52 kg/day (1.15 lbs/day). This represents a reduction of approximately 79% of the watershed nonpoint sources from the existing loads.

5.11.3 Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events can transport significant quantities of nonpoint source loads to lake. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. This TMDL is based upon an annual period that takes into account both spring loads and summer water quality in order to effectively consider these critical conditions.

5.11.4 Seasonality

This TMDL was conducted with an explicit consideration of seasonal variation. The BATHTUB model used for this TMDL is designed to evaluate loads over a seasonal to annual averaging period. The annual loading analysis that was used is appropriate due to the facts that:

1. The analysis demonstrated that the TMDL could only attain water quality targets if a significant reduction was achieved in sediment phosphorus release.
2. There is a long response time between phosphorus loading and sediment response, typically on the order of several years (e.g. Chapra and Canale, 1991).

5.11.5 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the BATHTUB water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the watershed, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit total phosphorus load allocated to the margin of safety is 0.09 kg/day (0.2 lbs/day) for West Frankfort New Reservoir.

5.11.6 Reserve Capacity

This watershed is located in Franklin County, the population of which has increased by 1.4% between 2000 and 2010 (Stage 1 Report Section 2.6). In 2010, the U.S. Census Bureau estimated the Franklin County population at 39,570.

The Illinois Department of Public Health population projections (Shahidullah 2015) for Franklin County shows a slight population decline to 37,958 in the year 2025. Further, the Greater Egypt Regional Planning and Development Commission, referencing US Census Bureau projections, states that the population in the Greater Egypt 5-county area which includes Franklin County will be relatively steady (or slightly declining) through 2030 (GERPDC 2010).

A reserve capacity is not needed, due to the slight projected decrease in population, and because, at this time IEPA is not aware of any increases in discharges from the existing point sources, or the establishment of future municipal or industrial point sources.

5.11.7 TMDL Summary

The total phosphorus TMDL for West Frankfort New Reservoir, segment IL_RNQ, is presented in Table 5-21.

Table 5-21. West Frankfort New Reservoir IL_RNQ TMDL Summary

Allocation	Total Phosphorus Load kg/day (lbs/day)
Load Capacity (LC)	0.91 (2.01)
Wasteload Allocation (WLA)	0.30 (0.67)
Load Allocation (LA)	0.52 (1.15)
Margin of safety (10% of LC)	0.09 (0.20)

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6 LRS Development

This section presents the development of the total suspended solids Load Reduction Strategy for 5 streams in the Upper Big Muddy River watershed. IEPA requires a LRS to identify the load capacity, and the percentage reduction needed.

6.1 TSS Load Reduction Strategy - Streams

The load capacity was calculated by multiplying the total suspended solids concentration of 32.2 mg/L by the average annual 2015 Upper Big Muddy River flows estimated using a drainage area ratio approach and USGS measured flows for Upper Big Muddy River at Browns, IL (Gage 03378000). The percent reduction was calculated by comparing the average TSS concentrations for the monitoring stations located on the segment calculated from the full record of measured total suspended solids concentrations (Attachment 1 and Attachment 2) to the LRS target concentration.

Table 6-1 presents the TSS LRSs for all of the waterbodies in the Upper Big Muddy River watershed.

Table 6-1. Total Suspended Solids LRS

Stream (Segment ID)	Monitoring Station(s)	Target (mg/L)	Average Concentration (mg/L)	Current load (lbs/day)	Load capacity (lbs/day)	Percent Reduction
Big Muddy R. (IL_N-06)	N-06	32.2	43.7	16,148	11,910	26.2%
Big Muddy R. (IL_N-11)	N-11	32.2	53.0	31,932	19,395	39.3%
Big Muddy R. (IL_N-17)	N-17	32.2	110.3	27,108	7,911	70.8%
Pond Cr. (IL_NG-02)	NG-02	32.2	86.3	39,449	14,721	62.7%
M. Fk. Big Muddy (IL_NH-07)	NH-07, NH-08, NH-21	32.2	72.3	53,894	23,992	55.5%

7 Reasonable Assurances

Documenting adequate reasonable assurance increases the probability that regulatory and voluntary mechanisms will achieve pollution reduction levels specified in the TMDL and that the applicable WQS are attained.

The Illinois EPA NPDES regulatory program and the issuance of an NPDES permit provide the reasonable assurance that the WLAs in the TMDL will be achieved. That is because federal regulations implementing the CWA require that effluent limits in permits be consistent with "the assumptions and requirements of any available [WLA]" in an approved TMDL [40 CFR 122.44(d)(1)(vii)(B)]. For point sources, Illinois EPA administers the NPDES permitting program for wastewater treatment plants, MS4s and CAFOs. Wasteload allocations in the TMDL report will be included in the appropriate NPDES permits when permits are renewed.

For TMDLs for waters impaired by both point and nonpoint sources, determinations of reasonable assurance that the TMDLs load allocations will be achieved include whether practices capable of reducing the specified pollutant load exist, are technically feasible, and have a high likelihood of implementation. The nonpoint source load reductions can and will be achieved when there are good management practices and programs (technical and funding mechanisms) to assist in achieving good management practices. The Watershed Implementation Plan for the TMDLs contained in this report identifies practices that are capable of reducing the pollutant loads to the TMDL endpoints, and potential funding mechanisms for implementation.

For nonpoint sources, the primary strategy for reduction for attaining water quality standards in the Upper Big Muddy River watershed is to implement BMPs to reduce and treat agricultural and urban stormwater runoff, along with the use of in-stream restoration practices. This strategy relies on voluntary actions that includes accountability. Educational efforts and cost sharing programs are intended to achieve participation levels sufficient to attain water quality standards and meet the designated uses. An important key to the success of a TMDL program, in terms of engaging the public, is building linkages to other programs, such as nonpoint source management practices.

In rural areas many homes, businesses, and schools do not have access to central sewage disposal systems. County and local health departments operate sewage and water programs to assure that sewage and water systems are designed according to code so that neither the public health nor the environment is jeopardized. The counties and local health departments issue licenses and provide training to contractors, inspect and license pumper trucks, review sewage system applications, issue construction permits, assist in the design of sewage disposal systems, inspect new sewage disposal systems, investigate complaints, and carry out enforcement activities based upon county ordinances. These activities help to eliminate the discharge of raw sewage and reduce the bacterial contamination within the Upper Big Muddy River watershed.

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8 Public Participation and Involvement

[This section will be filled in following the public meeting]

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Attachment 1: Stage 1 Report









Attachment 2. 2015 IEPA Stage 2 Monitoring Data
2015 Upper Big Muddy River Watershed Data

Attachment 3:

QUAL2E Model Files
Calibration input
Calibration output

Attachment 4: BATHTUB Model Files

Herrin Old / IL_RNZD
- Calibration input
- Calibration output

Johnston City / IL_RNZE
- Calibration input
- Calibration output

Arrowhead (Williamson) / IL_RNZX
- Calibration input
- Calibration output

West Frankfort Old / IL_RNP
- Calibration input
- Calibration output

West Frankfort New/ IL_RNQ
- Calibration input
- Calibration output

Attachment 5: Load Duration Curve Analysis

IL_N-11 Fecal Coliform LDC
IL_NZN-13 Iron LDC
IL_NG-02 Chloride LDC
IL_NGAZ-JC-D1 Manganese LDC
IL_NH-06 Fecal Coliform LDC

Big Muddy Fish Data

Water body		Total	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date			1975JUL28	1964JUL02	1975JUL28	1988AUG17	1995AUG01
Station code			N-04	N-11	N-11	N-11	N-11
Species		50	18	15	21	15	19
Non-native proportion		0.06	0.17	0.06	0.36	0.36	0.11
Total fish		1612	199	384	107	83	117
Electrode minutes			60		60	60	60
Paddlefish	Polyodon spathula	1	1				
Shortnose gar	Lepisosteus platostomus	23			4	1	1
Longnose gar	Lepisosteus osseus	6			1		
Spotted gar	Lepisosteus oculatus	8	2			1	
Bowfin	Amia calva	6			4	1	
Gizzard shad	Dorosoma cepedianum	299	102	7	28	4	35
Goldeye	Hiodon alosoides	14	7		1		1
Grass pickerel	Esox americanus	2			1		
Silver carp	Hypophthalmichthys molitrix	3					
Carp	Cyprinus carpio	157	33	10	39	30	13
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)	148		148			
Silvery minnow	Hybognathus nuchalis	3					1
Redfin shiner	Lythrurus umbratilus	1			1		
Ribbon shiner	Lythrurus fumeus	5					
Red shiner	Cyprinella lutrensis	172	1		1		20
Bluntnose minnow	Pimephales notatus	4					
Bullhead minnow	Pimephales vigilax	21					1
Emerald shiner	Notropis atherinoides	10					
Sand shiner	Notropis ludibundus	1					
Bigmouth buffalo	Ictiobus cyprinellus	18	8		5		
Smallmouth buffalo	Ictiobus bubalus	111	1		4	3	6
Black buffalo	Ictiobus niger	5					
River carpsucker	Carpiodes carpio	14	1			1	
Creek chubsucker	Erimyzon oblongus	1					
River redhorse *T*	Moxostoma carinatum	1				1	
Shorthead redhorse	Moxostoma macrolepidotum	3				1	1
Channel catfish	Ictalurus punctatus	34	1	7	2	7	3
Blue catfish	Ictalurus furcatus	1					
Yellow bullhead	Ameiurus natalis	4		4			
Black bullhead	Ameiurus melas	3					
Flathead catfish	Pylodictis olivaris	8					2
Madtom spp.	Noturus spp.	61		61			
Pirate perch	Aphredoderus sayanus	5		4			
Blackstripe topminnow	Fundulus notatus	5					
Blackspotted topminnow	Fundulus olivaceus	1					
Mosquitofish	Gambusia affinis	1					
Brook silverside	Labidesthes sicculus	17			1		
White bass	Morone chrysops	5			1		1
Yellow bass	Morone mississippiensis	10					
Black crappie	Pomoxis nigromaculatus	32	5	14	3		
White crappie	Pomoxis annularis	34	5	7	1	3	4
Largemouth bass	Micropterus salmoides	16	6	1	2		4
Spotted bass	Micropterus punctulatus	19					7
Warmouth	Lepomis gulosus	26	9	7	2	2	
Green sunfish	Lepomis cyanellus	5		3			1
Bluegill	Lepomis macrochirus	49	6	11	3	8	1
Redear sunfish	Lepomis microlophus	1	1				
Longear sunfish	Lepomis megalotis	110	7	55	2	6	9
Orangespotted sunfish	Lepomis humilis	47		40	1		
Walleye	Stizostedion vitreum	1		1			
River darter	Percina shumardi	1					
Freshwater drum	Aplodinotus grunniens	79	3	4		14	6
	Total		199	384	107	83	117

Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
2000SEP06	2003JUL29	2008AUG20	2018JUL25
N-11	N-11	N-11	N-11
17	32	27	17
0.07	0.06	0.02	0.06
158	172	296	96
90	60	60	60
1	9	1	6
			5
		3	2
	1		
32	20	62	9
1	4		
		1	
		3	
11	11	4	6
	2		
	5		
53	39	54	4
4			
	5	13	2
2		6	2
	1		
3	1		1
19	12	33	33
		2	3
		2	10
	1		
	1		
	6	4	4
	1		
	3		
1	1	3	1
		1	
	2	3	
	1		
	1		
13	1	2	
2	1		
1		9	
1	1	8	
	2	12	
	3		
2	8	2	
	1	5	
		1	
3	2	14	1
	5	25	1
		6	
	1		
9	20	17	6
158	172	296	96

Water body		Total	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date			1975JUL28	1995JUL26	2000JUL17	2003JUL07
Station code			N-04	N-05	N-05	N-05
Species		92	18	21	16	20
Non-native proportion		0.04	0.17	0.01	0.04	
Total fish		42758	199	150	77	121
Electrode minutes			60	28	35.9	25.1
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula	47	1			
Shortnose gar	Lepisosteus platostomus	352				
Longnose gar	Lepisosteus osseus	99				
Spotted gar	Lepisosteus oculatus	84	2			
Bowfin	Amia calva	150				
Skipjack herring	Alosa chrysochloris	3				
Shad spp.	Dorosoma spp.	120				
Gizzard shad	Dorosoma cepedianum	4208	102			
Threadfin shad	Dorosoma petenense	44				
Goldeye	Hiodon alosoides	61	7			
Mooneye	Hiodon tergisus	1				
Grass pickerel	Esox americanus	332		9		
Grass carp	Ctenopharyngodon idella	25				
Bighead carp	Aristichthys nobilis	5				
Silver carp	Hypophthalmichthys molitrix	345				
Goldfish	Carassius auratus	4				
Carp	Cyprinus carpio	2392	33	2	3	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)	2744				
Golden shiner	Notemigonus crysoleucas	220		1	1	3
Creek chub	Semotilus atromaculatus	753				6
Central stoneroller	Campostoma anomalum	402				
Suckermouth minnow	Phenacobius mirabilis	29				
Blacknose dace	Rhinichthys atratulus	163				
Silver chub	Macrhybopsis storeriana	1				
Silvery minnow	Hybognathus nuchalis	416				
Redfin shiner	Lythrurus umbratilus	715		4		6
Ribbon shiner	Lythrurus fumeus	41				
Spotfin shiner	Cyprinella spiloptera	1				
Blacktail shiner	Cyprinella venusta	2				
Red shiner	Cyprinella lutrensis	1260	1			3
Pugnose minnow	Opsopoeodus emiliae	5				
Fathead minnow	Pimephales promelas	142				
Bluntnose minnow	Pimephales notatus	1933		32	1	4
Bullhead minnow	Pimephales vigilax	155				
Emerald shiner	Notropis atherinoides	219				
River shiner	Notropis blennius	1				
Sand shiner	Notropis ludibundus	464				
Mimic shiner	Notropis volucellus	35				
Channel shiner	Notropis wickliffi	51				
Bigmouth buffalo	Ictiobus cyprinellus	641	8			
Smallmouth buffalo	Ictiobus bubalus	721	1			
Black buffalo	Ictiobus niger	87				
Unidentified Carpsucker	Carpiodes sp.	2				
Quillback	Carpiodes cyprinus	9				
River carpsucker	Carpiodes carpio	107	1			
Highfin carpsucker	Carpiodes velifer	1				
White sucker	Catostomus commersoni	480		1		1
Spotted sucker	Minytrema melanops	104				
Creek chubsucker	Erimyzon oblongus	666		5	4	2
River redhorse *T*	Moxostoma carinatum	1				
Shorthead redhorse	Moxostoma macrolepidotum	7				
Golden redhorse	Moxostoma erythrurum	35				
Channel catfish	Ictalurus punctatus	717	1			
Blue catfish	Ictalurus furcatus	15				
Yellow bullhead	Ameiurus natalis	420				2
Black bullhead	Ameiurus melas	24				
Brown bullhead	Ameiurus nebulosus	1				
Flathead catfish	Pylodictis olivaris	194				
Madtom spp.	Noturus spp.	317				
Tadpole madtom	Noturus gyrinus	84		1	1	1
Freckled madtom	Noturus nocturnus	7				
Pirate perch	Aphredoderus sayanus	828			12	9
Blackstripe topminnow	Fundulus notatus	979		1	1	2
Blackspotted topminnow	Fundulus olivaceus	532		17	10	5
Mosquitofish	Gambusia affinis	896				
Brook silverside	Labidesthes sicculus	252				
Inland silversides	Menidia beryllina	14				
Mississippi silversides	Menidia beryllina	1				
Striped bass	Morone saxatilis	1				
White bass	Morone chrysops	154				

Water body		Total	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date			1975JUL28	1995JUL26	2000JUL17	2003JUL07
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops	3				
Yellow bass	Morone mississippiensis	36				
Flier	Centrarchus macropterus	93				
Black crappie	Pomoxis nigromaculatus	360	5			
Blacknose crappie	Pomoxis migromaculatus	5				
White crappie	Pomoxis annularis	510	5	2		1
Largemouth bass	Micropterus salmoides	1142	6	3	6	5
Spotted bass	Micropterus punctulatus	165				
Warmouth	Lepomis gulosus	590	9	2	1	3
Green sunfish	Lepomis cyanellus	2281		35	18	17
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus	2				
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus	38		1	1	
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus	12				
Bluegill	Lepomis macrochirus	5053	6	14	2	37
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus	1				
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus	4				
Redear sunfish	Lepomis microlophus	102	1			
Longear sunfish	Lepomis megalotis	3378	7	15	5	12
Orangespotted sunfish	Lepomis humilis	796				1
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	106				
Walleye	Stizostedion vitreum	5				
Sauger	Stizostedion canadense	2				
Blackside darter	Percina maculata	19		1	1	
Dusky darter	Percina sciera	2				
River darter	Percina shumardi	2				
Logperch	Percina caprodes	43				
Johnny darter	Etheostoma nigrum	318		1	9	
Bluntnose darter	Etheostoma chlorosomum	26				
Mud darter	Etheostoma asprigene	35		1		
Orangethroat darter	Etheostoma spectabile	90				
Spottail darter	Etheostoma squamiceps	7				
Slough darter	Etheostoma gracile	341		1	1	
Freshwater drum	Aplodinotus grunniens	870	3	1		1

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2008JUN17	2013AUG05	1975JUL24	1978JUL12	1980JUL08
Station code		N-05	N-05	N-06	N-06	N-06
Species		25	18	16	17	18
Non-native proportion		0.01		0.48	0.38	0.24
Total fish		158	76	211	187	171
Electrode minutes		22	26.83	60		60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula			1		
Shortnose gar	Lepisosteus platostomus			1	4	1
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					1
Bowfin	Amia calva			2		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		1	22	38	57
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides			3		1
Mooneye	Hiodon tergisus				1	
Grass pickerel	Esox americanus	3	5			
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	1		102	71	41
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas	10				
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	18				
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	1		4	11	12
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	10				1
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus			29	21	8
Smallmouth buffalo	Ictiobus bubalus	1		5	1	7
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio				3	2
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	2	1			
Spotted sucker	Minytrema melanops	9	2			
Creek chubsucker	Erimyzon oblongus	15				
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					1
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	1	1			
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris				2	
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus	2	1			
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	1	3			
Blackstripe topminnow	Fundulus notatus	11	15			
Blackspotted topminnow	Fundulus olivaceus	11	5			
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus				1	3
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops				1	

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2008JUN17	2013AUG05	1975JUL24	1978JUL12	1980JUL08
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus		1			
Black crappie	Pomoxis nigromaculatus			4	1	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	1		2	4	3
Largemouth bass	Micropterus salmoides	1	8	4	9	9
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	2	3	1		
Green sunfish	Lepomis cyanellus	22	5			
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	8	9	20	10	12
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus	1				
Longear sunfish	Lepomis megalotis	20	12	7	4	5
Orangespotted sunfish	Lepomis humilis	5				6
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum		2			
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	1	1			
Freshwater drum	Aplodinotus grunniens	1		4	5	1

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1988AUG15	1990JUL10	1992JUL17	1994AUG01	1995AUG01
Station code		N-06	N-06	N-06	N-06	N-06
Species		18	16	16	20	22
Non-native proportion		0.22	0.25	0.15	0.18	0.18
Total fish		200	55	40	275	176
Electrode minutes		60	60	60		60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	4	1			2
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus	1				
Bowfin	Amia calva	1				3
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	14	8	2	85	19
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides		1		5	4
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		1			
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	44	14	6	50	31
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	12	12	1		17
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					1
Bullhead minnow	Pimephales vigilax	3				1
Emerald shiner	Notropis atherinoides		1			
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	19		5	13	7
Smallmouth buffalo	Ictiobus bubalus	14	5	3	45	21
Black buffalo	Ictiobus niger		1	3	4	
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio			1		
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	1	1	3	4	1
Blue catfish	Ictalurus furcatus				1	
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	1	1	2	2	
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					
Blackstripe topminnow	Fundulus notatus					1
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus					3
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops			1	2	1

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1988AUG15	1990JUL10	1992JUL17	1994AUG01	1995AUG01
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis		1			
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus				4	
Blacknose crappie	Pomoxis nigromaculatus					
White crappie	Pomoxis annularis	12	3	2	6	11
Largemouth bass	Micropterus salmoides			1	1	2
Spotted bass	Micropterus punctulatus	6	2	4	10	10
Warmouth	Lepomis gulosus	5			7	2
Green sunfish	Lepomis cyanellus				1	1
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	27		2	6	21
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	27	2	1	23	6
Orangespotted sunfish	Lepomis humilis	1			1	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	8	1	3	5	11

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1998AUG20	2000SEP22	2003JUL10	2008AUG20	1964JUL10
Station code		N-06	N-06	N-06	N-06	N-07
Species		30	25	25	28	9
Non-native proportion		0.24	0.07	0.08	0.04	
Total fish		136	167	203	277	424
Electrode minutes		60	60	60	60	
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1	3	4	2	1
Longnose gar	Lepisosteus osseus	2			1	
Spotted gar	Lepisosteus oculatus	2	2		3	
Bowfin	Amia calva	1	1		2	
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	17	12	33	89	25
Threadfin shad	Dorosoma petenense			6		
Goldeye	Hiodon alosoides	1		1		
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus				1	
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	18	11	10	10	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					243
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	2		5		
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus	3		13		
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta				2	
Red shiner	Cyprinella lutrensis	2	23	21	45	
Pugnose minnow	Opsopoeodus emiliae	1				
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		1			
Bullhead minnow	Pimephales vigilax	1		1		
Emerald shiner	Notropis atherinoides		1		7	
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus	2				
Channel shiner	Notropis wickliffi			13		
Bigmouth buffalo	Ictiobus cyprinellus	4	4	3	2	
Smallmouth buffalo	Ictiobus bubalus	8	32	12	18	
Black buffalo	Ictiobus niger		1	2	5	
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio	3	1		4	
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum			1		
Channel catfish	Ictalurus punctatus	1		1	4	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					2
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris				1	
Madtom spp.	Noturus spp.					5
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus			1		1
Blackstripe topminnow	Fundulus notatus	4	2			
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus	9	38		21	
Inland silversides	Menidia beryllina	14				
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops	1		7	1	

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1998AUG20	2000SEP22	2003JUL10	2008AUG20	1964JUL10
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis	2	1		2	
Flier	Centrarchus macropterus					1
Black crappie	Pomoxis nigromaculatus		1	3	4	1
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	4	1	6	3	2
Largemouth bass	Micropterus salmoides	4	1	5	6	
Spotted bass	Micropterus punctulatus	10	7	13	4	
Warmouth	Lepomis gulosus	1	3		2	
Green sunfish	Lepomis cyanellus	1	5			
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	12	10	34	11	
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	2	3	4	9	
Orangespotted sunfish	Lepomis humilis		2			127
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid			1	1	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera				1	
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene			1		
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	3	1	2	16	16

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1964JUL03	1975JUL24	1964JUL02	1975JUL28	1988AUG17
Station code		N-08	N-10	N-11	N-11	N-11
Species		9	20	15	21	15
Non-native proportion		0.06	0.11	0.06	0.36	0.36
Total fish		158	316	384	107	83
Electrode minutes			60		60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus		2		4	1
Longnose gar	Lepisosteus osseus				1	
Spotted gar	Lepisosteus oculatus					1
Bowfin	Amia calva	1	4		4	1
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		136	7	28	4
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides		4		1	
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus				1	
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus		1			
Carp	Cyprinus carpio	4	35	10	39	30
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)	83		148		
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus				1	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis				1	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		1			
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		20		5	
Smallmouth buffalo	Ictiobus bubalus				4	3
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					1
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	3				
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					1
Shorthead redhorse	Moxostoma macrolepidotum					1
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		1	7	2	7
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis		1	4		
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.	10		61		
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	16		4		
Blackstripe topminnow	Fundulus notatus					
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus				1	
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops		2		1	

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1964JUL03	1975JUL24	1964JUL02	1975JUL28	1988AUG17
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississipplensis		1			
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		26	14	3	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	1	22	7	1	3
Largemouth bass	Micropterus salmoides		17	1	2	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	3	2	7	2	2
Green sunfish	Lepomis cyanellus	20		3		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	5	22	11	3	8
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus		3			
Longear sunfish	Lepomis megalotis	12	8	55	2	6
Orangespotted sunfish	Lepomis humilis			40	1	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum			1		
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens		8	4		14

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1995AUG01	2000SEP06	2003JUL29	2008AUG20	1988AUG16
Station code		N-11	N-11	N-11	N-11	N-12
Species		19	17	32	27	20
Non-native proportion		0.11	0.07	0.06	0.02	0.11
Total fish		117	158	172	296	97
Electrode minutes		60	90	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1	1	9	1	3
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus				3	
Bowfin	Amia calva			1		2
Skipjack herring	Alosa chrysochloris					
Shad spp	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	35	32	20	62	24
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides	1	1	4		
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus				1	2
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix				3	
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	13	11	11	4	11
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	1		2		
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus			5		
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	20	53	39	54	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		4			
Bullhead minnow	Pimephales vigilax	1		5	13	
Emerald shiner	Notropis atherinoides		2		6	
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus			1		
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		3	1		1
Smallmouth buffalo	Ictiobus bubalus	6	19	12	33	1
Black buffalo	Ictiobus niger				2	1
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio				2	2
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus			1		
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum	1		1		
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	3		6	4	8
Blue catfish	Ictalurus furcatus			1		
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas			3		
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	2	1	1	3	4
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus				1	
Blackstripe topminnow	Fundulus notatus			2	3	
Blackspotted topminnow	Fundulus olivaceus			1		
Mosquitofish	Gambusia affinis			1		
Brook silverside	Labidesthes sicculus		13	1	2	1
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops	1	2	1		1

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1995AUG01	2000SEP06	2003JUL29	2008AUG20	1988AUG16
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis		1		9	
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		1	1	8	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	4		2	12	1
Largemouth bass	Micropterus salmoides	4		3		1
Spotted bass	Micropterus punctulatus	7	2	8	2	
Warmouth	Lepomis gulosus			1	5	
Green sunfish	Lepomis cyanellus	1			1	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	1	3	2	14	10
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	9		5	25	6
Orangespotted sunfish	Lepomis humilis				6	11
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					1
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi			1		
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	6	9	20	17	6

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1992AUG17	1994AUG09	1995AUG02	1998SEP08	2000SEP06
Station code		N-12	N-12	N-12	N-12	N-12
Species		11	15	21	17	19
Non-native proportion		0.22	0.21	0.11	0.33	0.14
Total fish		36	76	163	123	136
Electrode minutes		60	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus		4	2	2	4
Longnose gar	Lepisosteus osseus	3	1		3	
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva		7	2	6	1
Skipjack herring	Alosa chrysochloris		1			
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		20	66	36	29
Threadfin shad	Dorosoma petenense				12	
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	8	16	18	28	19
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis			3		10
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					4
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					12
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					1
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	1		2	5	6
Smallmouth buffalo	Ictiobus bubalus	1	9	3	6	6
Black buffalo	Ictiobus niger		1			
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus				1	
River carpsucker	Carpiodes carpio	2	1		3	4
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	8	3		4	6
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	5	3	3	4	6
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					
Blackstripe topminnow	Fundulus notatus			2		1
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis			1		
Brook silverside	Labidesthes sicculus					6
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops		2	2	2	4

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1992AUG17	1994AUG09	1995AUG02	1998SEP08	2000SEP06
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		1	1		
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis			2	1	
Largemouth bass	Micropterus salmoides			12	1	
Spotted bass	Micropterus punctulatus			2		
Warmouth	Lepomis gulosus			1		
Green sunfish	Lepomis cyanellus			1		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	1	5	30	1	2
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	2		3		
Orangespotted sunfish	Lepomis humilis	1		1		2
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	4	2	6	8	13

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2003JUL29	2008AUG26	2011AUG18	2012OCT29	2013AUG06
Station code		N-12	N-12	N-12	N-12	N-12
Species		24	27	26	29	29
Non-native proportion		0.08	0.03	0.06	0.11	0.11
Total fish		143	407	287	249	240
Electrode minutes		60	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	7	1	4	7	24
Longnose gar	Lepisosteus osseus	2		8	1	24
Spotted gar	Lepisosteus oculatus	1	3	2	1	
Bowfin	Amia calva	2	1	1	1	
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	41	170	156	4	19
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides	1		1	2	4
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella				10	1
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix		1	5	3	9
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	11	10	13	15	16
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	8				
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	26	19	1	25	34
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					1
Bullhead minnow	Pimephales vigilax	2	2	1	14	8
Emerald shiner	Notropis atherinoides	4	19		9	7
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus			2		1
Mimic shiner	Notropis volucellus				28	1
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		2	6	21	9
Smallmouth buffalo	Ictiobus bubalus	7	13	11	18	30
Black buffalo	Ictiobus niger	1		2	6	1
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus				1	
River carpsucker	Carpiodes carpio					2
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum	2				
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	8	4	4	25	8
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis		1			
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	1	5	6	1	4
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					
Blackstripe topminnow	Fundulus notatus		14			
Blackspotted topminnow	Fundulus olivaceus				4	
Mosquitofish	Gambusia affinis	1				
Brook silverside	Labidesthes sicculus		20			2
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops	1	7	8	1	2

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2003JUL29	2008AUG26	2011AUG18	2012OCT29	2013AUG06
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		4	5		1
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	1	2	10	5	1
Largemouth bass	Micropterus salmoides	2	9	3	1	
Spotted bass	Micropterus punctulatus			5	1	3
Warmouth	Lepomis gulosus		7		1	
Green sunfish	Lepomis cyanellus		1			1
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	2	23	21	2	2
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus			1		
Longear sunfish	Lepomis megalotis		10	6	36	11
Orangespotted sunfish	Lepomis humilis	1	33	1	1	3
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid		1			
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi	1				
Logperch	Percina caprodes		1			
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	10	24	4	5	11

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2014SEP24	1975AUG06	1975AUG05	1975JUL30	1988AUG16
Station code		N-12	N-13	N-15	N-16	N-16
Species		20	14	18	19	16
Non-native proportion		0.02	0.34	0.34	0.4	0.34
Total fish		180	192	169	148	106
Electrode minutes		60	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	5	5	1		1
Longnose gar	Lepisosteus osseus	1			1	
Spotted gar	Lepisosteus oculatus				1	
Bowfin	Amia calva	1	1	2		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	72	28	26	20	9
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides				3	
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix	3				
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	1	66	57	59	36
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera	1				
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	49				3
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax	5				4
Emerald shiner	Notropis atherinoides	18				
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	2	1	6	4	3
Smallmouth buffalo	Ictiobus bubalus		1	4	1	4
Black buffalo	Ictiobus niger					1
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio	2		2	1	2
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum	1				
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	2	2	7	2	5
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris				2	6
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					
Blackstripe topminnow	Fundulus notatus	5				
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis	1				
Brook silverside	Labidesthes sicculus	1		3		
Inland silversides	Menidia beryllina					
Mississippi silverside	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops				1	

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2014SEP24	1975AUG06	1975AUG05	1975JUL30	1988AUG16
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis			1	1	
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		6	10	3	
Blacknose crapple	Pomoxis migromaculatus					
White crapple	Pomoxis annularis		1	11	18	1
Largemouth bass	Micropterus salmoides		23	1	3	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus				4	1
Green sunfish	Lepomis cyanellus			1		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus		20	15	16	12
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus		1			
Longear sunfish	Lepomis megalotis	4	5	12	2	2
Orangespotted sunfish	Lepomis humilis	1		1		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	5	32	9	6	16

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2003JUL17	1975JUL29	1988AUG17	1995AUG03	2003JUL16
Station code		N-16	N-17	N-17	N-17	N-17
Species		25	13	20	17	20
Non-native proportion		0.01	0.26	0.24	0.16	0.03
Total fish		197	147	132	167	76
Electrode minutes		58	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	2		2		3
Longnose gar	Lepisosteus osseus					1
Spotted gar	Lepisosteus oculatus		1	1		1
Bowfin	Amia calva	3	1		1	1
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	54	42	20	75	16
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides		4		1	
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	2	38	32	27	2
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	12				7
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					1
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	48		3	1	24
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax	14			4	2
Emerald shiner	Notropis atherinoides		1			
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi	1				
Bigmouth buffalo	Ictiobus cyprinellus	1	9	2		
Smallmouth buffalo	Ictiobus bubalus			2	7	3
Black buffalo	Ictiobus niger	1				1
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio				1	
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	2	4	3	2	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	5		3	3	
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	2				
Blackstripe topminnow	Fundulus notatus	1		1		
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis	3		1		
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina	1				
Striped bass	Morone saxatilis					
White bass	Morone chrysops	1				2

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2003JUL17	1975JUL29	1988AUG17	1995AUG03	2003JUL16
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops				1	
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus	1	15	1	2	1
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis		19	2	2	1
Largemouth bass	Micropterus salmoides	5	2	2	9	1
Spotted bass	Micropterus punctulatus				1	1
Warmouth	Lepomis gulosus			2	1	1
Green sunfish	Lepomis cyanellus			2		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	10	5	25	19	3
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	2		12		
Orangespotted sunfish	Lepomis humilis	5		1		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes	1				
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene	3				
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	17	6	15	10	4

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1975JUL29	1975JUL25	1975AUG12	1988AUG17	2011SEP20
Station code		N-18	N-20	N-23	N-23	N-23
Species		16	15	17	16	23
Non-native proportion		0.15	0.29	0.34	0.24	0.04
Total fish		137	90	136	87	224
Electrode minutes		60	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula			2		1
Shortnose gar	Lepisosteus platostomus		1	1	6	10
Longnose gar	Lepisosteus osseus			1	1	6
Spotted gar	Lepisosteus oculatus					7
Bowfin	Amia calva	2			1	2
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	14	32	26	5	17
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides	1	4			
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella			1		
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					7
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	20	26	45	21	2
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		5		1	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax				1	
Emerald shiner	Notropis atherinoides		2			
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	12	4	11	9	14
Smallmouth buffalo	Ictiobus bubalus	4		1	1	16
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio	1		3	5	1
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse "T"	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		2	5	7	4
Blue catfish	Ictalurus furcatus					2
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	1	2	3	4	16
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	2				
Blackstripe topminnow	Fundulus notatus					
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus					5
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					4

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1975JUL29	1975JUL25	1975AUG12	1988AUG17	2011SEP20
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus	14	1	3		6
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	15	4	11		10
Largemouth bass	Micropterus salmoides	5	1	6		9
Spotted bass	Micropterus punctulatus				2	
Warmouth	Lepomis gulosus	7		1		2
Green sunfish	Lepomis cyanellus					
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	16	2	13	2	37
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	21	3			9
Orangespotted sunfish	Lepomis humilis				3	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	2	1	3	18	37

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2012OCT26	2013AUG16	1964JUL03	1975AUG12	1975AUG05
Station code		N-23	N-23	N-24	N-25	N-26
Species		20	31	10	14	16
Non-native proportion		0.39	0.36		0.43	0.11
Total fish		333	578	219	209	185
Electrode minutes		60	60		60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	83	32		3	4
Longnose gar	Lepisosteus osseus	1	14			
Spotted gar	Lepisosteus oculatus		5			
Bowfin	Amia calva		1	1	1	
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	7	110	16	56	106
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides		1			1
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella	1	10			
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix	120	168			
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	10	28		89	21
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)			30		
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	6	21			
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax	3	15			
Emerald shiner	Notropis atherinoides	13	51			
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus		16			
Mimic shiner	Notropis volucellus		3			
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	6	7		8	7
Smallmouth buffalo	Ictiobus bubalus	22	26		1	1
Black buffalo	Ictiobus niger	14	4			
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio	7	10		3	1
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni			19		
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	17	11		7	2
Blue catfish	Ictalurus furcatus	3				
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	4	3		1	
Madtom spp.	Noturus spp.			71		
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus			50		
Blackstripe topminnow	Fundulus notatus		2			
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus	1	11			
Inland silversides	Menidia beryllina					
Mississippi silverside	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops		8			

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		2012OCT26	2013AUG16	1964JUL03	1975AUG12	1975AUG05
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus				4	2
Blacknose crappie	Pomoxis nigromaculatus					
White crappie	Pomoxis annularis		1		19	16
Largemouth bass	Micropterus salmoides		2	2	6	1
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus			1		2
Green sunfish	Lepomis cyanellus		1	5		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus		4	3	6	12
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					1
Longear sunfish	Lepomis megalotis	4	1	2		2
Orangespotted sunfish	Lepomis humilis	2		19		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera		1			
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	9	10		5	6

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1975AUG13	1964JUL01	1975AUG13	1978AUG17	1979AUG13
Station code		N-27	N-28	N-99	N-99	N-99
Species		15	13	16	17	16
Non-native proportion		0.33	0.01	0.15	0.15	0.16
Total fish		240	367	130	221	119
Electrode minutes		60		30	90	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula			36		
Shortnose gar	Lepisosteus platostomus			1	2	2
Longnose gar	Lepisosteus osseus	1				
Spotted gar	Lepisosteus oculatus	1		1		
Bowfin	Amia calva	7		2		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.		6		106	8
Gizzard shad	Dorosoma cepedianum	40		26		
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides			1		
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		2			
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	78	2	20	17	18
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)		68			
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	1		2	5	5
Smallmouth buffalo	Ictiobus bubalus	1		1	2	7
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio				2	6
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus				2	
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	30	15	1	2	13
Blue catfish	Ictalurus furcatus					1
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	2			2	3
Madtom spp.	Noturus spp.		75			
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus		16			
Blackstripe topminnow	Fundulus notatus					
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops			1	3	8

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1975AUG13	1964JUL01	1975AUG13	1978AUG17	1979AUG13
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus		1			
Black crappie	Pomoxis nigromaculatus	7	12	1	3	1
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	15	1	2	7	4
Largemouth bass	Micropterus salmoides	21		8	22	7
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	1	7	2		1
Green sunfish	Lepomis cyanellus		3		1	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	33	78	25	41	28
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis		32		1	1
Orangespotted sunfish	Lepomis humilis		48		1	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	2	1		2	6

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1980JUL29	1986AUG14	1988AUG18	1990SEP26	1992AUG18
Station code		N-99	N-99	N-99	N-99	N-99
Species		15	14	21	12	14
Non-native proportion		0.4	0.12	0.03	0.2	0.01
Total fish		98	93	235	45	67
Electrode minutes		60	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula	1				
Shortnose gar	Lepisosteus platostomus	1		8	2	1
Longnose gar	Lepisosteus osseus	4				1
Spotted gar	Lepisosteus oculatus			3		
Bowfin	Amia calva		5	2		1
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	6	24	35		35
Threadfin shad	Dorosoma petenense	12		2		
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	27	11	4	8	1
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis			1		
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax			2		
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	8	8	2	1	
Smallmouth buffalo	Ictiobus bubalus	7		3		5
Black buffalo	Ictiobus niger			1		
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio		5	3	1	
Highfin carpsucker	Carpiodes velifer					1
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	1	4	13	14	1
Blue catfish	Ictalurus furcatus	1				
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	8	4	1	2	8
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					
Blackstripe topminnow	Fundulus notatus					
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis				1	
White bass	Morone chrysops	7	2		3	3

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1980JUL29	1986AUG14	1988AUG18	1990SEP26	1992AUG18
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		4	1		1
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis		2	1	5	1
Largemouth bass	Micropterus salmoides	2	7	5	4	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	1	1			
Green sunfish	Lepomis cyanellus					
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus		13	44	1	7
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis			8		
Orangespotted sunfish	Lepomis humilis			43		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	12	3	53	3	1

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1994AUG15	1995AUG12	1998SEP08	2000SEP07	2003JUL30
Station code		N-99	N-99	N-99	N-99	N-99
Species		15	11	22	22	23
Non-native proportion		0.06	0.16	0.12	0.19	0.16
Total fish		114	49	141	126	131
Electrode minutes		60	60	60	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula			3	2	
Shortnose gar	Lepisosteus platostomus			3	3	9
Longnose gar	Lepisosteus osseus					1
Spotted gar	Lepisosteus oculatus				1	1
Bowfin	Amia calva		3	2	2	1
Skipjack herring	Alosa chrysochloris					1
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	13	6	30	12	37
Threadfin shad	Dorosoma petenense			3		
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis				3	
Silver carp	Hypophthalmichthys molitrix	1				9
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	6	8	14	21	12
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					5
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis				4	3
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides			6	3	2
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	5	6	7	7	10
Smallmouth buffalo	Ictiobus bubalus	19	13	5	17	10
Black buffalo	Ictiobus niger			9	5	
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio	1			1	2
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					1
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	7		17	12	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	7	2	10	2	2
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					
Blackstripe topminnow	Fundulus notatus			1		
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis		1	1		
Brook silverside	Labidesthes sicculus			1	2	1
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops	2		1	1	6

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River
Date		1994AUG15	1995AUG12	1998SEP08	2000SEP07	2003JUL30
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis	1		4		
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus	6	2		3	1
Blacknose crappie	Pomoxis migromaculatus					
White crapple	Pomoxis annularis	4	1		2	
Largemouth bass	Micropterus salmoides	16	2	2		3
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus			1		
Green sunfish	Lepomis cyanellus				1	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	24	5	15	4	4
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis					1
Orangespotted sunfish	Lepomis humilis			1		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	2		5	18	9

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Cedar Creek
Date		2008AUG26	2010NOV09	2013AUG08	2014SEP25	1964JUL09
Station code		N-99	N-99	N-99	N-99	NA-01
Species		26	20	32	18	9
Non-native proportion		0.08	0.12	0.06	0.05	
Total fish		177	158	416	167	84
Electrode minutes		60	60	60	60	
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	2	1	18	1	
Longnose gar	Lepisosteus osseus		1	12	2	
Spotted gar	Lepisosteus oculatus		3	6		
Bowfin	Amia calva	4		3		
Skipjack herring	Alosa chrysochloris				1	
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	45	18	229	82	
Threadfin shad	Dorosoma petenense	1	1			
Goldeye	Hiodon alosoides			1	1	
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					3
Grass carp	Ctenopharyngodon idella	1		1		
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix	2		5	8	
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	10	18	17	1	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					39
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis			2		
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	2		9	14	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax			2		
Emerald shiner	Notropis atherinoides	7		12	24	
River shiner	Notropis blennius			1		
Sand shiner	Notropis ludibundus				1	
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		10	4	1	
Smallmouth buffalo	Ictiobus bubalus	7	6	19	3	
Black buffalo	Ictiobus niger		1	1		
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio	1		4	5	
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	29	2	12	6	
Blue catfish	Ictalurus furcatus	3		3		
Yellow bullhead	Ameiurus natalis					
Black bullhead	Ameiurus melas					1
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	4		4	1	
Madtom spp.	Noturus spp.					11
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus					17
Blackstripe topminnow	Fundulus notatus	1		1		
Blackspotted topminnow	Fundulus olivaceus			1		
Mosquitofish	Gambusia affinis			1		
Brook silverside	Labidesthes sicculus	10				
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops	7	31	5	2	

Water body		Big Muddy River	Big Muddy River	Big Muddy River	Big Muddy River	Cedar Creek
Date		2008AUG26	2010NOV09	2013AUG08	2014SEP25	1964JUL09
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops		1			
Yellow bass	Morone mississippiensis	2				
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus	1	2	2		
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	3	2	1		
Largemouth bass	Micropterus salmoides	3	34			2
Spotted bass	Micropterus punctulatus					2
Warmouth	Lepomis gulosus		1	7		3
Green sunfish	Lepomis cyanellus					2
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					1
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	6	14	14		1
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis		4	5		2
Orangespotted sunfish	Lepomis humilis	3	1	3	2	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum	1				
Sauger	Stizostedion canadense	1	1			
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	21	6	11	12	

Water body		Cedar Creek	Cedar Creek	Cedar Creek	Cedar Creek	Cave Creek
Date		1995JUL28	2003JUL23	2003JUL22	2008JUL29	1995JUL24
Station code		NA-01	NA-02	NA-03	NA-03	NAC-01
Species		12	13	17	27	11
Non-native proportion		0.07	0.04			
Total fish		32	52	75	176	85
Electrode minutes		25.36	35	26.05	38	27
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus		4	1		
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus			1		
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	10	13	2	3	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	2	2			
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas	3			3	
Creek chub	Semotilus atromaculatus				2	17
Central stoneroller	Campostoma anomalum					7
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis			8		
Redfin shiner	Lythrurus umbratilus				16	
Ribbon shiner	Lythrurus fumeus	1				
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					6
Pugnose minnow	Opsopoeodus emiliae			1		
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus			2	1	3
Bullhead minnow	Pimephales vigilax			1		
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi			21		
Bigmouth buffalo	Ictiobus cyprinellus	1		1	4	
Smallmouth buffalo	Ictiobus bubalus				4	
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni				2	22
Spotted sucker	Minytrema melanops		2	5	4	
Creek chubsucker	Erimyzon oblongus				1	14
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum				1	
Channel catfish	Ictalurus punctatus		1			
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis				1	
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus		1	1		
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	3	2			1
Blackstripe topminnow	Fundulus notatus		2	5	16	
Blackspotted topminnow	Fundulus olivaceus	1		2	7	2
Mosquitofish	Gambusia affinis				2	
Brook silverside	Labidesthes sicculus				1	
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Cedar Creek	Cedar Creek	Cedar Creek	Cedar Creek	Cave Creek
Date		1995JUL28	2003JUL23	2003JUL22	2008JUL29	1995JUL24
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus				3	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	2	2	2	7	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus				2	
Green sunfish	Lepomis cyanellus	3	1		11	8
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					1
Bluegill	Lepomis macrochirus	1	5	8	35	
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus	2				
Redear sunfish	Lepomis microlophus				6	
Longear sunfish	Lepomis megalotis	2	13	13	21	1
Orangespotted sunfish	Lepomis humilis				13	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid				1	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum			1	2	3
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	1			3	
Freshwater drum	Aplodinotus grunniens		4		4	

Water body		Cave Creek	Kinkaid Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek
Date		2008JUN09	1964JUL09	1995JUL20	1998AUG20	2000AUG16
Station code		NAC-02	NB-01	NC-03	NC-03	NC-03
Species		15	13	16	10	20
Non-native proportion			0.04	0.44	0.22	0.17
Total fish		130	892	57	37	111
Electrode minutes		42		30	60	70
Seine hauls						1
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus		1			1
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					1
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum			3	10	26
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio		7	25	8	19
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)		705			
Golden shiner	Notemigonus crysoleucas	1		1		
Creek chub	Semotilus atromaculatus	1				
Central stoneroller	Campostoma anomalum	10				
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	13				
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis			4		5
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	25				
Bullhead minnow	Pimephales vigilax			1		
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					1
Smallmouth buffalo	Ictiobus bubalus					3
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					1
River carpsucker	Carpiodes carpio				1	1
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni		2			
Spotted sucker	Minytrema melanops		9			
Creek chubsucker	Erimyzon oblongus	22				
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum		29			
Channel catfish	Ictalurus punctatus			1	8	7
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	2	25			
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris			2		1
Madtom spp.	Noturus spp.		3			
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	1	1	1		
Blackstripe topminnow	Fundulus notatus	8		1		1
Blackspotted topminnow	Fundulus olivaceus	4		1		
Mosquitofish	Gambusia affinis			4		
Brook silverside	Labidesthes sicculus				2	2
Inland silverside	Menidia beryllina					
Mississippi silverside	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Cave Creek	Kinkaid Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek
Date		2008JUN09	1964JUL09	1995JUL20	1998AUG20	2000AUG16
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis		3			7
Largemouth bass	Micropterus salmoides	1	2	1	2	8
Spotted bass	Micropterus punctulatus		36			
Warmouth	Lepomis gulosus			1		1
Green sunfish	Lepomis cyanellus	17	26	1		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	6	6	5	1	8
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	17	37	5	2	10
Orangespotted sunfish	Lepomis humilis				1	3
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	2				
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens				2	4

Water body		Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek
Date		2003JUL15	1964JUL09	1964JUL14	1995JUL20	2000JUL24
Station code		NC-03	NC-07	NC-08	NC-09	NC-09
Species		19	4	12	30	20
Non-native proportion		0.16			0.11	0.07
Total fish		79	74	197	232	204
Electrode minutes		60			35	33.2
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva	1				
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	17		1	16	20
Threadfin shad	Dorosoma petenense				7	
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		6			
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	13			19	14
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)		29	110		
Golden shiner	Notemigonus crysoleucas				4	
Creek chub	Semotilus atromaculatus					1
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	1			2	
Pugnose minnow	Opsopoeodus emiliae				1	
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					2
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	3				
Smallmouth buffalo	Ictiobus bubalus				1	
Black buffalo	Ictiobus niger	1				
Unidentified Carpsucker	Carpiodes sp.			1		
Quillback	Carpiodes cyprinus	1				
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni			11	1	29
Spotted sucker	Minytrema melanops			5	5	1
Creek chubsucker	Erimyzon oblongus				3	5
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	2			2	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis		4	10	3	3
Black bullhead	Ameiurus melas				1	
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris	1				
Madtom spp.	Noturus spp.			12		
Tadpole madtom	Noturus gyrinus				5	3
Freckled madtom	Noturus nocturnus	1				
Pirate perch	Aphredoderus sayanus			1	4	13
Blackstripe topminnow	Fundulus notatus				5	31
Blackspotted topminnow	Fundulus olivaceus	1				1
Mosquitofish	Gambusia affinis				5	3
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek
Date		2003JUL15	1964JUL09	1964JUL14	1995JUL20	2000JUL24
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus				1	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	1		2	30	
Largemouth bass	Micropterus salmoides	4		1	1	9
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	2		1	6	1
Green sunfish	Lepomis cyanellus	2	12	8	9	43
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	3		9	75	21
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus				1	
Longear sunfish	Lepomis megalotis	17	23	7	2	1
Orangespotted sunfish	Lepomis humilis	1		18	6	2
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid				2	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes				1	
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene				12	
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile				1	1
Freshwater drum	Aplodinotus grunniens	7			1	

Water body		Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek
Date		2013JUL15	1995SEP06	2013AUG12	1995JUL18	2003JUL15
Station code		NC-09	NC-10	NC-10	NC-11	NC-11
Species		14	20	22	8	10
Non-native proportion		0.01	0.06		0.07	0.11
Total fish		77	108	330	29	39
Electrode minutes		28.25	46.09	28.53	30	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus				1	1
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		4	12	5	9
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	1	7		2	4
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas	2				
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis				3	
Redfin shiner	Lythrurus umbratilus		1	11		
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	4	1	37	14	3
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	3	10	5		
Bullhead minnow	Pimephales vigilax		10	17		
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus			142		
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					1
Smallmouth buffalo	Ictiobus bubalus					2
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse "T"	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		1	3		2
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	5	1	2		
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris		3		1	5
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus			12		
Freckled madtom	Noturus nocturnus			5		
Pirate perch	Aphredoderus sayanus	3	1			
Blackstripe topminnow	Fundulus notatus	5	1	1		
Blackspotted topminnow	Fundulus olivaceus	1	10	7		
Mosquitofish	Gambusia affinis	1	4		2	
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek	Beaucoup Creek
Date		2013JUL15	1995SEP06	2013AUG12	1995JUL18	2003JUL15
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	1	1			
Largemouth bass	Micropterus salmoides	4	2	3		
Spotted bass	Micropterus punctulatus			2		
Warmouth	Lepomis gulosus			1		
Green sunfish	Lepomis cyanellus	14	4	1		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	23	22	10		
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis		22	46		4
Orangespotted sunfish	Lepomis humilis			5		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	10		5		
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene			1		
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile			2		
Freshwater drum	Aplodinotus grunniens		2		1	7

Water body		Rattlesnake Creek	Rattlesnake Creek	Walkers Creek	Walkers Creek	Galum Creek
Date		1995JUL18	2003JUL14	1995JUL31	2013JUN24	1995JUL18
Station code		NCB-01	NCB-01	NCC-01	NCC-01	NCD-03
Species		15	20	10	12	14
Non-native proportion		0.08	0.02			
Total fish		62	129	50	148	59
Electrode minutes		30	18.63			
Seine hauls				2	6	2
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus				1	1
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum				44	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					1
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	4		1		
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	5	2			
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus	7	16			
Central stoneroller	Campostoma anomalum		10			
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis		33			
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		11	9	4	18
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	1	1			
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		1			
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	1	18			
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus			2		3
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	3		7		
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	5	5			1
Blackstripe topminnow	Fundulus notatus		1		1	
Blackspotted topminnow	Fundulus olivaceus		1	2	1	2
Mosquitofish	Gambusia affinis		2			7
Brook silverside	Labidesthes sicculus					3
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Rattlesnake Creek	Rattlesnake Creek	Walkers Creek	Walkers Creek	Galum Creek
Date		1995JUL18	2003JUL14	1995JUL31	2013JUN24	1995JUL18
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus	4				
Black crappie	Pomoxis nigromaculatus				8	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis				6	2
Largemouth bass	Micropterus salmoides	1	7		12	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus					
Green sunfish	Lepomis cyanellus	13	8	1	1	8
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus	1				
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	6	3	19	66	7
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					1
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	5	1	1	1	3
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	1	3	2	3	
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					1
Orangethroat darter	Etheostoma spectabile	3	2			
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	2	3	6		1
Freshwater drum	Aplodinotus grunniens					

Water body		Galum Creek	Galum Creek	Galum Creek	Galum Creek	Pipestone Creek
Date		1995JUL27	2003JUL14	1964JUL14	2003JUL15	1995JUL12
Station code		NCD-05	NCD-05	NCD-06	NCD-07	NCDA-01
Species		9	9	5	16	18
Non-native proportion		0.08			0.23	0.02
Total fish		129	122	276	81	352
Electrode minutes		30			60	
Seine hauls			14			
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum				19	6
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					2
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	10			19	6
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)			206		
Golden shiner	Notemigonus crysoleucas					21
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					1
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	12			4	13
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	2				
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus				2	
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio				3	
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	15			4	168
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis			3		1
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris				2	
Madtom spp.	Noturus spp.			4		
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus				1	
Pirate perch	Aphredoderus sayanus			38		2
Blackstripe topminnow	Fundulus notatus	13	14			4
Blackspotted topminnow	Fundulus olivaceus		2			5
Mosquitofish	Gambusia affinis		13		1	10
Brook silverside	Labidesthes sicculus					43
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Galum Creek	Galum Creek	Galum Creek	Galum Creek	Pipestone Creek
Date		1995JUL27	2003JUL14	1964JUL14	2003JUL15	1995JUL12
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis nigromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	3	20		1	1
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus		1		1	
Green sunfish	Lepomis cyanellus	10	1	2	4	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus	4				
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus			4		
Bluegill	Lepomis macrochirus	39	68	7	9	34
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus		1			
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	18	1	12	6	3
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	3				1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum		1		1	3
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					28
Freshwater drum	Aplodinotus grunniens				4	

Water body		Pipestone Creek	Rocky Fork	Little Galum Creek	Little Galum Creek	Little Galum Creek
Date		2003JUL14	2013JUN13	2013JUL31	1995JUL12	2008JUN11
Station code		NCDA-01	NCDAA-01	NCDB-	NCDB-01	NCDB-01
Species		6	13	12	12	11
Non-native proportion						
Total fish		22	230	246	131	259
Electrode minutes			26.22		30	
Seine hauls		3		9.9		7.5
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1				
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum					
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus		46		12	
Central stoneroller	Campostoma anomalum		8		35	
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus			214	4	60
Ribbon shiner	Lythrurus fumeus			1		
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	8	1	5	1	19
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus			5		6
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus		118			3
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni			1		145
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse "T"	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis		1		1	
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus		17	1	6	
Blackstripe topminnow	Fundulus notatus	2		2		4
Blackspotted topminnow	Fundulus olivaceus	2	15	9	1	
Mosquitofish	Gambusia affinis			1		
Brook silverside	Labidesthes sicculus					
Inland silverside	Menidia beryllina					
Mississippi silverside	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Pipestone Creek	Rocky Fork	Little Galum Creek	Little Galum Creek	Little Galum Creek
Date		2003JUL14	2013JUN13	2013JUL31	1995JUL12	2008JUN11
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides		4	2	8	14
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus				1	
Green sunfish	Lepomis cyanellus		4		42	1
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	8	2		19	5
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis		6	1		1
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata	1				
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum			4	1	1
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps		7			
Slough darter	Etheostoma gracile		1			
Freshwater drum	Aplodinotus grunniens					

Water body		Little Galum Creek	Bonnie Creek	Bonnie Creek	Panther Creek	Panther Creek
Date		2013JUL31	1995JUL27	2013JUN13	1995JUL25	2000JUL24
Station code		NCDB-01	NCDC-01	NCDC-01	NCE-02	NCE-02
Species		12	15	11	25	18
Non-native proportion					0.01	0.04
Total fish		88	145	120	248	115
Electrode minutes			35.17			53.5
Seine hauls		8.1		9.7	2	
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					1
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum				5	2
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus				6	1
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio				2	5
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas		4			
Creek chub	Semotilus atromaculatus	16	8			
Central stoneroller	Campostoma anomalum	4				
Suckermouth minnow	Phenacobius mirabilis	1		1		
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storerlana					
Silvery minnow	Hybognathus nuchalis					1
Redfin shiner	Lythrurus umbratilus	7		3	4	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		2	17	30	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	10	3	1	11	
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus	8	2			
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus				1	
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops				1	
Creek chubsucker	Erimyzon oblongus		1			
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus				6	7
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	3	1			
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus		3		2	3
Blackstripe topminnow	Fundulus notatus	5	1	4	6	10
Blackspotted topminnow	Fundulus olivaceus	14	2	10	6	1
Mosquitofish	Gambusia affinis				7	
Brook silverside	Labidesthes sicculus			1	3	4
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Little Galum Creek	Bonnie Creek	Bonnie Creek	Panther Creek	Panther Creek
Date		2013JUL31	1995JUL27	2013JUN13	1995JUL25	2000JUL24
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					3
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis				2	
Largemouth bass	Micropterus salmoides	6	2	32	2	17
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus					3
Green sunfish	Lepomis cyanellus	6	28			3
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus		23	44	95	41
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus				1	
Longear sunfish	Lepomis megalotis		64	4	21	5
Orangespotted sunfish	Lepomis humilis					1
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					3
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata				1	
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes				3	
Johnny darter	Etheostoma nigrum	8		3	24	4
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene				4	
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile		1		1	
Freshwater drum	Aplodinotus grunniens				4	

Water body		White Walnut Cree	ittle Beaucoup Cre	ittle Beaucoup Cre	Swanwick Creek	Swanwick Creek
Date		2013JUL22	1995AUG01	2008JUL08	1995JUL20	2008JUN11
Station code		NCH-01	NCI-01	NCI-01	NCK-01	NCK-02
Species		13	13	12	17	15
Non-native proportion					0.14	
Total fish		219	104	55	130	73
Electrode minutes		20.1	25.17	24.5	35	23.4
Seine hauls					60	
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	2			27	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		6	1	1	1
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio				18	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas		3	14		1
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	2	7			1
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		1			1
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni				6	
Spotted sucker	Minytrema melanops				1	
Creek chubsucker	Erimyzon oblongus		12	3		4
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus				2	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	4			6	1
Black bullhead	Ameiurus melas				3	
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	3	18	5	1	2
Blackstripe topminnow	Fundulus notatus	18		4	3	7
Blackspotted topminnow	Fundulus olivaceus	10	8	4		
Mosquitofish	Gambusia affinis	17	1	4		
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		White Walnut Cree	ttle Beaucoup Cree	ttle Beaucoup Cree	Swanwick Creek	Swanwick Creek
Date		2013JUL22	1995AUG01	2008JUL08	1995JUL20	2008JUN11
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis				5	1
Largemouth bass	Micropterus salmoides	16		4	1	1
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus				2	
Green sunfish	Lepomis cyanellus	40	19	3	2	18
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	73	20	9	36	30
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus	2		2		
Longear sunfish	Lepomis megalotis	27	6	2	15	3
Orangespotted sunfish	Lepomis humilis				1	1
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid		1			
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	5				
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile		1			1
Freshwater drum	Aplodinotus grunniens					

Water body		Locust Creek	Locust Creek	Locust Creek	Glenn Creek	Crab Orchard Creek
Date		1995JUL20	2000JUL11	2013JUL15	2013JUN24	1995JUL18
Station code		NCN-02	NCN-02	NCN-02	NCS-01	ND-01
Species		22	19	12	18	18
Non-native proportion		0.01		0.02	0.06	0.12
Total fish		166	142	251	383	82
Electrode minutes		30	35.7	35.03		30
Seine hauls					7.26	
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus				5	1
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					2
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	12	7		16	32
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	1	1			
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	1		4	22	10
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas				10	
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					5
Redfin shiner	Lythrurus umbratilus	2	1			
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis				1	5
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	16				
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					1
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus				93	
Smallmouth buffalo	Ictiobus bubalus				17	5
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	1	6			
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus	2	2			
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		1			
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	9	11	4		
Black bullhead	Ameiurus melas		1			
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					1
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus	6	6	3		
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	9	5	3	1	
Blackstripe topminnow	Fundulus notatus	8	2	14	14	1
Blackspotted topminnow	Fundulus olivaceus	3	6	6	3	
Mosquitofish	Gambusia affinis				77	1
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Locust Creek	Locust Creek	Locust Creek	Glenn Creek	Crab Orchard Creek
Date		1995JUL20	2000JUL11	2013JUL15	2013JUN24	1995JUL18
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis	1				1
Flier	Centrarchus macropterus				25	
Black crappie	Pomoxis nigromaculatus				2	1
Blacknose crappie	Pomoxis migromaculatus				5	
White crappie	Pomoxis annularis	5	1		10	
Largemouth bass	Micropterus salmoides	2	12	7	43	7
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus			3		
Green sunfish	Lepomis cyanellus	16	7	16		1
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	36	43	163	38	4
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	27	27	17		1
Orangespotted sunfish	Lepomis humilis	3				3
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	3		6		
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes	1				
Johnny darter	Etheostoma nigrum	1	2	5		
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene				1	
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	1	1			
Freshwater drum	Aplodinotus grunniens					

Water body		Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek
Date		2003JUL16	2008SEP02	2003JUL23	2008JUL07	1995JUL14
Station code		ND-01	ND-01	ND-04	ND-04	ND-08
Species		27	29	17	13	11
Non-native proportion		0.08	0.05	0.07	0.07	
Total fish		270	285	183	99	72
Electrode minutes		60	53	60	26.1	21
Seine hauls				3		
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	9				
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva	4	1	1		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	50	88	30	6	2
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus			8	2	2
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis		2			
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	22	12	12	7	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	85				
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus	4				
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	2	2			
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	2	2			
Bullhead minnow	Pimephales vigilax	3	5			
Emerald shiner	Notropis atherinoides		6			
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi	14				
Bigmouth buffalo	Ictiobus cyprinellus	3	1			
Smallmouth buffalo	Ictiobus bubalus	7	13			
Black buffalo	Ictiobus niger	1	3			
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus	1				
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni			3		
Spotted sucker	Minytrema melanops		2			
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum	2				
Channel catfish	Ictalurus punctatus	1		1	5	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					7
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris				1	
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus	1				
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus		1	1		4
Blackstripe topminnow	Fundulus notatus		1	4	1	1
Blackspotted topminnow	Fundulus olivaceus		1			
Mosquitofish	Gambusia affinis			20		2
Brook silverside	Labidesthes sicculus		4			1
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops		3			

Water body		Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek
Date		2003JUL16	2008SEP02	2003JUL23	2008JUL07	1995JUL14
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis		2			
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		12	3	2	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	1	4			
Largemouth bass	Micropterus salmoides	6	6	10	3	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	1	13	3		
Green sunfish	Lepomis cyanellus	4	1	4	7	44
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	6	34	31	22	4
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus			1		
Longear sunfish	Lepomis megalotis	9	44	34	34	2
Orangespotted sunfish	Lepomis humilis	3	12		3	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					1
Walleye	Stizostedion vitreum		2			
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes	4				
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene	1				
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					2
Freshwater drum	Aplodinotus grunniens	24	7	17	6	

Water body		Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek	Little Crab Orchard	Piles Fork
Date		2000JUL26	1995AUG04	2000JUL26	1995JUL07	1995JUL10
Station code		ND-08	ND-14	ND-14	NDA-01	NDB-03
Species		7	16	15	23	12
Non-native proportion			0.04	0.02	0.17	0.14
Total fish		61	95	55	117	50
Electrode minutes		25.62	30	35.5	23.5	23.16
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	39	17	4	1	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		1	4		
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio		4	1	19	7
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas				1	
Creek chub	Semotilus atromaculatus				14	
Central stoneroller	Campostoma anomalum				3	
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus				5	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					1
Bluntnose minnow	Pimephales notatus				4	
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					5
Smallmouth buffalo	Ictiobus bubalus				4	2
Black buffalo	Ictiobus niger					4
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni				3	
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus				5	1
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		2	1		
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis		6	5		1
Black bullhead	Ameiurus melas		5			1
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus		1	4	2	
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	1		1	9	
Blackstripe topminnow	Fundulus notatus	1		3	2	
Blackspotted topminnow	Fundulus olivaceus				3	4
Mosquitofish	Gambusia affinis		1		2	
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Crab Orchard Creek	Crab Orchard Creek	Crab Orchard Creek	Little Crab Orchard	Piles Fork
Date		2000JUL26	1995AUG04	2000JUL26	1995JUL07	1995JUL10
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis		1			
Flier	Centrarchus macropterus		1	1	1	2
Black crappie	Pomoxis nigromaculatus		1			
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	1	2	1	6	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus				2	
Green sunfish	Lepomis cyanellus	13	38	16	7	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	3	10	11	8	3
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	3	4	1	3	19
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid				2	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes			1		
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum				1	
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile				10	
Freshwater drum	Aplodinotus grunniens		1	1		

Water body		Piles Fork	Glade Creek	Drury Creek	Drury Creek	Drury Creek
Date		2013JUN10	2013MAY29	1964JUL10	2000JUL25	1995AUG03
Station code		NDB-05	NDBA-01	NDC-01	NDC-01	NDC-02
Species		12	9	6	21	24
Non-native proportion						
Total fish		116	865	1055	149	377
Electrode minutes		20.92			24.4	30
Seine hauls			8.1			
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					2
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus	1				
Bowfin	Amia calva				1	
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		2		3	5
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus			1	1	1
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)			904		
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					6
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis				26	201
Redfin shiner	Lythrurus umbratilus	2				4
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis				31	24
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	5			5	5
Bullhead minnow	Pimephales vigilax				1	
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops			1	1	
Creek chubsucker	Erimyzon oblongus					
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					2
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis			43	4	6
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.			11		
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	1	6	17	3	2
Blackstripe topminnow	Fundulus notatus		158		2	1
Blackspotted topminnow	Fundulus olivaceus	25			1	
Mosquitofish	Gambusia affinis	7	507			13
Brook silverside	Labidesthes sicculus					4
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Piles Fork	Glade Creek	Drury Creek	Drury Creek	Drury Creek
Date		2013JUN10	2013MAY29	1964JUL10	2000JUL25	1995AUG03
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					1
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	2			7	6
Spotted bass	Micropterus punctulatus					4
Warmouth	Lepomis gulosus	1			4	
Green sunfish	Lepomis cyanellus	10	22	50	22	25
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	16	141		10	25
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					1
Longear sunfish	Lepomis megalotis	45	6	28	20	21
Orangespotted sunfish	Lepomis humilis		22			
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1		1	2
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes				2	
Johnny darter	Etheostoma nigrum	1			2	10
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile				2	5
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens					

Water body		Drury Creek	Drury Creek	Drury Creek	Sycamore Creek	Sycamore Creek
Date		2003JUL22	2013JUN10	2008JUN16	2008JUN05	2013JUN10
Station code		NDC-02	NDC-02	NDC-99	NDCA-01	NDCA-02
Species		17	19	18	10	8
Non-native proportion				0.04		
Total fish		70	365	171	46	51
Electrode minutes		29.33	28.33	35	19.2	15.22
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1	2			
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva			1		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	1		6		
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		1	1		
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio			7		
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus	6			9	
Central stoneroller	Campostoma anomalum	7	6		10	18
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	4				
Redfin shiner	Lythrurus umbratilus		1	38		
Ribbon shiner	Lythrurus fumeus	1	3			
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	14	18			8
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		55	1	9	
Bullhead minnow	Pimephales vigilax		6			
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus		168			
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi	2				
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni			12	1	
Spotted sucker	Minytrema melanops			11		
Creek chubsucker	Erimyzon oblongus			1	5	
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus			2		
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	3			2	
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus		1			
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	2				
Blackstripe topminnow	Fundulus notatus		11			
Blackspotted topminnow	Fundulus olivaceus	1		4		
Mosquitofish	Gambusia affinis	1	3			2
Brook silverside	Labidesthes sicculus			1		
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Drury Creek	Drury Creek	Drury Creek	Sycamore Creek	Sycamore Creek
Date		2003JUL22	2013JUN10	2008JUN16	2008JUN05	2013JUN10
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus		1			
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	4	2	13	1	2
Spotted bass	Micropterus punctulatus			6		
Warmouth	Lepomis gulosus					
Green sunfish	Lepomis cyanellus	14	20	10	2	2
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	4	10	7	3	12
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	4	53	48		6
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid				3	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					1
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	1	3			
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile				1	
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile		1			
Freshwater drum	Aplodinotus grunniens			2		

Water body		Indian Creek	Indian Creek	Indian Creek	Indian Creek	Grassy Creek
Date		1995JUL26	2000JUL25	2008JUN10	2008JUL29	1995JUL06
Station code		NDCB-01	NDCB-01	NDCB-01	NDCB-02	NDD-03
Species		14	15	9	15	15
Non-native proportion						
Total fish		176	49	37	1503	732
Electrode minutes		30	44.5	27.1	27.8	31
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum					
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		1			
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus	5			69	36
Central stoneroller	Campostoma anomalum	14			133	54
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					163
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	7		3	26	11
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	15	5	3	622	228
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	1			1	1
Spotted sucker	Minytrema melanops		1			
Creek chubsucker	Erimyzon oblongus	19	2		116	57
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	3			1	7
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus		1			
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus		6	1		
Blackstripe topminnow	Fundulus notatus		1	15	5	1
Blackspotted topminnow	Fundulus olivaceus	18			6	8
Mosquitofish	Gambusia affinis					
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Indian Creek	Indian Creek	Indian Creek	Indian Creek	Grassy Creek
Date		1995JUL26	2000JUL25	2008JUN10	2008JUL29	1995JUL06
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	2	1	1	3	
Spotted bass	Micropterus punctulatus		1			
Warmouth	Lepomis gulosus			1		
Green sunfish	Lepomis cyanellus	25	8	4	76	49
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	2	3	1	135	1
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	53	10	8	293	97
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	3	3		4	3
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile	9	3		13	16
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile		3			
Freshwater drum	Aplodinotus grunniens					

Water body		Grassy Creek	Grassy Creek	Little Grassy Creek	Little Grassy Creek	Wolf Creek
Date		2008JUN16	1995JUN02	1995JUL05	2008JUN12	1995JUL28
Station code		NDD-03	NDD-04	NDDA-01	NDDA-01	NDJ-01
Species		15	13	16	10	22
Non-native proportion						
Total fish		346	155	336	55	165
Electrode minutes		35.4	28.33	30	37.1	30
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		1	4		5
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus			5	2	
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas		1	1		
Creek chub	Semotilus atromaculatus	17				4
Central stoneroller	Campostoma anomalum	33				26
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	25				1
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					1
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas			140		
Bluntnose minnow	Pimephales notatus	104	31	3	14	25
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	1				2
Spotted sucker	Minytrema melanops		1			4
Creek chubsucker	Erimyzon oblongus	10				2
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus			6	7	1
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	3	4	11		3
Black bullhead	Ameiurus melas					2
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus			3		
Blackstripe topminnow	Fundulus notatus	4	1	1	3	
Blackspotted topminnow	Fundulus olivaceus	6	3	1	4	1
Mosquitofish	Gambusia affinis					6
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Grassy Creek	Grassy Creek	Little Grassy Creek	Little Grassy Creek	Wolf Creek
Date		2008JUN16	1995JUN02	1995JUL05	2008JUN12	1995JUL28
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	6	2	11	1	2
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus		2	1		
Green sunfish	Lepomis cyanellus	10	23	5	6	11
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	25	9	56	7	20
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus			30	1	
Longear sunfish	Lepomis megalotis	77	66	56	10	21
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid			2		7
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes		11			3
Johnny darter	Etheostoma nigrum	4				10
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile	21				7
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					1
Freshwater drum	Aplodinotus grunniens					

Water body		Wolf Creek	Little Muddy River	Little Muddy River	Little Muddy River	Little Muddy River
Date		2008JUN16	1995JUL19	2000JUL27	2013AUG12	1964JUL10
Station code		NDJ-01	NE-04	NE-04	NE-04	NE-05
Species		20	19	24	25	13
Non-native proportion			0.22	0.11		0.05
Total fish		245	158	174	150	226
Electrode minutes		27.6	50	40	28.67	
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus			1		
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus		1			
Bowfin	Amia calva	1	2	1		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		71	45		
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	25	3	2	3	4
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio		35	19		8
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					47
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus	13				
Central stoneroller	Campostoma anomalum	17				
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	8		1	1	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		1	3		
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	34	1	4	1	
Bullhead minnow	Pimephales vigilax				1	
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus				1	
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		2	2		2
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					1
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops			3	2	7
Creek chubsucker	Erimyzon oblongus	7				
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus			1		6
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	1	1			
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					1
Madtom spp.	Noturus spp.					28
Tadpole madtom	Noturus gyrinus				3	
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	6		9	2	11
Blackstripe topminnow	Fundulus notatus	11	1		18	
Blackspotted topminnow	Fundulus olivaceus	2		7	7	
Mosquitofish	Gambusia affinis	2			1	
Brook silverside	Labidesthes sicculus			5	2	
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Wolf Creek	Little Muddy River	Little Muddy River	Little Muddy River	Little Muddy River
Date		2008JUN16	1995JUL19	2000JUL27	2013AUG12	1964JUL10
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus			3	1	6
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis		3	2		7
Largemouth bass	Micropterus salmoides	4	2	17	7	
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus		8	11	12	11
Green sunfish	Lepomis cyanellus	15	6	6	10	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					1
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus		1			
Bluegill	Lepomis macrochirus	42	4	13	17	
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus		1			
Longear sunfish	Lepomis megalotis	38	6	2	36	74
Orangespotted sunfish	Lepomis humilis		1	10	7	10
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	3				
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata			2	1	
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes	5			4	
Johnny darter	Etheostoma nigrum	6			5	
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene				2	
Orangethroat darter	Etheostoma spectabile	4			1	
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	1			5	
Freshwater drum	Aplodinotus grunniens		8	5		2

Water body		Little Muddy River	Little Muddy River	Little Muddy River	Little Muddy River	Little Muddy River
Date		1995JUL19	2000AUG16	2003JUL17	2008JUN19	1995AUG07
Station code		NE-05	NE-05	NE-05	NE-05	NE-06
Species		19	20	19	21	8
Non-native proportion		0.31	0.13	0.19	0.02	
Total fish		49	104	102	226	156
Electrode minutes		40	60	60	50	27
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1	1	4		
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus	2	2	2	4	
Bowfin	Amia calva			2		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	7	25	9	16	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	1				
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	15	14	19	4	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					100
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	2	12		13	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		1		5	14
Bullhead minnow	Pimephales vigilax	3		3		
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		2	2	2	
Smallmouth buffalo	Ictiobus bubalus		4	1	1	
Black buffalo	Ictiobus niger		1		1	
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus	1				
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					16
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		3	1	7	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					3
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris		1			
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus				2	
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	1	1	2		11
Blackstripe topminnow	Fundulus notatus				2	1
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis	1			1	
Brook silverside	Labidesthes sicculus				2	
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Little Muddy River	Little Muddy River	Little Muddy River	Little Muddy River	Little Muddy River
Date		1995JUL19	2000AUG16	2003JUL17	2008JUN19	1995AUG07
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus	1	3	2	3	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	3	3	4	4	
Largemouth bass	Micropterus salmoides	1	2	7		1
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	1	3	13	56	
Green sunfish	Lepomis cyanellus	2			2	7
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	2	6	3	26	
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis		2	3	8	
Orangespotted sunfish	Lepomis humilis	1	10	16	61	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid			2		3
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene	1				
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile			1		
Freshwater drum	Aplodinotus grunniens	3	8	6	6	

Water body		Little Muddy River	Little Muddy River	Little Muddy River	Six Mile Creek	Reese Creek
Date		1964JUL01	2003JUL08	2013JUL17	1995JUL13	1995JUL13
Station code		NE-08	NE-09	NE-09	NEA-02	NEB-02
Species		7	18	17	19	17
Non-native proportion			0.04		0.01	
Total fish		116	94	196	251	276
Electrode minutes			42.13	44.7		
Seine hauls					2	
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva		1			
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		5	7		1
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	3			12	15
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio		4		2	
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)	29				
Golden shiner	Notemigonus crysoleucas				9	
Creek chub	Semotilus atromaculatus				20	
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus			3	2	19
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis				14	
Pugnose minnow	Opsopoeodus emiliae		1			
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus		6	8		
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus		3			
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni		7			
Spotted sucker	Minytrema melanops	11	6			
Creek chubsucker	Erimyzon oblongus		2		1	
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum	2				
Channel catfish	Ictalurus punctatus			1		
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	6		5	2	1
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.	9				
Tadpole madtom	Noturus gyrinus			2		
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	23	1	6	15	15
Blackstripe topminnow	Fundulus notatus		8	42		3
Blackspotted topminnow	Fundulus olivaceus				16	
Mosquitofish	Gambusia affinis			1	1	9
Brook silverside	Labidesthes sicculus				1	1
Inland silverside	Menidia beryllina					
Mississippi silverside	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Little Muddy River	Little Muddy River	Little Muddy River	Six Mile Creek	Reese Creek
Date		1964JUL01	2003JUL08	2013JUL17	1995JUL13	1995JUL13
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					4
Black crappie	Pomoxis nigromaculatus		1			2
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis			3		
Largemouth bass	Micropterus salmoides		7	3		2
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus			2		2
Green sunfish	Lepomis cyanellus	5	7	19	8	13
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus		32	65	32	41
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus			4		
Longear sunfish	Lepomis megalotis	28	1	16	25	1
Orangespotted sunfish	Lepomis humilis				4	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid			1		
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata		1			
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum		1	8	31	
Bluntnose darter	Etheostoma chlorosomum				11	10
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile				45	137
Freshwater drum	Aplodinotus grunniens					

Water body		Reese Creek	Little Indian Creek	Puncheon Creek	Puncheon Creek	Puncheon Creek
Date		2008JUL08	1995JUL21	1995JUL25	2003JUL08	2013JUL17
Station code		NEB-02	NEE-01	NEI-01	NEI-01	NEI-01
Species		21	16	13	17	12
Non-native proportion						
Total fish		98	127	161	131	152
Electrode minutes		31.7		17.5	25.93	17.33
Seine hauls			2			
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1				
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	1				
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	7	1	2	2	
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas	3			12	
Creek chub	Semotilus atromaculatus	1	4	78	1	18
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis				3	
Redfin shiner	Lythrurus umbratilus		21		1	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	3	4	7	2	7
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops	2				
Creek chubsucker	Erimyzon oblongus	1	3	3	16	3
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	2	1	14		19
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus				1	
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus	2				
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	9	1	2	6	6
Blackstripe topminnow	Fundulus notatus	3	6	2	9	10
Blackspotted topminnow	Fundulus olivaceus	4				4
Mosquitofish	Gambusia affinis		30	2		2
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Reese Creek	Little Indian Creek	Puncheon Creek	Puncheon Creek	Puncheon Creek
Date		2008JUL08	1995JUL21	1995JUL25	2003JUL08	2013JUL17
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus	11				
Black crappie	Pomoxis nigromaculatus	12			1	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis		1			
Largemouth bass	Micropterus salmoides	1	2		6	29
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	6	1		2	
Green sunfish	Lepomis cyanellus	4	20	12	20	8
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	9	16	17	45	34
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus				1	
Longear sunfish	Lepomis megalotis	8	6	1		
Orangespotted sunfish	Lepomis humilis	8				
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid		5		2	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum			18	1	12
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile		5	3		
Freshwater drum	Aplodinotus grunniens					

Water body		Hurricane Creek	Hurricane Creek	Pond Creek	Pond Creek	Pond Creek
Date		1995JUL17	2008JUN10	1995JUL21	2000AUG17	1995JUL11
Station code		NF-01	NF-01	NG-03	NG-03	NG-04
Species		12	16	15	17	19
Non-native proportion			0	0.24	0.27	0.04
Total fish		99	239	113	97	167
Electrode minutes			36	50	40	30
Seine hauls		2				
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus			1	1	
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		14	44	31	1
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	4	8	1		27
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio		1	27	26	6
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					1
Silvery minnow	Hybognathus nuchalis				2	
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		11	4	1	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					1
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	1		3		
Smallmouth buffalo	Ictiobus bubalus			2	3	
Black buffalo	Ictiobus niger				2	
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					4
Spotted sucker	Minytrema melanops					1
Creek chubsucker	Erimyzon oblongus					1
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		2	2	1	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis					4
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus		2			
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	5	1			20
Blackstripe topminnow	Fundulus notatus					2
Blackspotted topminnow	Fundulus olivaceus	6	50			
Mosquitofish	Gambusia affinis		17	1		
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Hurricane Creek	Hurricane Creek	Pond Creek	Pond Creek	Pond Creek
Date		1995JUL17	2008JUN10	1995JUL21	2000AUG17	1995JUL11
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus	7				1
Black crappie	Pomoxis nigromaculatus	4		2		
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis			1		
Largemouth bass	Micropterus salmoides	14	4	1	3	3
Spotted bass	Micropterus punctulatus				1	
Warmouth	Lepomis gulosus	2	5	5	2	8
Green sunfish	Lepomis cyanellus	2	44		1	12
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	27	42	3	3	42
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus		1			
Longear sunfish	Lepomis megalotis	25	31	16	11	25
Orangespotted sunfish	Lepomis humilis				3	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	1	5			1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes	1			1	
Johnny darter	Etheostoma nigrum					2
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile		1			
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					5
Freshwater drum	Aplodinotus grunniens				5	

Water body		Pond Creek	Pond Creek	Lake Creek	Lake Creek	d. Fk. Big Muddy Ri
Date		2003JUL21	2008JUN12	1995JUL25	2008JUN12	1964JUL02
Station code		NG-04	NG-05	NGA-02	NGA-02	NH-06
Species		18	11	14	12	11
Non-native proportion		0.01				0.05
Total fish		178	189	105	244	136
Electrode minutes		37.22		27.3	28.1	
Seine hauls			8.7			
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva	8				
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	2				
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	39		6	12	4
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus	2				
Carp	Cyprinus carpio					5
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					37
Golden shiner	Notemigonus crysoleucas	2	8		4	
Creek chub	Semotilus atromaculatus		2			
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus		12		2	
Ribbon shiner	Lythrurus fumeus		3			
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		1			
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni			1		
Spotted sucker	Minytrema melanops	1		1		
Creek chubsucker	Erimyzon oblongus	2		3	3	
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis			1	1	2
Black bullhead	Ameiurus melas				1	
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					3
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	24		4	1	34
Blackstripe topminnow	Fundulus notatus	3	18	2	1	
Blackspotted topminnow	Fundulus olivaceus	6			8	
Mosquitofish	Gambusia affinis	10				
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Pond Creek	Pond Creek	Lake Creek	Lake Creek	d. Fk. Big Muddy Ri
Date		2003JUL21	2008JUN12	1995JUL25	2008JUN12	1964JUL02
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus	19				2
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					3
Largemouth bass	Micropterus salmoides	4		2		
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	7		1		9
Green sunfish	Lepomis cyanellus	19	81	31	180	3
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus			2		
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	22	44	21	25	29
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus		4	2		
Longear sunfish	Lepomis megalotis	6	3	27	6	4
Orangespotted sunfish	Lepomis humilis					1
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid		12			
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum			1		
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	2	1			
Freshwater drum	Aplodinotus grunniens					

Water body		d. Fk. Big Muddy Ri	tle Fork Big Muddy	d. Fk. Big Muddy Ri	l. Fork Big Muddy R	d. Fk. Big Muddy Ri
Date		1995JUL25	2000SEP05	2003JUL09	2013JUN11	2003JUL10
Station code		NH-07	NH-07	NH-07	NH-09	NH-23
Species		19	22	21	10	25
Non-native proportion		0.1	0.07	0.14		0.11
Total fish		205	240	122	58	229
Electrode minutes		60	60	60	18	60
Seine hauls		60				
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					1
Longnose gar	Lepisosteus osseus	1				
Spotted gar	Lepisosteus oculatus	2	1	1		3
Bowfin	Amia calva	1	4	4		10
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	37	50	2		13
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus			4		
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	20	17	17		26
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas			1	4	
Creek chub	Semotilus atromaculatus				7	
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus					
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis			2		1
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus					
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	8	17	3		2
Smallmouth buffalo	Ictiobus bubalus	3	7	1		14
Black buffalo	Ictiobus niger		1	1		
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					1
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		1			
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	3	2	1		2
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					2
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	6	5	2	3	6
Blackstripe topminnow	Fundulus notatus	2	2		4	1
Blackspotted topminnow	Fundulus olivaceus	1			2	
Mosquitofish	Gambusia affinis			1		1
Brook silverside	Labidesthes sicculus		2			
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		d. Fk. Big Muddy Ri	dle Fork Big Muddy	d. Fk. Big Muddy Ri	. Fork Big Muddy R	d. Fk. Big Muddy Ri
Date		1995JUL25	2000SEP05	2003JUL09	2013JUN11	2003JUL10
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis		1			
Flier	Centrarchus macropterus					1
Black crappie	Pomoxis nigromaculatus		2	1		5
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	2	2	2		7
Largemouth bass	Micropterus salmoides	2	2	12		13
Spotted bass	Micropterus punctulatus					2
Warmouth	Lepomis gulosus	21	22	21		37
Green sunfish	Lepomis cyanellus	8	9	9	25	8
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	67	60	26	8	32
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	8	10		3	5
Orangespotted sunfish	Lepomis humilis	10	11	9	1	33
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid		1	1		
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum				1	
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile			1		
Freshwater drum	Aplodinotus grunniens	3	11			3

Water body		d. Fk. Big Muddy Riv	d. Fk. Big Muddy Ri	dle Fork Big Muddy	Ewing Creek	Ewing Creek
Date		2008AUG20	1995JUL17	2000AUG17	1995JUL11	2000JUL26
Station code		NH-23	NH-26	NH-26	NHB-01	NHB-01
Species		25	19	30	20	21
Non-native proportion		0.08	0.08	0.09	0.01	0.02
Total fish		338	220	243	476	196
Electrode minutes		60	60	60	28.08	43
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus	1				
Longnose gar	Lepisosteus osseus			1		
Spotted gar	Lepisosteus oculatus	1		1		
Bowfin	Amia calva	5	1	1		
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	85	63	61	10	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		1		1	1
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix	1				
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	27	17	23	4	4
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas		1		1	1
Creek chub	Semotilus atromaculatus				3	4
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus		2	1	50	1
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	2				
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus				29	2
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides	3				3
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	7	55	6		
Smallmouth buffalo	Ictiobus bubalus	44	1	3		
Black buffalo	Ictiobus niger	1		3		
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus			1		
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni					9
Spotted sucker	Minytrema melanops		1	1		
Creek chubsucker	Erimyzon oblongus				20	30
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus			6		
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	8		2	4	1
Black bullhead	Ameiurus melas		1		1	
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris			1		
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus		1	3		
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	6	2	3	6	34
Blackstripe topminnow	Fundulus notatus	6	5	2	10	12
Blackspotted topminnow	Fundulus olivaceus				8	
Mosquitofish	Gambusia affinis		5	1	3	2
Brook silverside	Labidesthes sicculus	10		2		
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		d. Fk. Big Muddy Rid	d. Fk. Big Muddy Ri	le Fork Big Muddy	Ewing Creek	Ewing Creek
Date		2008AUG20	1995JUL17	2000AUG17	1995JUL11	2000JUL26
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis	1		3		
Flier	Centrarchus macropterus		3	1		
Black crappie	Pomoxis nigromaculatus	5	27	17		
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	9	2	2		1
Largemouth bass	Micropterus salmoides	8		8	10	11
Spotted bass	Micropterus punctulatus		1			
Warmouth	Lepomis gulosus	36		44	1	
Green sunfish	Lepomis cyanellus	3			36	8
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	39	31	27	19	24
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	6		4	257	42
Orangespotted sunfish	Lepomis humilis	14		7		
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					1
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					1
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile			1	3	3
Freshwater drum	Aplodinotus grunniens	10		7		

Water body		Ewing Creek	Little Bessie Creek	Akin Creek	Akin Creek	Sugar Camp Creek
Date		2013JUN11	2013JUN11	2008JUN04	2013MAY30	1995JUL25
Station code		NHB-02	NHD-01	NHG-01	NHG-01	NHH-01
Species		17	12	6	5	17
Non-native proportion						
Total fish		210	88	17	30	241
Electrode minutes		22.63	15.28	16.7	24	29.1
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum					1
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus					5
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					14
Creek chub	Semotilus atromaculatus	24		1	2	
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	3		1		
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis					
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas			1		
Bluntnose minnow	Pimephales notatus	58	2			1
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	2			1	1
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus	1	1			45
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	2	2			3
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus	1				
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	2	5			5
Blackstripe topminnow	Fundulus notatus	14	9	1		14
Blackspotted topminnow	Fundulus olivaceus	12	5		12	32
Mosquitofish	Gambusia affinis	1	2			2
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Ewing Creek	Little Bessie Creek	Akin Creek	Akin Creek	Sugar Camp Creek
Date		2013JUN11	2013JUN11	2008JUN04	2013MAY30	1995JUL25
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	3	7			
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus					5
Green sunfish	Lepomis cyanellus	26	21	1	13	15
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus			4		
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	40	30	8	1	15
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	13	3			79
Orangespotted sunfish	Lepomis humilis	1				3
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid				1	
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	7	1			1
Freshwater drum	Aplodinotus grunniens					

Water body		Sugar Camp Creek	Gun Creek	Gun Creek	Casey Fork	Casey Fork
Date		2003JUL21	1995JUL21	2008AUG18	1990JUL24	1992JUL14
Station code		NHH-01	NI-01	NI-01	NJ-07	NJ-07
Species		23	17	13	14	4
Non-native proportion			0.02	0.03	0.14	0.25
Total fish		254	84	103	44	20
Electrode minutes		33.38	30	15.8	60	60
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus				1	
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		1	13	4	
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus	12				
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus				1	
Carp	Cyprinus carpio		2	3	S	S
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas		1			
Creek chub	Semotilus atromaculatus	2				
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis	1				
Redfin shiner	Lythrurus umbratilus	8	1			
Ribbon shiner	Lythrurus fumeus	6				
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	6				
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	34				
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus			1	1	
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	2	3	9		
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus	24	2			
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		1		S	S
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	7	6			
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	19	10	5	1	
Blackstripe topminnow	Fundulus notatus	4	6	24	1	
Blackspotted topminnow	Fundulus olivaceus	5				
Mosquitofish	Gambusia affinis	3	5	10		
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Sugar Camp Creek	Gun Creek	Gun Creek	Casey Fork	Casey Fork
Date		2003JUL21	1995JUL21	2008AUG18	1990JUL24	1992JUL14
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus				3	
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis				8	5
Largemouth bass	Micropterus salmoides	1	2	11	9	5
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	1	7	1		
Green sunfish	Lepomis cyanellus	38	8	4		
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	31	26	5	3	
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus					
Longear sunfish	Lepomis megalotis	29	2	15		
Orangespotted sunfish	Lepomis humilis	11			1	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes	3				
Johnny darter	Etheostoma nigrum					
Bluntnose darter	Etheostoma chlorosomum	1				
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	6	1	2		
Freshwater drum	Aplodinotus grunniens				1	

Water body		Casey Fork	Casey Fork	Casey Fork	Casey Fork	Casey Fork
Date		1995JUN22	1995JUL21	2000JUL27	2003JUL09	2008JUN18
Station code		NJ-07	NJ-07	NJ-07	NJ-07	NJ-07
Species		14	15	24	14	22
Non-native proportion		0.11	0.01	0.09		0.02
Total fish		217	132	222	268	279
Electrode minutes			15	60	60	60
Seine hauls					3	
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus	1				1
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	22	22	25	21	15
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus			3	4	
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio	24	1	20		6
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas	2				10
Creek chub	Semotilus atromaculatus					
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus		1	1	2	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis		48	4		5
Pugnose minnow	Opsopoeodus emiliae			1		
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus			4		4
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus	7				3
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni		2	13	9	5
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					
River redhorse "T"	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus	5		3		6
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	1	1	3	1	3
Black bullhead	Ameiurus melas				1	
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus			5		3
Blackstripe topminnow	Fundulus notatus		3	4		16
Blackspotted topminnow	Fundulus olivaceus			1		
Mosquitofish	Gambusia affinis		11			
Brook silverside	Labidesthes sicculus			2		
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops	2				

Water body		Casey Fork	Casey Fork	Casey Fork	Casey Fork	Casey Fork
Date		1995JUN22	1995JUL21	2000JUL27	2003JUL09	2008JUN18
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					5
Black crappie	Pomoxis nigromaculatus	10		1		1
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis	16		5	1	3
Largemouth bass	Micropterus salmoides	29	2	23	10	3
Spotted bass	Micropterus punctulatus					
Warmouth	Lepomis gulosus	4	2	9	4	16
Green sunfish	Lepomis cyanellus		4	6	21	9
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus		14			
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus		3			
Bluegill	Lepomis macrochirus	90	10	64	39	95
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus			2		
Longear sunfish	Lepomis megalotis		5	8	84	28
Orangespotted sunfish	Lepomis humilis			8	59	12
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid			1	1	1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum		1			
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile					
Freshwater drum	Aplodinotus grunniens	4	2	6	11	29

Water body		Casey Fork	Casey Fork	Casey Fork	Casey Fork	Atchison Creek
Date		2013SEP13	1995JUL27	2003JUL07	1964JUL03	2013JUN12
Station code		NJ-07	NJ-10	NJ-10	NJ-30	NJA-02
Species		17	16	11	9	11
Non-native proportion						0.02
Total fish		227	122	229	126	55
Electrode minutes		21	26	38.25		19.57
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus	1	1			
Bowfin	Amia calva				1	
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum	37	3	12		9
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus				3	
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio					1
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)				66	
Golden shiner	Notemigonus crysoleucas	34		1		
Creek chub	Semotilus atromaculatus			14		
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus		2			
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	8	1	1		
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	6	16			
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni		2	35		1
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus					1
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus					1
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis		2		1	1
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.				14	
Tadpole madtom	Noturus gyrinus					
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus				2	2
Blackstripe topminnow	Fundulus notatus	14	1	3		13
Blackspotted topminnow	Fundulus olivaceus					
Mosquitofish	Gambusia affinis	3	1	5		
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Casey Fork	Casey Fork	Casey Fork	Casey Fork	Atchison Creek
Date		2013SEP13	1995JUL27	2003JUL07	1964JUL03	2013JUN12
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops			1		
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus	1				
Black crappie	Pomoxis nigromaculatus	2				
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis					
Largemouth bass	Micropterus salmoides	8	5	29	1	5
Spotted bass	Micropterus punctulatus		2			
Warmouth	Lepomis gulosus				1	
Green sunfish	Lepomis cyanellus	18	6	60	24	
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus			1		
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	48	65	66	12	11
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus	3				
Longear sunfish	Lepomis megalotis	18	11	1	1	9
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	11				1
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	3				
Bluntnose darter	Etheostoma chlorosomum					
Mud darter	Etheostoma asprigene	4				
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	8	1			
Freshwater drum	Aplodinotus grunniens		3			

Water body		Sevenmile Creek	Sevenmile Creek	Seven Mile Creek	Rayse Creek	Rayse Creek
Date		1995JUL27	2000JUL17	2013JUN12	2008AUG18	1995JUL26
Station code		NJC-01	NJC-01	NJC-01	NK-01	NK-02
Species		16	9	17	22	21
Non-native proportion			0.04			0.01
Total fish		157	75	175	694	191
Electrode minutes		21	38.5	37	34.3	30
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum			19		
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus				6	2
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carasslus auratus					
Carp	Cyprinus carpio		3			1
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas					4
Creek chub	Semotilus atromaculatus	17	5		20	20
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis					
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	9		1		8
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis	2			114	
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	19	1	10	206	2
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus					
Smallmouth buffalo	Ictiobus bubalus			1		
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	1		1	6	4
Spotted sucker	Minytrema melanops					
Creek chubsucker	Erimyzon oblongus	9	11		21	29
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus				7	
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis			4	40	9
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris				1	
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus			1	7	2
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	8	26	2	9	16
Blackstripe topminnow	Fundulus notatus	11	1	27	39	2
Blackspotted topminnow	Fundulus olivaceus				5	
Mosquitofish	Gambusia affinis				13	
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Sevenmile Creek	Sevenmile Creek	Seven Mile Creek	Rayse Creek	Rayse Creek
Date		1995JUL27	2000JUL17	2013JUN12	2008AUG18	1995JUL26
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis			1		1
Largemouth bass	Micropterus salmoides	1	3	4	11	4
Spotted bass	Micropterus punctulatus	2				
Warmouth	Lepomis gulosus	1			1	
Green sunfish	Lepomis cyanellus	31	11	16	23	28
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus					7
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					3
Bluegill	Lepomis macrochirus	36	14	66	5	39
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					1
Redear sunfish	Lepomis microlophus			11		1
Longear sunfish	Lepomis megalotis	4		8	115	2
Orangespotted sunfish	Lepomis humilis					
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid					
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	1			34	1
Bluntnose darter	Etheostoma chlorosomum				1	
Mud darter	Etheostoma asprigene			1		
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	5			10	1
Freshwater drum	Aplodinotus grunniens			2		4

Water body		Rayse Creek	Rayse Creek	Snow Creek	Snow Creek	Snow Creek
Date		2000JUL18	2013AUG05	1995JUL26	2000JUL18	2008JUN17
Station code		NK-02	NK-02	NL-01	NL-01	NL-01
Species		15	20	25	19	15
Non-native proportion				0.02		
Total fish		281	235	341	190	175
Electrode minutes		44	22.6	29.2	49	28.5
Seine hauls						
Hours set						
Paddlefish	Polyodon spathula					
Shortnose gar	Lepisosteus platostomus					
Longnose gar	Lepisosteus osseus					
Spotted gar	Lepisosteus oculatus					
Bowfin	Amia calva					
Skipjack herring	Alosa chrysochloris					
Shad spp.	Dorosoma spp.					
Gizzard shad	Dorosoma cepedianum		3	4		
Threadfin shad	Dorosoma petenense					
Goldeye	Hiodon alosoides					
Mooneye	Hiodon tergisus					
Grass pickerel	Esox americanus		16	2		
Grass carp	Ctenopharyngodon idella					
Bighead carp	Aristichthys nobilis					
Silver carp	Hypophthalmichthys molitrix					
Goldfish	Carassius auratus					
Carp	Cyprinus carpio			6		
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)					
Golden shiner	Notemigonus crysoleucas			2	2	
Creek chub	Semotilus atromaculatus	86		2	7	
Central stoneroller	Campostoma anomalum					
Suckermouth minnow	Phenacobius mirabilis	27				
Blacknose dace	Rhinichthys atratulus					
Silver chub	Macrhybopsis storeriana					
Silvery minnow	Hybognathus nuchalis					
Redfin shiner	Lythrurus umbratilus	11	2	26	3	
Ribbon shiner	Lythrurus fumeus					
Spotfin shiner	Cyprinella spiloptera					
Blacktail shiner	Cyprinella venusta					
Red shiner	Cyprinella lutrensis				2	15
Pugnose minnow	Opsopoeodus emiliae					
Fathead minnow	Pimephales promelas					
Bluntnose minnow	Pimephales notatus	37	3	39	15	13
Bullhead minnow	Pimephales vigilax					
Emerald shiner	Notropis atherinoides					
River shiner	Notropis blennius					
Sand shiner	Notropis ludibundus					
Mimic shiner	Notropis volucellus					
Channel shiner	Notropis wickliffi					
Bigmouth buffalo	Ictiobus cyprinellus			1		
Smallmouth buffalo	Ictiobus bubalus					
Black buffalo	Ictiobus niger					
Unidentified Carpsucker	Carpiodes sp.					
Quillback	Carpiodes cyprinus					
River carpsucker	Carpiodes carpio					
Highfin carpsucker	Carpiodes velifer					
White sucker	Catostomus commersoni	30	2	11	7	11
Spotted sucker	Minytrema melanops					3
Creek chubsucker	Erimyzon oblongus	7	11	57	6	6
River redhorse *T*	Moxostoma carinatum					
Shorthead redhorse	Moxostoma macrolepidotum					
Golden redhorse	Moxostoma erythrurum					
Channel catfish	Ictalurus punctatus		1			
Blue catfish	Ictalurus furcatus					
Yellow bullhead	Ameiurus natalis	1	6	3	3	2
Black bullhead	Ameiurus melas					
Brown bullhead	Ameiurus nebulosus					
Flathead catfish	Pylodictis olivaris					
Madtom spp.	Noturus spp.					
Tadpole madtom	Noturus gyrinus	1	1		1	
Freckled madtom	Noturus nocturnus					
Pirate perch	Aphredoderus sayanus	16	5		12	4
Blackstripe topminnow	Fundulus notatus	5	19	12	13	13
Blackspotted topminnow	Fundulus olivaceus		21	1	1	13
Mosquitofish	Gambusia affinis		6	3	1	
Brook silverside	Labidesthes sicculus					
Inland silversides	Menidia beryllina					
Mississippi silversides	Menidia beryllina					
Striped bass	Morone saxatilis					
White bass	Morone chrysops					

Water body		Rayse Creek	Rayse Creek	Snow Creek	Snow Creek	Snow Creek
Date		2000JUL18	2013AUG05	1995JUL26	2000JUL18	2008JUN17
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops					
Yellow bass	Morone mississippiensis					
Flier	Centrarchus macropterus					
Black crappie	Pomoxis nigromaculatus					
Blacknose crappie	Pomoxis migromaculatus					
White crappie	Pomoxis annularis			2		
Largemouth bass	Micropterus salmoides	17	16	3	11	9
Spotted bass	Micropterus punctulatus			6		
Warmouth	Lepomis gulosus			2		4
Green sunfish	Lepomis cyanellus	10	11	67	21	6
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus					
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus			3		
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus					
Bluegill	Lepomis macrochirus	3	56	43	65	49
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus					
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus					
Redear sunfish	Lepomis microlophus		12	7		
Longear sunfish	Lepomis megalotis		39	35	5	24
Orangespotted sunfish	Lepomis humilis				5	
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid		1			2
Walleye	Stizostedion vitreum					
Sauger	Stizostedion canadense					
Blackside darter	Percina maculata					
Dusky darter	Percina sciera					
River darter	Percina shumardi					
Logperch	Percina caprodes					
Johnny darter	Etheostoma nigrum	26	3	1	10	1
Bluntnose darter	Etheostoma chlorosomum		1			
Mud darter	Etheostoma asprigene					
Orangethroat darter	Etheostoma spectabile					
Spottail darter	Etheostoma squamiceps					
Slough darter	Etheostoma gracile	4		2		
Freshwater drum	Aplodinotus grunniens			1		

Water body		Mud Creek	Prairie Creek	Andy Creek	Andy Creek
Date		2008JUN09	2013JUL23	1995JUL17	2008JUN11
Station code		NZL-01	NZM-02	NZN-13	NZN-15
Species		18	6	18	14
Non-native proportion				0.04	0.05
Total fish		121	53	252	84
Electrode minutes		19	20.67	22.67	27.6
Seine hauls					
Hours set					
Paddlefish	Polyodon spathula				
Shortnose gar	Lepisosteus platostomus				
Longnose gar	Lepisosteus osseus				
Spotted gar	Lepisosteus oculatus				
Bowfin	Amia calva				1
Skipjack herring	Alosa chrysochloris				
Shad spp.	Dorosoma spp.				
Gizzard shad	Dorosoma cepedianum				8
Threadfin shad	Dorosoma petenense				
Goldeye	Hiodon alosoides				
Mooneye	Hiodon tergisus				
Grass pickerel	Esox americanus			1	1
Grass carp	Ctenopharyngodon idella				
Bighead carp	Aristichthys nobilis				
Silver carp	Hypophthalmichthys molitrix				
Goldfish	Carassius auratus				
Carp	Cyprinus carpio			9	4
Non-carp minnow spp.	Cyprinidae spp. (except Cyprinus carpio)				
Golden shiner	Notemigonus crysoleucas	3	9	5	2
Creek chub	Semotilus atromaculatus	7	3		
Central stoneroller	Campostoma anomalum	1			
Suckermouth minnow	Phenacobius mirabilis				
Blacknose dace	Rhinichthys atratulus				
Silver chub	Macrhybopsis storeriana				
Silvery minnow	Hybognathus nuchalis				
Redfin shiner	Lythrurus umbratilus	13			
Ribbon shiner	Lythrurus fumeus				
Spotfin shiner	Cyprinella spiloptera				
Blacktail shiner	Cyprinella venusta				
Red shiner	Cyprinella lutrensis	6			
Pugnose minnow	Opsopoeodus emiliae				
Fathead minnow	Pimephales promelas				
Bluntnose minnow	Pimephales notatus	27			
Bullhead minnow	Pimephales vigilax				
Emerald shiner	Notropis atherinoides				
River shiner	Notropis blennius				
Sand shiner	Notropis ludibundus				
Mimic shiner	Notropis volucellus				
Channel shiner	Notropis wickliffi				
Bigmouth buffalo	Ictiobus cyprinellus			3	
Smallmouth buffalo	Ictiobus bubalus			2	
Black buffalo	Ictiobus niger				
Unidentified Carpsucker	Carpiodes sp.				
Quillback	Carpiodes cyprinus			2	
River carpsucker	Carpiodes carpio				
Highfin carpsucker	Carpiodes velifer				
White sucker	Catostomus commersoni			2	2
Spotted sucker	Minytrema melanops				
Creek chubsucker	Erimyzon oblongus	2		5	
River redhorse *T*	Moxostoma carinatum				
Shorthead redhorse	Moxostoma macrolepidotum				
Golden redhorse	Moxostoma erythrurum				
Channel catfish	Ictalurus punctatus				
Blue catfish	Ictalurus furcatus				
Yellow bullhead	Ameiurus natalis			1	
Black bullhead	Ameiurus melas			3	
Brown bullhead	Ameiurus nebulosus				
Flathead catfish	Pylodictis olivaris				
Madtom spp.	Noturus spp.				
Tadpole madtom	Noturus gyrinus				
Freckled madtom	Noturus nocturnus				
Pirate perch	Aphredoderus sayanus	4	16	7	1
Blackstripe topminnow	Fundulus notatus	7			16
Blackspotted topminnow	Fundulus olivaceus	13			
Mosquitofish	Gambusia affinis	1		1	
Brook silverside	Labidesthes sicculus				
Inland silversides	Menidia beryllina				
Mississippi silversides	Menidia beryllina				
Striped bass	Morone saxatilis				
White bass	Morone chrysops				

Water body		Mud Creek	Prairie Creek	Andy Creek	Andy Creek
Date		2008JUN09	2013JUL23	1995JUL17	2008JUN11
Striped bass x White bass hybrid (Wiper)	Morone saxatilis x M. chrysops				
Yellow bass	Morone mississippiensis				
Flier	Centrarchus macropterus				
Black crappie	Pomoxis nigromaculatus	1			3
Blacknose crappie	Pomoxis migromaculatus				
White crappie	Pomoxis annularis				
Largemouth bass	Micropterus salmoides			2	
Spotted bass	Micropterus punctulatus				
Warmouth	Lepomis gulosus			5	5
Green sunfish	Lepomis cyanellus	4	21	22	2
Green sunfish x Warmouth hybrid	Lepomis cyanellus x L. gulosus				
Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus				
Longear sunfish x Green sunfish hybrid	Lepomis megalotis x L. cyanellus				
Bluegill	Lepomis macrochirus	23	3	172	35
Bluegill x Redear sunfish hybrid	Lepomis macrochirus x L. microlophus				
Longear sunfish x Bluegill hybrid	Lepomis megalotis x L. macrochirus				
Redear sunfish	Lepomis microlophus				
Longear sunfish	Lepomis megalotis	3			2
Orangespotted sunfish	Lepomis humilis	3			
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid			7	1
Walleye	Stizostedion vitreum				
Sauger	Stizostedion canadense				
Blackside darter	Percina maculata				
Dusky darter	Percina sciera				
River darter	Percina shumardi				
Logperch	Percina caprodes				
Johnny darter	Etheostoma nigrum	1			
Bluntnose darter	Etheostoma chlorosomum				
Mud darter	Etheostoma asprigene				1
Orangethroat darter	Etheostoma spectabile	2			
Spottail darter	Etheostoma squamiceps				
Slough darter	Etheostoma gracile		1	2	
Freshwater drum	Aplodinotus grunniens			1	

Water body		Total	Big Muddy River	Big Muddy River
ID			14458	14457
Date			2016NOV10	2016NOV09
Station code			N-12	N-23
Species		29	24	20
Non-native proportion		0.04	0.03	0.15
Total fish		241	144	97
Electrode minutes			60	60
Seine hauls				
Shortnose gar	Lepisosteus platostomus	10	2	8
Longnose gar	Lepisosteus osseus	6	2	4
Spotted gar	Lepisosteus oculatus	2	2	
Skipjack herring	Alosa chrysochloris	1		1
Gizzard shad	Dorosoma cepedianum	57	54	3
Goldeye	Hiodon alosoides	1	1	
Grass carp	Ctenopharyngodon idella	2	1	1
Silver carp	Hypophthalmichthys molitrix	8		8
Carp	Cyprinus carpio	10	4	6
Redfin shiner	Lythrurus umbratilus	1	1	
Spotfin shiner	Cyprinella spiloptera	13	6	7
Steelcolor shiner	Cyprinella whipplei	2	2	
Red shiner	Cyprinella lutrensis	10	10	
Bullhead minnow	Pimephales vigilax	9	8	1
Emerald shiner	Notropis atherinoides	6	2	4
Bigmouth buffalo	Ictiobus cyprinellus	28	16	12
Smallmouth buffalo	Ictiobus bubalus	9	1	8
Black buffalo	Ictiobus niger	2		2
Channel catfish	Ictalurus punctatus	3	2	1
Blackspotted topminnow	Fundulus olivaceus	1	1	
Brook silverside	Labidesthes sicculus	2	2	
White bass	Morone chrysops	1	1	
Black crappie	Pomoxis nigromaculatus	3	1	2
White crappie	Pomoxis annularis	4	4	
Spotted bass	Micropterus punctulatus	1		1
Bluegill	Lepomis macrochirus	13	7	6
Longear sunfish	Lepomis megalotis	15	11	4
Orangespotted sunfish	Lepomis humilis	2		2
Freshwater drum	Aplodinotus grunniens	19	3	16

Water body		Total	Big Muddy River	Big Muddy River	Big Muddy River
Date			2017NOV02	2017NOV03	2017OCT24
Station code			N-12	N-99	N-23
Species		35	26	23	20
Non-native proportion		0.05	0.07	0.04	0.23
Total fish		322	111	145	66
Electrode minutes			60	60	60
Seine hauls					
Shortnose gar	Lepisosteus platostomus	14	1	10	3
Longnose gar	Lepisosteus osseus	7	1	1	5
Spotted gar	Lepisosteus oculatus	1		1	
Bowfin	Amia calva	4	3	1	
Gizzard shad	Dorosoma cepedianum	83	37	39	7
Threadfin shad	Dorosoma petenense	2		2	
Grass carp	Ctenopharyngodon idella	2			2
Silver carp	Hypophthalmichthys molitrix	15		3	12
Carp	Cyprinus carpio	9	8	1	
Redfin shiner	Lythrurus umbratilus	9	4	4	1
Bluntnose minnow	Pimephales notatus	3			3
Bullhead minnow	Pimephales vigilax	15	5	10	
Emerald shiner	Notropis atherinoides	18	1	8	9
Sand shiner	Notropis ludibundus	3	3		
Bigmouth buffalo	Ictiobus cyprinellus	5	2		3
Smallmouth buffalo	Ictiobus bubalus	8	5	2	1
Black buffalo	Ictiobus niger	11	5	3	3
River carpsucker	Carpiodes carpio	6	3	1	2
Shorthead redhorse	Moxostoma macrolepidotum	1	1		
Channel catfish	Ictalurus punctatus	3		1	2
Flathead catfish	Pylodictis olivaris	1			1
Blackstripe topminnow	Fundulus notatus	5	1	4	
Blackspotted topminnow	Fundulus olivaceus	1	1		
Mosquitofish	Gambusia affinis	5	5		
Brook silverside	Labidesthes sicculus	2	1	1	
Inland silversides	Menidia beryllina	1			1
White bass	Morone chrysops	6		3	3
Black crappie	Pomoxis nigromaculatus	1	1		
Largemouth bass	Micropterus salmoides	2	2		
Warmouth	Lepomis gulosus	1	1		
Green sunfish	Lepomis cyanellus	5	2	1	2
Bluegill	Lepomis macrochirus	32	8	20	4
Longear sunfish	Lepomis megalotis	15	3	11	1
Orangespotted sunfish	Lepomis humilis	7	1	6	
Freshwater drum	Aplodinotus grunniens	19	6	12	1

Water body		Total	Big Muddy River	Big Muddy River	Big Muddy River	Cedar Creek
Date			2018JUL12	2018JUL25	2018JUL25	2018MAY29
Station code			N-05	N-06	N-11	NA-04
Species		64	16	23	17	9
Non-native proportion		0		0.15	0.06	
Total fish		5740	95	134	96	255
Electrode minutes			33	60	60	34.72
Seine hauls						
Unidentified Gar	Lepisosteus sp.	13				
Shortnose gar	Lepisosteus platostomus	46		15	6	
Longnose gar	Lepisosteus osseus	15		2	5	
Spotted gar	Lepisosteus oculatus	10		5	2	
Bowfin	Amia calva	8		5		
Gizzard shad	Dorosoma cepedianum	31		8	9	
Grass pickerel	Esox americanus	27	2			
Grass carp	Ctenopharyngodon idella	2		1		
Silver carp	Hypophthalmichthys molitrix	1		1		
Carp	Cyprinus carpio	40		18	6	
Golden shiner	Notemigonus crysoleucas	16	1			
Creek chub	Semotilus atromaculatus	699				142
Central stoneroller	Campostoma anomalum	734				59
Silver chub	Macrhybopsis storeriana	11				
Silvery minnow	Hybognathus nuchalis	8				
Redfin shiner	Lythrurus umbratilus	288	8			
Spotfin shiner	Cyprinella spiloptera	1				
Red shiner	Cyprinella lutrensis	60		4	4	
Bluntnose minnow	Pimephales notatus	720	3	1		6
Bullhead minnow	Pimephales vigilax	4			2	
Emerald shiner	Notropis atherinoides	40		1	2	
Sand shiner	Notropis ludibundus	176				
Silverjaw minnow	Notropis buccatus	85				
Bigmouth buffalo	Ictiobus cyprinellus	9		5	1	
Smallmouth buffalo	Ictiobus bubalus	64		30	33	
Black buffalo	Ictiobus niger	11		7	3	
River carpsucker	Carpiodes carpio	19		8	10	
White sucker	Catostomus commersoni	129				
Spotted sucker	Minytrema melanops	3				
Creek chubsucker	Erimyzon oblongus	159	4			2
Golden redhorse	Moxostoma erythrurum	1				
Channel catfish	Ictalurus punctatus	22	1	5	4	
Yellow bullhead	Ameiurus natalis	71				2
Black bullhead	Ameiurus melas	2				
Flathead catfish	Pylodictis olivaris	4		1	1	
Tadpole madtom	Noturus gyrinus	8	1			
Pirate perch	Aphredoderus sayanus	118	7			
Blackstripe topminnow	Fundulus notatus	263	4			
Blackspotted topminnow	Fundulus olivaceus	118	15			
Mosquitofish	Gambusia affinis	39	1			
White bass	Morone chrysops	7				
Flier	Centrarchus macropterus	2				
Black crappie	Pomoxis nigromaculatus	3				
White crappie	Pomoxis annularis	5		5		
Largemouth bass	Micropterus salmoides	292	5	1		
Spotted bass	Micropterus punctulatus	3		3		
Warmouth	Lepomis gulosus	22	11	1		1
Green sunfish	Lepomis cyanellus	225	3			17
Bluegill	Lepomis macrochirus	416	7		1	2
Redear sunfish	Lepomis microlophus	31				
Longear sunfish	Lepomis megalotis	448	22	2	1	
Orangespotted sunfish	Lepomis humilis	1				
Unidentified Sunfish hybrid	Unidentified Centrarchidae hybrid	9				
Sauger	Stizostedion canadense	3				
Blackside darter	Percina maculata	2				
Dusky darter	Percina sciera	1				
Logperch	Percina caprodes	5				
Johnny darter	Etheostoma nigrum	59				
Bluntnose darter	Etheostoma chlorosomum	1				
Rainbow darter	Etheostoma caeruleum	2				
Mud darter	Etheostoma asprigene	1				
Orangethroat darter	Etheostoma spectabile	79				24
Stripetail darter	Etheostoma kennicotti	5				
Fantail darter	Etheostoma flabellare	4				
Slough darter	Etheostoma gracile	3				
Freshwater drum	Aplodinotus grunniens	36		5	6	

*Six Mile Creek -poor sample; high conductivity had to use MS,lots of debris made it hard to sample

Mill Creek	Alto Pass Creek	Kinkaid Creek	Little Kinkaid Creek	Beaucoup Creek	Rattlesnake Creek	anther Creek (South	Swanwick Creek	Crab Orchard Creek	le Crab Orchard Cre
2018JUN06	2018JUN06	2019JUN05	2018JUN05	2018JUL09	2018JUN05	2018JUN20	2018JUN20	2018JUN11	2018JUN14
NAFA-02	NAI-01	NB-02	NBA-01	NC-09	NCB-01	NCE-02	NCK-02	ND-06	NDA-01
10	6	18	23	14	17	14	14	16	17
				0.06		0.01			
130	289	990	804	111	218	114	103	188	105
21.62	43.37	36	33.75	22.6	32.55	32.23	26	36.13	31.93
		13							
						1			
						2			
			1			12			
				6				8	9
				7		1			
							2	1	7
9	172	58	24	23	20			6	
65	44	180	364		14				
					7				1
2		38	4		9		13	1	
		10			22				
7		312	54	1	26				7
		145	23		8				
		75	10						
		16	3		1				
			1		1				
		3		15				48	
			1						
						7			
1		4	5	3		5	3		5
								1	1
				28	1		7	3	3
		13	17	2	16	1	15	25	3
1	2		1						1
			5	4					6
					1	1			
									1
1			224	4		8	3	4	3
			2			3	1	1	1
3	4		10	8	21		11	16	2
39	29		22	7	13	66	28	45	29
				2			6	7	
		108	18		51	3	10	18	24
							1		
	1				2			2	1
							1		
		1							
		3	1			1			
		3		1	4		2		
								1	
			2						
		1							
2	37	2	8		1				
		5							
			4						
									1
						3		1	

Indian Creek	Little Grassy Creek	Little Muddy River	*Six Mile Creek	Little Indian Creek	Pond Creek	Sugar Camp Creek	Casey Fork	Dodds Creek	Rayse Creek
2018JUN12	2018JUN12	2018JUL09	2018JUN20	2018JUN21	2018JUN11	2018JUN19	2018JUL12	2018JUN19	2018JUN21
NDCB-02	NDDA-01	NE-06	NEA-02	NEE-01	NG-05	NHH-02	NJ-10	NJB-01	NK-01
13	9	17	4	10	9	15	17	12	13
547	38	196	8	193	150	143	145	92	204
37	30.37	24				22	23.22	17.93	22.5
	1		1						
				4					
7		18		3	1	16	1	62	33
6		1							
51	7	3		145			1		
							1		16
230	2	16		5		8	7	4	29
		62				4	7	6	26
15		12				54	6		
1	2								
2		1				1	4	1	31
						2			
						1			4
		17				30	3	3	8
		24		22	50	1	14	4	16
5	12	11	2	2	60	2	2		1
				1	11		7	3	
					2				
3	1	3		5	9	1	10	1	
			1						
81	2	9		1	4	10	8	3	5
9	3	7	4		8	8	39	1	5
					3		8		
131	8	2		5		4	2	1	24
1					2				
		1							
		7				1	25	3	6
5									
		2							

Novack Creek	Mud Creek	Big Muddy River
2018JUL09	2018JUN14	2018SEP06
NKC-01	NZL-01	N-03
11	16	22
		0.06
208	38	146
24	21.8	60
	2	22
		8
		3
		1
		1
		1
		8
	1	
102	2	
	1	
		11
6		
		1
	3	
	2	
		2
		37
		3
		1
		1
		1
4		
	1	
		2
2	1	
		2
5	3	
33	3	
	1	
	1	
		7
6		
6	1	
34	3	7
5		
	11	3
		3
5	2	
		21

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Website: www.summitenviro.com

CLIENT: Mach Mining
PDL: 21407-1
SAMPLE ID: Pond 1
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.9	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	144	mg/L	10	2320 B	10/31/19 OG
Sulfate	113	mg/L	5	4500 E	10/29/19 KR
Chloride	80	mg/L	10	4500 B	10/29/19 KR
Hardness	244	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	< 5	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.372	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.195	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21407-2
SAMPLE ID: Pond 2
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT: DRY
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	*	Unit	1 - 14	4500 B	*
Acidity	*	mg/L	10	2310 B	*
Alkalinity	*	mg/L	10	2320 B	*
Sulfate	*	mg/L	5	4500 E	*
Chloride	*	mg/L	10	4500 B	*
Hardness	*	mg/L	10	2340 C	*
Total Suspended Solids	*	mg/L	5	2540 D	*
Settleable Solids	*	mL/L	0.25	2540 F	*
Cyanide	*	mg/L	0.02	335.4	*
Phenols, Total Recoverable	*	mg/L	0.01	420.4	*
Antimony	*	mg/L	0.0100	200.7	*
Arsenic	*	mg/L	0.0100	200.7	*
Beryllium	*	mg/L	0.0010	200.7	*
Cadmium, Total	*	mg/L	0.0020	200.7	*
Cadmium, Dissolved	*	mg/L	0.0020	200.7	*
Chromium	*	mg/L	0.0050	200.7	*
Copper	*	mg/L	0.0050	200.7	*
Iron, Total	*	mg/L	0.100	200.7	*
Iron, Dissolved	*	mg/L	0.100	200.7	*
Lead	*	mg/L	0.0060	200.7	*
Manganese, Total	*	mg/L	0.0100	200.7	*
Manganese, Dissolved	*	mg/L	0.0100	200.7	*
Mercury	*	mg/L	0.002	245.1	*
Nickel, Total	*	mg/L	0.0050	200.7	*
Nickel, Dissolved	*	mg/L	0.0050	200.7	*
Selenium	*	mg/L	0.0100	200.7	*
Silver	*	mg/L	0.0050	200.7	*
Thallium	*	mg/L	0.0200	200.7	*
Zinc	*	mg/L	0.0200	200.7	*

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21407-3
SAMPLE ID: Pond 3
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	10.7	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	176	mg/L	10	2320 B	10/31/19 OG
Sulfate	40	mg/L	5	4500 E	10/29/19 KR
Chloride	15	mg/L	10	4500 B	10/29/19 KR
Hardness	180	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	48	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	1.72	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.625	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21407-4
SAMPLE ID: Pond 4
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.3	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	136	mg/L	10	2320 B	10/31/19 OG
Sulfate	93	mg/L	5	4500 E	10/29/19 KR
Chloride	30	mg/L	10	4500 B	10/29/19 KR
Hardness	300	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	11	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.593	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.368	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.0203	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT:	Mach Mining	**REPORT DATE:**	11/19/19
PDL:	21407-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/25/19	**DATE RECEIVED:**	10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.3	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	160	mg/L	10	2320 B	10/31/19 OG
Sulfate	60	mg/L	5	4500 E	10/29/19 KR
Chloride	18	mg/L	10	4500 B	10/29/19 KR
Hardness	276	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	39	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	2.48	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.736	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.0052	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.0255	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21407-6
SAMPLE ID: Pond 6
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.4	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	640	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,320	mg/L	5	4500 E	10/29/19 KR
Chloride	1,490	mg/L	10	4500 B	10/29/19 KR
Hardness	340	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	15	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.651	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.0772	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.0245	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	0.0168	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.0217	mg/L	0.0200	200.7	11/15/19 WA

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21407-7
SAMPLE ID: Pond 7
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.5	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	412	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,220	mg/L	5	4500 E	10/29/19 KR
Chloride	1,350	mg/L	10	4500 B	10/29/19 KR
Hardness	580	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	12	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	0.0089	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	0.0072	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	0.0123	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.801	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	2.05	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	1.82	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.140	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	0.113	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.227	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT: Mach Mining
PDL: 21407-8
SAMPLE ID: Pond 8
DATE SAMPLED: 10/25/19

REPORT DATE: 11/19/19
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	6.9	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	26	mg/L	10	2310 B	10/31/19 OG
Alkalinity	312	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,633	mg/L	5	4500 E	10/29/19 KR
Chloride	1,590	mg/L	10	4500 B	10/29/19 KR
Hardness	980	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	91	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	1.50	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	0.0114	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	0.0031	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	0.0155	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	60.3	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	4.19	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	3.61	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.222	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	0.100	mg/L	0.0050	200.7	11/15/19 WA
Selenium	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	0.288	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT:	Mach Mining	**REPORT DATE:**	11/19/19
PDL:	21407-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/25/19	**DATE RECEIVED:**	10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	484	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,600	mg/L	5	4500 E	10/29/19 KR
Chloride	1,380	mg/L	10	4500 B	10/29/19 KR
Hardness	400	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	22	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/15/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Iron, Total	0.647	mg/L	0.100	200.7	11/15/19 WA
Iron, Dissolved	< 0.100	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/15/19 WA
Manganese, Total	0.239	mg/L	0.0100	200.7	11/15/19 WA
Manganese, Dissolved	< 0.0100	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.0488	mg/L	0.0050	200.7	11/15/19 WA
Nickel, Dissolved	0.0341	mg/L	0.0050	200.7	11/15/19 WA
Selenium	0.0172	mg/L	0.0100	200.7	11/15/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/15/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA
Zinc	< 0.0200	mg/L	0.0200	200.7	11/15/19 WA

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-1	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.6	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	116	mg/L	10	2320 B	10/31/19 OG
Sulfate	100	mg/L	5	4500 E	11/1/19 KR
Chloride	56	mg/L	10	4500 B	11/1/19 OG
Hardness	240	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	9	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.003	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.680	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.063	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.052	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-2	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.2	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	112	mg/L	10	2320 B	10/31/19 OG
Sulfate	350	mg/L	5	4500 E	11/1/19 KR
Chloride	52	mg/L	10	4500 B	11/1/19 OG
Hardness	304	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	7	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0009	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	0.0008	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.195	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.376	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.323	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.023	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.019	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.004	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-3	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.0	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	148	mg/L	10	2320 B	10/31/19 OG
Sulfate	46	mg/L	5	4500 E	11/1/19 KR
Chloride	< 10	mg/L	10	4500 B	11/1/19 OG
Hardness	184	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	5	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.001	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.003	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.634	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.106	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.250	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.025	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-4	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.9	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	12	mg/L	10	2310 B	10/31/19 OG
Alkalinity	156	mg/L	10	2320 B	10/31/19 OG
Sulfate	86	mg/L	5	4500 E	11/1/19 KR
Chloride	14	mg/L	10	4500 B	11/1/19 OG
Hardness	232	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	24	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.499	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.067	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.085	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.005	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.003	mg/L	0.001	3125 B	11/25/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-5	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.8	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	108	mg/L	10	2320 B	10/31/19 OG
Sulfate	180	mg/L	5	4500 E	11/1/19 KR
Chloride	32	mg/L	10	4500 B	11/1/19 OG
Hardness	284	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	43	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.002	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	1.575	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.321	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.296	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.135	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.004	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.003	mg/L	0.001	3125 B	11/25/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-6	**COMMENT:**	Precip/ Grab W2
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/28/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.2	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	16	mg/L	10	2310 B	10/31/19 OG
Alkalinity	272	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,567	mg/L	5	4500 E	11/1/19 KR
Chloride	880	mg/L	10	4500 B	11/1/19 OG
Hardness	632	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	31	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0073	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	0.0073	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.012	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.704	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.147	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	1.749	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	1.749	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.096	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.094	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.019	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-7	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.1	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	16	mg/L	10	2310 B	10/31/19 OG
Alkalinity	392	mg/L	10	2320 B	10/31/19 OG
Sulfate	967	mg/L	5	4500 E	11/1/19 KR
Chloride	776	mg/L	10	4500 B	11/1/19 OG
Hardness	628	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	26	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.006	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.290	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.062	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.320	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.128	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.021	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.021	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.006	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-8	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.2	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	340	mg/L	10	2320 B	10/31/19 OG
Sulfate	967	mg/L	5	4500 E	11/1/19 KR
Chloride	1,516	mg/L	10	4500 B	11/1/19 OG
Hardness	672	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	25	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.007	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.391	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.103	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.417	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.197	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.023	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.021	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.009	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21426-9	**COMMENT:**	Grab W2
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/30/19	**DATE RECEIVED:**	10/30/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.3	Unit	1 - 14	4500 B	10/30/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	320	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,333	mg/L	5	4500 E	11/1/19 KR
Chloride	834	mg/L	10	4500 B	11/1/19 OG
Hardness	524	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	27	mg/L	5	2540 D	10/30/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/30/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0005	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.009	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.001	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.267	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.351	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.224	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.033	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.026	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.022	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	0.0005	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21449-1	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/5/19	**DATE RECEIVED:**	11/5/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.7	Unit	1 - 14	4500 B	11/5/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	36	mg/L	10	2320 B	11/11/19 OG
Sulfate	540	mg/L	5	4500 E	11/11/19 KR
Chloride	26	mg/L	10	4500 B	11/6/19 KR
Hardness	610	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	39	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/5/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/14/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.354	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.063	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.037	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.006	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.005	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.015	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-1	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.6	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	116	mg/L	10	2320 B	11/11/19 OG
Sulfate	120	mg/L	5	4500 E	11/11/19 KR
Chloride	52	mg/L	10	4500 B	11/12/19 OG
Hardness	220	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.359	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.077	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.044	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.002	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.001	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.011	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-2	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	108	mg/L	10	2320 B	11/11/19 OG
Sulfate	60	mg/L	5	4500 E	11/11/19 KR
Chloride	< 10	mg/L	10	4500 B	11/12/19 OG
Hardness	108	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.003	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.275	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.073	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.054	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.002	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.009	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-3	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.2	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	100	mg/L	10	2320 B	11/11/19 OG
Sulfate	100	mg/L	5	4500 E	11/11/19 KR
Chloride	36	mg/L	10	4500 B	11/12/19 OG
Hardness	180	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.002	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.249	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.059	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.004	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.008	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-4	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.1	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	104	mg/L	10	2320 B	11/11/19 OG
Sulfate	145	mg/L	5	4500 E	11/11/19 KR
Chloride	34	mg/L	10	4500 B	11/12/19 OG
Hardness	188	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	35	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.002	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.002	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	1.233	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.245	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.213	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.126	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.007	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21451-5
SAMPLE ID: Pond 6
DATE SAMPLED: 11/6/19

REPORT DATE: 11/27/19
COMMENT: Grab W3
SAMPLED BY: Client-BM
DATE RECEIVED: 11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.6	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	12	mg/L	10	2310 B	11/11/19 OG
Alkalinity	176	mg/L	10	2320 B	11/11/19 OG
Sulfate	560	mg/L	5	4500 E	11/11/19 KR
Chloride	248	mg/L	10	4500 B	11/12/19 OG
Hardness	480	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	13	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0014	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	0.0014	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.004	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.002	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.520	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.112	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.438	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.390	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.025	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.024	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.009	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-6	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	32	mg/L	10	2310 B	11/11/19 OG
Alkalinity	720	mg/L	10	2320 B	11/11/19 OG
Sulfate	1,800	mg/L	5	4500 E	11/11/19 KR
Chloride	1,600	mg/L	10	4500 B	11/12/19 OG
Hardness	980	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0003	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.010	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.463	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	0.112	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.404	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.394	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.011	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.010	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.020	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21451-7	**COMMENT:**	Grab W3
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/6/19	**DATE RECEIVED:**	11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	24	mg/L	10	2310 B	11/11/19 OG
Alkalinity	668	mg/L	10	2320 B	11/11/19 OG
Sulfate	1,867	mg/L	5	4500 E	11/11/19 KR
Chloride	1,799	mg/L	10	4500 B	11/12/19 OG
Hardness	780	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0003	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.010	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.399	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.374	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.356	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.011	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.010	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.020	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT: Mach Mining
PDL: 21451-8
SAMPLE ID: Pond 9
DATE SAMPLED: 11/6/19

REPORT DATE: 11/27/19
COMMENT: Grab W3
SAMPLED BY: Client-BM
DATE RECEIVED: 11/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	11/6/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	432	mg/L	10	2320 B	11/11/19 OG
Sulfate	1,467	mg/L	5	4500 E	11/11/19 KR
Chloride	1,200	mg/L	10	4500 B	11/12/19 OG
Hardness	460	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	46	mg/L	5	2540 D	11/7/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.008	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.004	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.210	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.057	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.013	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.013	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.021	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-1	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.1	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	80	mg/L	10	2320 B	11/19/19 KR
Sulfate	115	mg/L	5	4500 E	11/15/19 KR
Chloride	54	mg/L	10	4500 B	11/18/19 OG
Hardness	108	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	7	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.260	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.085	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-2	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.3	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	100	mg/L	10	2320 B	11/19/19 KR
Sulfate	660	mg/L	5	4500 E	11/15/19 KR
Chloride	156	mg/L	10	4500 B	11/18/19 OG
Hardness	460	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	17	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	0.0008	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	0.0008	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.164	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.068	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.511	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	0.511	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.003	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-3	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.5	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	64	mg/L	10	2320 B	11/19/19 KR
Sulfate	63	mg/L	5	4500 E	11/15/19 KR
Chloride	12	mg/L	10	4500 B	11/18/19 OG
Hardness	104	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	5	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.473	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.209	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-4	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.9	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	88	mg/L	10	2320 B	11/19/19 KR
Sulfate	107	mg/L	5	4500 E	11/15/19 KR
Chloride	22	mg/L	10	4500 B	11/18/19 OG
Hardness	168	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	19	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.019	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.127	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.058	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-5	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.4	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	72	mg/L	10	2320 B	11/19/19 KR
Sulfate	130	mg/L	5	4500 E	11/15/19 KR
Chloride	38	mg/L	10	4500 B	11/18/19 OG
Hardness	176	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	19	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.384	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.147	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.139	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-6	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.1	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	172	mg/L	10	2320 B	11/19/19 KR
Sulfate	760	mg/L	5	4500 E	11/15/19 KR
Chloride	526	mg/L	10	4500 B	11/18/19 OG
Hardness	420	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	10	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	0.0007	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	0.0007	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.007	mg/L	0.001	3125 B	11/27/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.155	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.088	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.508	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	0.508	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.009	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-7	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	16	mg/L	10	2310 B	11/19/19 KR
Alkalinity	740	mg/L	10	2320 B	11/19/19 KR
Sulfate	1,933	mg/L	5	4500 E	11/15/19 KR
Chloride	1,849	mg/L	10	4500 B	11/18/19 OG
Hardness	1,200	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	14	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.021	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.045	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	1.156	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	0.943	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.597	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	0.597	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.020	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-8	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.0	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	630	mg/L	10	2320 B	11/19/19 KR
Sulfate	1,700	mg/L	5	4500 E	11/15/19 KR
Chloride	1,500	mg/L	10	4500 B	11/18/19 OG
Hardness	760	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	14	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.014	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.072	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.149	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	0.416	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	0.416	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.016	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21478-9	**COMMENT:**	Grab Wk4
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	440	mg/L	10	2320 B	11/19/19 KR
Sulfate	1,500	mg/L	5	4500 E	11/15/19 KR
Chloride	1,250	mg/L	10	4500 B	11/18/19 OG
Hardness	360	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	16	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.010	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.008	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	< 0.050	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.016	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT: Mach Mining
PDL: 21505-1
SAMPLE ID: Pond 1
DATE SAMPLED: 11/20/19

REPORT DATE: 12/6/19
COMMENT: Grab W5
SAMPLED BY: Client-BM
DATE RECEIVED: 11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.9	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	68	mg/L	10	2320 B	11/22/19 KR
Sulfate	120	mg/L	5	4500 E	11/25/19 KR
Chloride	60	mg/L	10	4500 B	11/21/19 KR
Hardness	120	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	8	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.002	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.808	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.197	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.121	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.057	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.003	mg/L	0.001	3125 B	12/2/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-2	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.7	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	100	mg/L	10	2320 B	11/22/19 KR
Sulfate	590	mg/L	5	4500 E	11/25/19 KR
Chloride	172	mg/L	10	4500 B	11/21/19 KR
Hardness	550	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	5	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	0.0013	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	0.0013	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.002	mg/L	0.001	3125 B	12/2/19 AK
Copper	0.005	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.218	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.104	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.641	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.641	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.029	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.029	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.006	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-3	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	44	mg/L	10	2320 B	11/22/19 KR
Sulfate	68	mg/L	5	4500 E	11/25/19 KR
Chloride	16	mg/L	10	4500 B	11/21/19 KR
Hardness	104	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.548	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.262	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.185	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.146	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.002	mg/L	0.001	3125 B	12/2/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT: Mach Mining
PDL: 21505-4
SAMPLE ID: Pond 4
DATE SAMPLED: 11/20/19

REPORT DATE: 12/6/19
COMMENT: Grab W5
SAMPLED BY: Client-BM
DATE RECEIVED: 11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.3	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	68	mg/L	10	2320 B	11/22/19 KR
Sulfate	117	mg/L	5	4500 E	11/25/19 KR
Chloride	24	mg/L	10	4500 B	11/21/19 KR
Hardness	176	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	11	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.327	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.118	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.101	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.040	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.005	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.005	mg/L	0.001	3125 B	12/2/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-5	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.7	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	68	mg/L	10	2320 B	11/22/19 KR
Sulfate	135	mg/L	5	4500 E	11/25/19 KR
Chloride	38	mg/L	10	4500 B	11/21/19 KR
Hardness	172	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	20	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.001	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.754	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.241	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.226	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.131	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.003	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.003	mg/L	0.001	3125 B	12/2/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT: Mach Mining
PDL: 21505-6
SAMPLE ID: Pond 6
DATE SAMPLED: 11/20/19

REPORT DATE: 12/6/19
COMMENT: Grab W5
SAMPLED BY: Client-BM
DATE RECEIVED: 11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.2	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	132	mg/L	10	2320 B	11/22/19 KR
Sulfate	933	mg/L	5	4500 E	11/25/19 KR
Chloride	605	mg/L	10	4500 B	11/21/19 KR
Hardness	372	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	8	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	0.0010	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	0.0009	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.006	mg/L	0.001	3125 B	12/2/19 AK
Copper	0.012	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.302	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.071	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.675	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.629	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.032	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.028	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.016	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-7	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.7	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	556	mg/L	10	2320 B	11/22/19 KR
Sulfate	1,800	mg/L	5	4500 E	11/25/19 KR
Chloride	1,719	mg/L	10	4500 B	11/21/19 KR
Hardness	740	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	12	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.012	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.750	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.223	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.558	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.558	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.017	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.016	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.018	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT: Mach Mining
PDL: 21505-8
SAMPLE ID: Pond 8
DATE SAMPLED: 11/20/19

REPORT DATE: 12/6/19
COMMENT: Grab W5
SAMPLED BY: Client-BM
DATE RECEIVED: 11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	18	mg/L	10	2310 B	11/22/19 KR
Alkalinity	640	mg/L	10	2320 B	11/22/19 KR
Sulfate	2,000	mg/L	5	4500 E	11/25/19 KR
Chloride	1,969	mg/L	10	4500 B	11/21/19 KR
Hardness	800	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	14	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.004	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.015	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	1.919	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.366	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.569	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.566	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.014	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.012	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.024	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21505-9	**COMMENT:**	Grab W5
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	480	mg/L	10	2320 B	11/22/19 KR
Sulfate	1,733	mg/L	5	4500 E	11/25/19 KR
Chloride	1,530	mg/L	10	4500 B	11/21/19 KR
Hardness	310	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	18	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	0.003	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.004	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.013	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	0.385	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	0.166	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.091	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.048	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.022	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.020	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.027	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

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CLIENT: Mach Mining
PDL: 21533-1
SAMPLE ID: Pond 2
DATE SAMPLED: 11/26/19

REPORT DATE: 12/11/19
COMMENT: W1 makeup
SAMPLED BY: Client-JP
DATE RECEIVED: 11/26/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.6	Unit	1 - 14	4500 B	11/26/19 OG
Acidity	< 10	mg/L	10	2310 B	12/2/19 OG
Alkalinity	120	mg/L	10	2320 B	12/2/19 OG
Sulfate	867	mg/L	5	4500 E	11/26/19 KR
Chloride	250	mg/L	10	4500 B	12/3/19 KR
Hardness	800	mg/L	10	2340 C	12/2/19 OG
Total Suspended Solids	8	mg/L	5	2540 D	12/3/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/26/19 OG
Cyanide	< 0.02	mg/L	0.02	335.4	12/10/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/5/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/5/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/5/19 AK
Cadmium, Total	0.0022	mg/L	0.0002	3125 B	12/5/19 AK
Cadmium, Dissolved	0.0017	mg/L	0.0002	3125 B	12/5/19 AK
Chromium	0.005	mg/L	0.001	3125 B	12/5/19 AK
Copper	0.013	mg/L	0.001	3125 B	12/5/19 AK
Iron, Total	0.063	mg/L	0.050	3125 B	12/5/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/5/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/5/19 AK
Manganese, Total	0.711	mg/L	0.020	3125 B	12/5/19 AK
Manganese, Dissolved	0.219	mg/L	0.020	3125 B	12/5/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.048	mg/L	0.001	3125 B	12/5/19 AK
Nickel, Dissolved	0.031	mg/L	0.001	3125 B	12/5/19 AK
Selenium	0.008	mg/L	0.002	3125 B	12/5/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/5/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/5/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/5/19 AK

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CLIENT: Mach Mining
PDL: 21550-1
SAMPLE ID: Pond 1
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.4	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	10	mg/L	10	2310 B	12/9/19 OG
Alkalinity	92	mg/L	10	2320 B	12/9/19 OG
Sulfate	82	mg/L	5	4500 E	12/9/19 OG
Chloride	34	mg/L	10	4500 B	12/6/19 KR
Hardness	100	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	29	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.004	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	1.897	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.253	mg/L	0.050	3125 B	12/10/19 AK
Lead	0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.121	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.074	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.002	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21550-2
SAMPLE ID: Pond 2
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.3	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	14	mg/L	10	2310 B	12/9/19 OG
Alkalinity	72	mg/L	10	2320 B	12/9/19 OG
Sulfate	640	mg/L	5	4500 E	12/9/19 OG
Chloride	175	mg/L	10	4500 B	12/6/19 KR
Hardness	608	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	9	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0039	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0038	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.004	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.421	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.149	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	1.185	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	1.185	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.074	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.074	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.016	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	0.059	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21550-3
SAMPLE ID: Pond 3
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.3	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	< 10	mg/L	10	2310 B	12/9/19 OG
Alkalinity	52	mg/L	10	2320 B	12/9/19 OG
Sulfate	41	mg/L	5	4500 E	12/9/19 OG
Chloride	< 10	mg/L	10	4500 B	12/6/19 KR
Hardness	64	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	23	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.004	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	2.247	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.324	mg/L	0.050	3125 B	12/10/19 AK
Lead	0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.123	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.103	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

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CLIENT: Mach Mining
PDL: 21550-4
SAMPLE ID: Pond 4
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.5	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	14	mg/L	10	2310 B	12/9/19 OG
Alkalinity	128	mg/L	10	2320 B	12/9/19 OG
Sulfate	95	mg/L	5	4500 E	12/9/19 OG
Chloride	18	mg/L	10	4500 B	12/6/19 KR
Hardness	236	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	15	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.002	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.612	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.151	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.750	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.736	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21550-5
SAMPLE ID: Pond 5
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.8	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	12	mg/L	10	2310 B	12/9/19 OG
Alkalinity	80	mg/L	10	2320 B	12/9/19 OG
Sulfate	90	mg/L	5	4500 E	12/9/19 OG
Chloride	20	mg/L	10	4500 B	12/6/19 KR
Hardness	148	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	30	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.001	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.003	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	1.666	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.349	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.174	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.149	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Selenium	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21550-6
SAMPLE ID: Pond 6
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.8	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	14	mg/L	10	2310 B	12/9/19 OG
Alkalinity	120	mg/L	10	2320 B	12/9/19 OG
Sulfate	780	mg/L	5	4500 E	12/9/19 OG
Chloride	610	mg/L	10	4500 B	12/6/19 KR
Hardness	550	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	< 5	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0065	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0060	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.006	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.364	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.128	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	1.734	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	1.603	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.106	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.103	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.022	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	0.095	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21550-7
SAMPLE ID: Pond 7
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	7.8	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	20	mg/L	10	2310 B	12/9/19 OG
Alkalinity	472	mg/L	10	2320 B	12/9/19 OG
Sulfate	1,220	mg/L	5	4500 E	12/9/19 OG
Chloride	1,150	mg/L	10	4500 B	12/6/19 KR
Hardness	680	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	12	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0009	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0009	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.014	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.909	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.538	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.776	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.776	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.023	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.021	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.020	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	0.217	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21550-8
SAMPLE ID: Pond 8
DATE SAMPLED: 12/6/19

REPORT DATE: 12/16/19
COMMENT: Grab W6
SAMPLED BY: Client-BM
DATE RECEIVED: 12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.0	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	18	mg/L	10	2310 B	12/9/19 OG
Alkalinity	428	mg/L	10	2320 B	12/9/19 OG
Sulfate	940	mg/L	5	4500 E	12/9/19 OG
Chloride	1,000	mg/L	10	4500 B	12/6/19 KR
Hardness	610	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	14	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0010	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0010	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.012	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.505	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.311	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.694	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.694	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.024	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.024	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.016	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	0.185	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/16/19
PDL:	21550-9	**COMMENT:**	Grab W6
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/6/19	**DATE RECEIVED:**	12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	< 10	mg/L	10	2310 B	12/9/19 OG
Alkalinity	352	mg/L	10	2320 B	12/9/19 OG
Sulfate	1,000	mg/L	5	4500 E	12/9/19 OG
Chloride	1,000	mg/L	10	4500 B	12/6/19 KR
Hardness	450	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	29	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	0.002	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0019	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0019	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.010	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.513	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.103	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.661	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.661	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.048	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.048	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.027	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	11/19/19
PDL:	21406-1	**COMMENT:**	
SAMPLE ID:	417	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	10/25/19	**DATE RECEIVED:**	10/25/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.4	Unit	1 - 14	4500 B	10/25/19 KR
Acidity	< 10	mg/L	10	2310 B	10/31/19 OG
Alkalinity	644	mg/L	10	2320 B	10/31/19 OG
Sulfate	1,220	mg/L	5	4500 E	10/29/19 KR
Chloride	1,250	mg/L	10	4500 B	10/29/19 KR
Hardness	344	mg/L	10	2340 C	11/1/19 OG
Total Suspended Solids	28	mg/L	5	2540 D	10/28/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	10/28/19 KR
Ammonia	1.99	mg/L	0.02	4500B,F	10/29/19 KR
Total Phosphorus	0.13	mg/L	0.05	365.4	10/29/19 KR
Total Nitrogen	2.8	mg/L (as N)	1.0	351.2 / 353.2	10/29/19 KR
Total Kjeldahl Nitrogen	2.3	mg/L (as N)	0.5	351.2	10/29/19 KR
Total Nitrate-Nitrite	0.5	mg/L (as N)	0.5	353.2	10/29/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	0.01	mg/L	0.01	420.4	11/4/19 KR
Antimony	< 0.0100	mg/L	0.0100	200.7	11/12/19 WA
Arsenic	< 0.0100	mg/L	0.0100	200.7	11/12/19 WA
Beryllium	< 0.0010	mg/L	0.0010	200.7	11/12/19 WA
Cadmium, Total	< 0.0020	mg/L	0.0020	200.7	11/12/19 WA
Cadmium, Dissolved	< 0.0020	mg/L	0.0020	200.7	11/15/19 WA
Chromium	< 0.0050	mg/L	0.0050	200.7	11/12/19 WA
Copper	< 0.0050	mg/L	0.0050	200.7	11/12/19 WA
Iron, Total	0.650	mg/L	0.100	200.7	11/12/19 WA
Iron, Dissolved	0.300	mg/L	0.100	200.7	11/15/19 WA
Lead	< 0.0060	mg/L	0.0060	200.7	11/12/19 WA
Manganese, Total	0.0590	mg/L	0.0100	200.7	11/12/19 WA
Manganese, Dissolved	0.0504	mg/L	0.0100	200.7	11/15/19 WA
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.0278	mg/L	0.0050	200.7	11/12/19 WA
Nickel, Dissolved	0.0192	mg/L	0.0050	200.7	11/15/19 WA
Selenium	0.0128	mg/L	0.0100	200.7	11/12/19 WA
Silver	< 0.0050	mg/L	0.0050	200.7	11/12/19 WA
Thallium	< 0.0200	mg/L	0.0200	200.7	11/12/19 WA
Zinc	< 0.0200	mg/L	0.0200	200.7	11/12/19 WA

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CLIENT:	Mach Mining	**REPORT DATE:**	11/26/19
PDL:	21437-1	**COMMENT:**	Grab W2
SAMPLE ID:	417	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/1/19	**DATE RECEIVED:**	11/1/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.2	Unit	1 - 14	4500 B	11/1/19 KR
Acidity	< 10	mg/L	10	2310 B	11/4/19 OG
Alkalinity	596	mg/L	10	2320 B	11/4/19 OG
Sulfate	1,633	mg/L	5	4500 E	11/5/19 KR
Chloride	1,300	mg/L	10	4500 B	11/6/19 KR
Hardness	280	mg/L	10	2340 C	11/5/19 KR
Total Suspended Solids	28	mg/L	5	2540 D	11/4/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/1/19 KR
Ammonia	2.10	mg/L	0.02	4500B,F	11/4/19 KR
Total Phosphorus	0.10	mg/L	0.05	365.4	11/4/19 KR
Total Nitrogen	3.1	mg/L (as N)	1.0	351.2 / 353.2	11/4/19 KR
Total Kjeldahl Nitrogen	2.6	mg/L (as N)	0.5	351.2	11/4/19 KR
Total Nitrate-Nitrite	0.5	mg/L (as N)	0.5	353.2	11/4/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/5/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/8/19 KR
Antimony	0.005	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.004	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.011	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.012	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.153	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.054	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	0.043	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/6/19 AK
Nickel, Total	0.015	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.013	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.019	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	11/27/19
PDL:	21457-1	**COMMENT:**	Grab W3
SAMPLE ID:	417	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/7/19	**DATE RECEIVED:**	11/7/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.4	Unit	1 - 14	4500 B	11/7/19 KR
Acidity	< 10	mg/L	10	2310 B	11/11/19 OG
Alkalinity	584	mg/L	10	2320 B	11/11/19 OG
Sulfate	1,367	mg/L	5	4500 E	11/11/19 KR
Chloride	1,350	mg/L	10	4500 B	11/12/19 OG
Hardness	260	mg/L	10	2340 C	11/12/19 KR
Total Suspended Solids	32	mg/L	5	2540 D	11/12/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/7/19 KR
Ammonia	2.01	mg/L	0.02	4500B,F	11/8/19 KR
Total Phosphorus	0.07	mg/L	0.05	365.4	11/13/19 KR
Total Nitrogen	3.5	mg/L (as N)	1.0	351.2 / 353.2	11/13/19 KR
Total Kjeldahl Nitrogen	3.0	mg/L (as N)	0.5	351.2	11/13/19 KR
Total Nitrate-Nitrite	0.5	mg/L (as N)	0.5	353.2	11/13/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/8/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	11/22/19 KR
Antimony	0.003	mg/L	0.002	3125 B	11/25/19 AK
Arsenic	0.003	mg/L	0.001	3125 B	11/25/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/25/19 AK
Chromium	0.009	mg/L	0.001	3125 B	11/25/19 AK
Copper	0.003	mg/L	0.001	3125 B	11/25/19 AK
Iron, Total	0.107	mg/L	0.050	3125 B	11/25/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/25/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/25/19 AK
Manganese, Total	0.037	mg/L	0.020	3125 B	11/25/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/25/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	0.008	mg/L	0.001	3125 B	11/25/19 AK
Nickel, Dissolved	0.007	mg/L	0.001	3125 B	11/25/19 AK
Selenium	0.022	mg/L	0.002	3125 B	11/25/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/25/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/25/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/25/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/3/19
PDL:	21479-1	**COMMENT:**	Grab Wk4
SAMPLE ID:	417	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/13/19	**DATE RECEIVED:**	11/13/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.4	Unit	1 - 14	4500 B	11/13/19 OG
Acidity	< 10	mg/L	10	2310 B	11/19/19 KR
Alkalinity	530	mg/L	10	2320 B	11/19/19 KR
Sulfate	1,567	mg/L	5	4500 E	11/15/19 KR
Chloride	1,799	mg/L	10	4500 B	11/18/19 OG
Hardness	1,000	mg/L	10	2340 C	11/18/19 KR
Total Suspended Solids	21	mg/L	5	2540 D	11/14/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/13/19 OG
Ammonia	1.78	mg/L	0.02	4500B,F	11/14/19 KR
Total Phosphorus	0.06	mg/L	0.05	365.4	11/13/19 KR
Total Nitrogen	3.0	mg/L (as N)	1.0	351.2 / 353.2	11/13/19 KR
Total Kjeldahl Nitrogen	2.5	mg/L (as N)	0.5	351.2	11/13/19 KR
Total Nitrate-Nitrite	0.5	mg/L (as N)	0.5	353.2	11/13/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/3/19 KR
Antimony	0.002	mg/L	0.002	3125 B	11/27/19 AK
Arsenic	0.002	mg/L	0.001	3125 B	11/27/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Cadmium, Total	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	11/27/19 AK
Chromium	0.014	mg/L	0.001	3125 B	11/27/19 AK
Copper	0.025	mg/L	0.001	3125 B	11/27/19 AK
Iron, Total	0.399	mg/L	0.050	3125 B	11/27/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	11/27/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	11/27/19 AK
Manganese, Total	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Manganese, Dissolved	< 0.020	mg/L	0.020	3125 B	11/27/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	11/20/19 AK
Nickel, Total	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Nickel, Dissolved	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Selenium	0.019	mg/L	0.002	3125 B	11/27/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	11/27/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	11/27/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	11/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/6/19
PDL:	21506-1	**COMMENT:**	Grab W5
SAMPLE ID:	417	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	11/20/19	**DATE RECEIVED:**	11/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	11/20/19 KR
Acidity	< 10	mg/L	10	2310 B	11/22/19 KR
Alkalinity	520	mg/L	10	2320 B	11/22/19 KR
Sulfate	1,833	mg/L	5	4500 E	11/25/19 KR
Chloride	1,570	mg/L	10	4500 B	11/21/19 KR
Hardness	380	mg/L	10	2340 C	11/21/19 KR
Total Suspended Solids	49	mg/L	5	2540 D	11/21/19 KR
Settleable Solids	< 0.25	mL/L	0.25	2540 F	11/21/19 KR
Ammonia	1.93	mg/L	0.02	4500B,F	11/27/19 KR
Total Phosphorus	< 0.05	mg/L	0.05	365.4	11/27/19 KR
Total Nitrogen	2.8	mg/L (as N)	1.0	351.2 / 353.2	11/27/19 KR
Total Kjeldahl Nitrogen	2.3	mg/L (as N)	0.5	351.2	11/27/19 KR
Total Nitrate-Nitrite	0.5	mg/L (as N)	0.5	353.2	11/27/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	11/25/19 OG
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/5/19 KR
Antimony	0.004	mg/L	0.002	3125 B	12/2/19 AK
Arsenic	0.004	mg/L	0.001	3125 B	12/2/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Cadmium, Total	0.0003	mg/L	0.0002	3125 B	12/2/19 AK
Cadmium, Dissolved	< 0.0002	mg/L	0.0002	3125 B	12/2/19 AK
Chromium	0.011	mg/L	0.001	3125 B	12/2/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Iron, Total	1.405	mg/L	0.050	3125 B	12/2/19 AK
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/2/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/2/19 AK
Manganese, Total	0.076	mg/L	0.020	3125 B	12/2/19 AK
Manganese, Dissolved	0.036	mg/L	0.020	3125 B	12/2/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/6/19 AK
Nickel, Total	0.016	mg/L	0.001	3125 B	12/2/19 AK
Nickel, Dissolved	0.014	mg/L	0.001	3125 B	12/2/19 AK
Selenium	0.023	mg/L	0.002	3125 B	12/2/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/2/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/2/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/2/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/16/19
PDL:	21551-1	**COMMENT:**	Grab W6
SAMPLE ID:	417	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/6/19	**DATE RECEIVED:**	12/6/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
pH	8.5	Unit	1 - 14	4500 B	12/6/19 KR
Acidity	< 10	mg/L	10	2310 B	12/9/19 OG
Alkalinity	604	mg/L	10	2320 B	12/9/19 OG
Sulfate	1,280	mg/L	5	4500 E	12/9/19 OG
Chloride	1,250	mg/L	10	4500 B	12/6/19 KR
Hardness	360	mg/L	10	2340 C	12/6/19 KR
Total Suspended Solids	29	mg/L	5	2540 D	12/9/19 OG
Settleable Solids	< 0.25	mL/L	0.25	2540 F	12/6/19 KR
Ammonia	1.04	mg/L	0.02	4500B,F	12/10/19 KR
Total Phosphorus	< 0.05	mg/L	0.05	365.4	12/10/19 KR
Total Nitrogen	3.0	mg/L (as N)	1.0	351.2 / 353.2	12/10/19 KR
Total Kjeldahl Nitrogen	2.5	mg/L (as N)	0.5	351.2	12/10/19 KR
Total Nitrate-Nitrite	0.5	mg/L (as N)	0.5	353.2	12/10/19 KR
Cyanide	< 0.02	mg/L	0.02	335.4	12/11/19 KR
Phenols, Total Recoverable	< 0.01	mg/L	0.01	420.4	12/10/19 KR
Antimony	0.005	mg/L	0.002	3125 B	12/10/19 AK
Arsenic	0.004	mg/L	0.001	3125 B	12/10/19 AK
Beryllium	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Cadmium, Total	0.0004	mg/L	0.0002	3125 B	12/10/19 AK
Cadmium, Dissolved	0.0003	mg/L	0.0002	3125 B	12/10/19 AK
Chromium	0.013	mg/L	0.001	3125 B	12/10/19 AK
Copper	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Iron, Total	0.392	mg/L	0.050	3125 B	12/10/19 AK
Iron, Dissolved	0.072	mg/L	0.050	3125 B	12/10/19 AK
Lead	< 0.002	mg/L	0.002	3125 B	12/10/19 AK
Manganese, Total	0.145	mg/L	0.020	3125 B	12/10/19 AK
Manganese, Dissolved	0.145	mg/L	0.020	3125 B	12/10/19 AK
Mercury	< 0.002	mg/L	0.002	245.1	12/13/19 AK
Nickel, Total	0.014	mg/L	0.001	3125 B	12/10/19 AK
Nickel, Dissolved	0.014	mg/L	0.001	3125 B	12/10/19 AK
Selenium	0.027	mg/L	0.002	3125 B	12/10/19 AK
Silver	< 0.001	mg/L	0.001	3125 B	12/10/19 AK
Thallium	< 0.0004	mg/L	0.0004	3125 B	12/10/19 AK
Zinc	< 0.050	mg/L	0.050	3125 B	12/10/19 AK

Reviewed By: Amber Wright

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	4.44	ηg/L	0.500	1631 E	1/13/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

*These results relate only to the samples as received.
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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.783	ηg/L	0.500	1631 E	1/13/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	3.65	ηg/L	0.500	1631 E	1/13/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.963	ηg/L	0.500	1631 E	1/13/20 WA

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	3.57	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/13/20 WA

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.09	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	0.974	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.29	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	1.86	ηg/L	0.500	1631 E	1/13/20 WA

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/14/20
PDL:	21634-11	**COMMENT:**	
SAMPLE ID:	Field Blank	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Mercury, Low Level	< 0.500	ηg/L	0.500	1631 E	1/13/20 WA

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21579-1	**COMMENT:**	
SAMPLE ID:	Mach	**SAMPLED BY:**	Client-CS
DATE SAMPLED:	12/16/19	**DATE RECEIVED:**	12/16/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/23/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21589-1	**COMMENT:**	
SAMPLE ID:	Mach 2	**SAMPLED BY:**	Client-CS
DATE SAMPLED:	12/18/19	**DATE RECEIVED:**	12/19/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21589-2	**COMMENT:**	
SAMPLE ID:	Mach 3	**SAMPLED BY:**	Client-CS
DATE SAMPLED:	12/19/19	**DATE RECEIVED:**	12/19/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.109	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.222	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.082	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.174	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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Website: www.summitenviro.com

CLIENT: Mach Mining
PDL: 21603-8
SAMPLE ID: Pond 8
DATE SAMPLED: 12/20/19

REPORT DATE: 12/30/19
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	12/30/19
PDL:	21603-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	12/20/19	**DATE RECEIVED:**	12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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Website: www.summitenviro.com

CLIENT: Mach Mining
PDL: 21603-10
SAMPLE ID: Mach 4 (417)
DATE SAMPLED: 12/20/19

REPORT DATE: 12/30/19
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 12/20/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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Website: www.summitenviro.com

CLIENT: Mach Mining
PDL: 21614-1
SAMPLE ID: Pond 1
DATE SAMPLED: 12/23/19

REPORT DATE: 1/2/20
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.139	mg/L	0.050	3125 B	12/27/19 AK

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Website: www.summitenviro.com

CLIENT: Mach Mining
PDL: 21614-2
SAMPLE ID: Pond 2
DATE SAMPLED: 12/23/19

REPORT DATE: 1/2/20
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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Website: www.summitenviro.com

CLIENT: Mach Mining
PDL: 21614-3
SAMPLE ID: Pond 3
DATE SAMPLED: 12/23/19

REPORT DATE: 1/2/20
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.250	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.123	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT: Mach Mining
PDL: 21614-5
SAMPLE ID: Pond 5
DATE SAMPLED: 12/23/19

REPORT DATE: 1/2/20
COMMENT:
SAMPLED BY: Client-BM
DATE RECEIVED: 12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.107	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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Website: www.summitenviro.com

CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.114	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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Website: www.summitenviro.com

CLIENT:	Mach Mining	**REPORT DATE:**	1/2/20
PDL:	21614-10	**COMMENT:**	
SAMPLE ID:	Mach 4 (417)	**SAMPLED BY:**	Client-BM
DATE SAMPLED:	12/23/19	**DATE RECEIVED:**	12/23/19

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	12/27/19 AK

Reviewed By: Amber Wright

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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Website: www.summitenviro.com

ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/7/20
PDL:	21625-10	**COMMENT:**	
SAMPLE ID:	Mach 6 (417)	**SAMPLED BY:**	Client
DATE SAMPLED:	1/2/20	**DATE RECEIVED:**	1/2/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/3/20 AK

Reviewed and Authorized By: Amber Wright
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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.362	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.573	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.126	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21630-5
SAMPLE ID: Pond 5
DATE SAMPLED: 1/3/20

REPORT DATE: 1/13/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.179	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.200	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/13/20
PDL:	21630-10	**COMMENT:**	
SAMPLE ID:	Mach 7 (417)	**SAMPLED BY:**	Client
DATE SAMPLED:	1/3/20	**DATE RECEIVED:**	1/3/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/10/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-1	**COMMENT:**	
SAMPLE ID:	Pond 1	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.400	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-2	**COMMENT:**	
SAMPLE ID:	Pond 2	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.085	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.730	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.280	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.299	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21633-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/6/20	**DATE RECEIVED:**	1/6/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT: Mach Mining
PDL: 21658-1
SAMPLE ID: Pond 1
DATE SAMPLED: 1/8/20

REPORT DATE: 1/17/20
COMMENT:
SAMPLED BY: Client
DATE RECEIVED: 1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.247	mg/L	0.050	3125 B	1/17/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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CHEMICAL ANALYSTS & CONSULTANTS

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Website: www.summitenviro.com

ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-3	**COMMENT:**	
SAMPLE ID:	Pond 3	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.595	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-4	**COMMENT:**	
SAMPLE ID:	Pond 4	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.118	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-5	**COMMENT:**	
SAMPLE ID:	Pond 5	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	0.265	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-6	**COMMENT:**	
SAMPLE ID:	Pond 6	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-7	**COMMENT:**	
SAMPLE ID:	Pond 7	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-8	**COMMENT:**	
SAMPLE ID:	Pond 8	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-9	**COMMENT:**	
SAMPLE ID:	Pond 9	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

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Amber Wright, Laboratory Director

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ANALYSIS REPORT

CLIENT:	Mach Mining	**REPORT DATE:**	1/17/20
PDL:	21658-10	**COMMENT:**	
SAMPLE ID:	Cell 417	**SAMPLED BY:**	Client
DATE SAMPLED:	1/8/20	**DATE RECEIVED:**	1/8/20

TEST DESCRIPTION	RESULT	UNITS	DETECTION LIMIT	METHOD	DATE/ ANALYST
Iron, Dissolved	< 0.050	mg/L	0.050	3125 B	1/17/20 AK

Reviewed and Authorized By: Amber Wright
Amber Wright, Laboratory Director

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DOCUMENT

13

Exhibit List for Williamson Energy, LLP

Pond Creek Mine NPDES Permit Hearing

NPDES Permit Number IL0077666

December 18, 2019 6:00 p.m.

Exhibit No.	Document Name	No. of Pages
1	Notice of Public Hearing	2
2	Draft NPDES Permit/Public Notice/Fact Sheet, July 12, 2018	40
3	Comments, Jerry Dudley, postmarked July 29, 2019	1+env.
4	Comments, Katherine Rice, postmarked July 29, 2019	1+env.
5	Postcard Comments, Bonnie Burton, postmarked July 29, 2019	2
6	Postcard Comments, Laraine Wright, postmarked July 29, 2019	2+env.
7	Comments, Chris Burton, postmarked July 30, 2019	1+env.
8	Letter, Debra Mileur, postmarked July 30, 2019	1+env.
9	Letter, Linda Craig, postmarked July 30, 2019	1+env.
10	Comments, Dotty Mitchell, postmarked July 31, 2019	1+env.
11	Letter, Evelyn Sternselli, postmarked August 1, 2019	1+env.
12	Comments, Doris Snider, postmarked August 2, 2019	1+env.
13	Comment and newspaper article, anonymous, postmarked July 29, 2019	2+env.
14	E-mail, Kathleen Doherty, July 31, 2019	1
15	E-mail, Ed Heierman, July 31, 2019	1
16	E-mail, Dawna Miller, August 4, 2019	1
17	E-mail, Jennifer (Jay) Bull, August 5, 2019	1
18	E-mail, Sandy Hoskins, August 5, 2019 2:03 PM	1
19	E-mail, Sandy Hoskins, August 5, 2019 2:09 PM	1
20	E-mail, Lisa Suits, August 5, 2019	1
21	Card with comments, Mae Hanns, dated August 5, 2019 (no postmark)	3+env.
22	Letter, Ruth Hawkins, postmarked August 5, 2019	1+env.
23	Letter, Neloa Jent, postmarked August 5, 2019	1+env.
24	Letter, Judith and Bill Rea, postmarked August 6, 2019	1+env.
25	Letter, Tim Moss, postmarked August 6, 2019	1+env.
26	Letter, Larry Hammel, postmarked August 7, 2019	1+env.
27	Letter, Wilma Hammel, postmarked August 7, 2019	3+env.
28	Letter, Linda Wright, postmarked August 6, 2019	1+env.
29	Letter, Robert Piland, postmarked August 7, 2019	1+env.
30	Letter, Carmen Burzynski, postmarked August 30, 2019	1+env.
31	E-mail, Matt Battaglia, August 8, 2019	1
32	E-mail, Kaitlin Battaglia, August 8, 2019	1
33	E-mail, Charles Mitroka, August 9, 2019	1
34	E-mail, Megan Flexter, August 9, 2019	1
35	E-mail, "Ananimal999," August 9, 2019	1
36	E-mail, Deb Browne, August 10, 2019	1
37	E-mail, Kathy Livingston, August 11, 2019	2
38	E-mail, Kelley Hessian, August 12, 2019	1
39	E-mail, Marian Smith Furlow, August 12, 2019	1
40	E-mails (10), 1 with comments, 9 with photographs, David L Freeman, August 12, 2019	10
41	E-mail, Sabrina Hardenbergh, August 12, 2019	2

42	E-mail, Jennifer Reiman, August 12, 2019	1
43	E-mail, Paula Meinert, August 12, 2019	1
44	E-mail, Patricia Mullen, August 12, 2019	1
45	E-mail, Betty Freeman, August 12, 2019	1
46	E-mail, Shirley Krienert, August 12, 2019	1
47	Letter and newspaper article, Isabel Madry Zimmerman, August 7, 2019	2
48	Letter and appendix, Lucia Amorelli, July 22, 2019	6
49	Letter, Jerry and Carolyn Worthen, Concerned Citizens of Southern Illinois, postmarked August 2, 2019	1+env.
50	Letter, Lynn Winston, received August 5, 2019	1
51	Letter, Christian Sasse, received August 6, 2019	1
52	Letter, Kathy Livingston, received August 12, 2019 (see Ex. 37)	2
53	Letter Karen Fiorino, postmarked August 7, 2019	2+env.
54	Comment and 2 newspaper articles, Russ Kramer and Judy Baker, received August 12, 2019	3
55	Letter, Kathy Renfro, Executive Director, Carbondale Park District, received August 9, 2019	1
56	Letter, Kay Rippelmeyer and David Tippy, received August 9, 2019	1
57	Letter, Dawna Miller, postmarked August 5, 2019 (see Ex. 16)	1+env.
58	Letter, Beth Spezia, received August 7, 2019	2
59	Letter Antonio Jacob Martinez, postmarked August 12, 2019	2+env.
60	Letter, Clara Smith, received August 12, 2019	1+env.
61	E-mail, Meghan Cole, November 11, 2019	1
62	E-mail, Michelle Knox, July 22, 2019	1
63	E-mail, Darla Judd, August 13, 2019	1
64	Comment, Wangler, postmarked July 29, 2019	1+env.
65	Letter, hearing request, State Representative Terri Bryant, received August 12, 2019	1
66	E-mail, Katie Keller, forwarded from Barb Lieberoff, July 24, 2019	1
67	E-mail, Nelma Battrell, July 26, 2019	1
68	E-mail, Katrina Renzaglia, July 26, 2019	1
69	E-mail, Joan Steele, July 26, 2019	1
70	E-mail, Patty Weyhrich, July 27, 2019	1
71	E-mail, Susan Livingston, July 27, 2019	1
72	E-mail, Robin Russell, July 28, 2019	1
73	E-mail, Jack McKillip, July 28, 2019	1
74	E-mail, Charles and Gayla Kain, July 29, 2019	1
75	E-mail, Michael Duncan, July 29, 2019	1
76	E-mail, Amber Hewette, July 29, 2019	1
77	E-mail, Tess D Ford, July 29, 2019	1
78	E-mail, Thomas Grant, July 30, 2019	1
79	E-mail, Robert Swenson, July 30, 2019	1
80	E-mail, R Neil Claussen, July 30, 2019	1
81	E-mail, Kathryn Jenkel, July 30, 2019	1
82	E-mail, Cheryl Couch, July 30, 2019	1
83	E-mail, Henry Gelstor, July 31, 2019	1
84	E-mail, Jon Womack, August 1, 2019	1
85	E-mail, Sheila Simon, August 1, 2019	2
86	E-mail, Christina Krost, August 2, 2019	2
87	E-mail, Ann Wheeler, August 2, 2019	1
88	E-mail, Toni Kennedy, August 3, 2019	1
89	E-mail, Dona Reese, August 4, 2019	1
90	E-mail, William Grisley, August 4, 2019	1
91	E-mail & Attachment, Kay M Rippelmeyer-Tippy, August 4, 2019 (see Ex. 56)	2
92	E-mail, Lawrence Schilling, August 4, 2019	1
93	E-mail, James Kimmel, August 4, 2019	1

94	E-mail, Jamie Nash-Mayberry, August 4, 2019	1
95	E-mail, J M Restivo, August 4, 2019	1
96	E-mail, Ruane & Debra Tanner, August 4, 2019	1
97	E-mail, Leonard Brantley, August 4, 2019	1
98	E-mail, Donna Brantley, August 4, 2019	1
99	E-mail, Monika Plumb, August 4, 2019	1
100	E-mail, Terry Gillespie, August 4, 2019	1
101	E-mail, Ed Doty, August 4, 2019	1
102	E-mail, Marilyn Willis, August 4, 2019	1
103	E-mail, Domenick Ronchetto, August 4, 2019	1
104	E-mail, Rebekah Wilkerson, August 4, 2019	1
105	E-mail, Michael K Calandro, August 4, 2019	1
106	E-mail, Brian Barker, August 5, 2019	1
107	E-mail, Pat Knox, August 6, 2019	1
108	E-mail, Michael W Eichholz, August 6, 2019	1
109	E-mail and attachment, Cameron Smith, August 6, 2019	3
110	E-mail, Les Winkeler, August 6, 2019	1
111	E-mail, Joseph Stafford, August 6, 2019	1
112	E-mail, Lee M Fronabarger, August 6, 2019	1
113	E-mail, Karen Fiorino, August 6, 2019 (see Ex. 53)	2
114	E-mail, Craig Wilson, August 7, 2019	1
115	E-mail, Stephanie Solbrig, August 7, 2019	1
116	E-mail, Kristine B McGuire, August 7, 2019	1
117	E-mail, Randie Simpson, August 7, 2019	1
118	E-mail, Gordon Smith, August 7, 2019	1
119	E-mail, Randall Snyder, August 7, 2019	1
120	E-mail, Jason Wild, August 7, 2019	1
121	E-mail, Gary Lukuc, August 7, 2019	1
122	E-mail, Cheryl Klopcic, August 7, 2019	1
123	E-mail, Beth Martell, August 7, 2019	2
124	E-mail, Beth A Roberts-Jacquot, August 7, 2019	1
125	E-mail, "Old Wives", August 7, 2019	1
126	E-mail, Earl Ray Jacquot, August 7, 2019	1
127	E-mail, Hayley Mason, August 7, 2019	1
128	E-mail, Amy Acorn, August 7, 2019	1
129	E-mail, Ivy P Rodger, August 8, 2019	1
130	E-mail, Michelle Wiseman, August 8, 2019	1
131	E-mail, Roger Davis, August 8, 2019	1
132	2 E-mails, Melanie Morrison, August 8, 2019	2
133	E-mail, Nancy Spear, August 8, 2019	1
134	E-mail, Michael T Madigan, August 8, 2019	2
135	Letter, Representative Terri Bryant, August 6, 2019, e-mailed by Kathy Willis on August 8, 2019 (see Ex. 65)	2
136	Letter, Senator Paul Schimpf, August 8, 2019, e-mailed by Kathy Willis on August 8, 2019	2
137	E-mail, Ruth and Russell Miner, August 8, 2019	1
138	E-mail, Allen and Madeline Meadows, August 8, 2019	1
139	E-mail and attachment, Barbara McKasson, August 8, 2019	4
140	E-mail, Barb Elam, August 8, 2019	1
141	E-mail, Kaitlin Battaglia, August 8, 2019 (see Ex. 32)	1
142	E-mail, Matt Battaglia, August 8, 2019 (see Ex. 31)	1
143	E-mail, Josh Crouch, August 8, 2019	1
144	E-mail, Deborah Saylor Connell, August 9, 2019	2
145	E-mail, "Murphy_momma," August 9, 2019	1

146	E-mail, Kathleen Gunkel, August 9, 2019	1
147	E-mail, Megan Flexter, August 9, 2019	1
148	E-mail, Elizabeth Connell, August 9, 2019	1
149	E-mail, Tom Harbert, August 9, 2019	1
150	E-mail, Eldon Benz, August 9, 2019	1
151	E-mail, Lisa Collins, August 9, 2019	1
152	E-mail, Catherine M Field, August 9, 2019	1
153	E-mail, Linda Wyatt, August 9, 2019	2
154	E-mail, Denise M Perry, August 9, 2019	1
155	E-mail, Dawn Roberts, August 9, 2019	1
156	E-mail, Jim Rodemaker, August 10, 2019	1
157	E-mail, Kim Swartz, August 10, 2019	1
158	E-mail and attachment, Cade Bursell, August 10, 2019	4
159	E-mail, Tom Ebenhoh, August 10, 2019	1
160	E-mail, Diana Brawley Sussman, August 10, 2019	1
161	E-mail, John Reimbold, August 10, 2019	1
162	E-mail, Daniel Hillyard, August 10, 2019	1
163	E-mail, Jesslyn Jobe, August 10, 2019	1
164	E-mail, Susan Walch-Pimentel, August 10, 2019	1
165	E-mail, Shannon Griffin, August 10, 2019	1
166	E-mail, Keith Pharis, August 10, 2019	1
167	E-mail, Tony Graham, August 10, 2019	1
168	E-mail, Mark Coats, August 10, 2019	1
169	E-mail, April Moritz, August 10, 2019	1
170	E-mail, Jill Skinner, August 11, 2019	1
171	E-mail, Michael D Covell, August 11, 2019	1
172	E-mail, Rhonda Rothrock, August 11, 2019	2
173	E-mail, John C McCall, August 11, 2019	1
174	E-mail, Barbara Luttenbacher, August 11, 2019	1
175	E-mail, William Terry, August 11, 2019	1
176	E-mail, Tom Redmond, August 11, 2019	1
177	E-mail, Thomas Tucker, August 11, 2019	1
178	E-mail, Darby Ortolano, August 11, 2019	1
179	E-mail and attachment, Edward J Brunner, August 11, 2019	3
180	E-mail, Mary O'Hara, August 11, 2019	2
181	E-mail, Ted and Gail Mieling, August 11, 2019	1
182	E-mail, Jyotsna Kapur, August 11, 2019	1
183	E-mail, Jennifer Haselhorst, August 11, 2019	1
184	E-mail, Christopher Brown, August 11, 2019	1
185	E-mail, Pam McLean Family, August 11, 2019	1
186	E-mail, Alex Bishop, August 11, 2019	1
187	E-mail, Abby Cripps, August 11, 2019	1
188	E-mail & Letter with 4 Attachments, Sierra Club (Illinois Chapter) and Prairie Rivers Network, August 12, 2019	93
189	E-mail and attachment, Jane Cogie, August 11, 2019	3
190	E-mail, Casey R Stout, August 12, 2019	1
191	E-mail, Jane Payne, August 12, 2019	1
192	E-mail, Becky Schneider, August 12, 2019	1
193	E-mail, Thomas Bik, August 12, 2019	1
194	E-mail, Mary Ellen DeClue, August 12, 2019	2
195	E-mail, Miles Maether, August 12, 2019	1
196	2 E-mails, Matthew Borowicz, August 12, 2019 and August 13, 2019	2
197	E-mail, Paula Bradshaw, August 12, 2019	1

198	E-mail, George Majka, August 12, 2019	1
199	E-mail, Matthew Blessing, August 12, 2019	1
200	E-mail, David Kidd, August 12, 2019	1
201	E-mail, Laurel Toussaint, August 12, 2019	1
202	E-mail, Carla Womack, August 12, 2019	1
203	E-mail, Jon Womack, August 12, 2019	1
204	E-mail and attachment, Jan Thomas, August 12, 2019	3
205	E-mail and Letter, James Plumley, Williamson Energy, LLC, July 17, 2019	3
206	E-mail, Steve Eberhart, August 12, 2019	1
207	2 E-mails and attachments, Southern Illinois Against Fracturing Our Environment, August 12, 2019	8
208	E-mail, Colleen Flanagan, August 12, 2019	1
209	E-mail, Jennifer Reiman, August 12, 2019	1
210	E-mail, Sarah Heyer, August 12, 2019	1
211	E-mail, Robert Morwell, August 12, 2019	1
212	E-mail and attachment, Joyce Blumenshine, August 12, 2019	3
213	E-mail, Gary Kolb, August 12, 2019	1
214	E-mail and 2 attachments, Leonard Jamie Snyder, City Attorney, City of Carbondale, August 12, 2019	15
215	E-mail, Isabel Zimmerman, August 12, 2019	1
216	E-mail, Mary Ann Stout, August 12, 2019	1
217	E-mail, Ann Fischer, August 12, 2019	1
218	2 E-mails, Linda Webb, August 12, 2019	2
219	E-mail, Priscilla R Pimentel, August 12, 2019	1
220	2 E-mails (identical), Paul Webb, August 12, 2019	2
221	E-mail, Rebecca Schlosser, August 12, 2019	1
222	E-mail, Dawn Roberts, August 12, 2019	1
223	E-mail, Molly Alter, August 12, 2019	1
224	E-mail, Karen Fiorino, August 12, 2019	1
225	E-mail, Craig Wilson, August 12, 2019	1
226	E-mail, Beau Henson, August 12, 2019	1
227	E-mail and attachment, John Wallace, Shawnee Chapter, Illinois Audubon Society, August 12, 2019	4
228	E-mail, JoAnn Pillatsch, August 12, 2019	1
229	E-mail, Jill Adams, August 12, 2019	1
230	E-mail, Brian Ritzel, August 12, 2019	1
231	E-mail and attachment, John Wallace and Karen Frailey, August 12, 2019	4
232	E-mail, Rachel Cristaudo, August 13, 2019	3
233	E-mail, Alex Trujillo, August 15, 2019	1
234	E-mail, Marian Smith Furlow, August 12, 2019	1
235	E-mail, Tony Graham, October 30, 2019	1
236	E-mail, Josh Crouch, October 31, 2019	1
237	E-mail and attachment, Lucia Amorelli, December 12, 2019	17
238	Hearing Board Designation Memo, Sanjay Sofat, BOW Chief, December 11, 2019	1
239	Big Muddy Monthly Mean Flow Line Graph, Illinois EPA Hearing Exhibit	1
240	Big Muddy Minimum Monthly Mean Flow Bar Chart, Illinois EPA Hearing Exhibit	1
241	Hearing oral comments with attachments, Clayton Cross, December 18, 2019	6
242	Written comments provided at hearing, Cameron Smith, December 18, 2019	2
243	Hearing oral comments, Connie Schmidt, December 18, 2019	1
244	Hearing oral comments, Galen Thomas, December 18, 2019	3
245	Written comments and gauge data provided at hearing, Jerry Worthen, December 18, 2019	5
246	Written comments provided at hearing, Barbara McKasson, December 18, 2019	5
247	Copies of petitions provided at hearing, John Wallace, December 18, 2019	38
248	Foresight Energy LP Financial Statements provided at hearing, Tenney Naumer, December 18, 2019	2
249	USEPA acid mine drainage info sheet provided at hearing, Mark Malkovich, December 18, 2019	2

250	Hearing oral comments, Karl Fraley, December 18, 2019	2
251	Hearing oral comments, Christina Krost, December 18, 2019	2
252	Written comments provided at hearing, Madeline Krost, December 18, 2019	1
253	Written comments provided at hearing, Lucia Amorelli, December 18, 2019	16
254	Written comments provided at hearing, Jane Cogie, December 18, 2019	1
255	Written comments provided at hearing, William Sasso, December 18, 2019	2
256	Written comments provided at hearing, Charles McCann, December 18, 2019	2
257	Letter, Susan Van Dyk, postmarked December 20, 2019	1+env.
258	Letter, Barb Elam, postmarked December 13, 2019	1+env.
259	Letter, Karen Fiorino, postmarked December 20, 2019	2+env.
260	Letters, Jason, Bella, Alycia, and Sophia Stephenson, postmarked December 20, 2019	4+env.
261	E-mail, Margaret Shaklee, December 17, 2019	1
262	E-mail, Dianne Ansari-Winn, December 17, 2019	1
263	E-mail, Vince Unger, December 17, 2019	1
264	E-mail, Karen Kortsch, December 17, 2019	1
265	E-mail, Nancy Irons, December 17, 2019	1
266	E-mail, Adair Small, December 17, 2019	1
267	E-mail, Rev. Pamela Rumancik, Unitarian Church of Hinsdale, December 17, 2019	1
268	E-mail, Karen Fort, December 17, 2019	1
269	E-mail, Marcia Bernstein, December 17, 2019	1
270	E-mail, Terry Kinsey, December 17, 2019	1
271	E-mail, Dr. Elizabeth Dowell, MD, December 17, 2019	1
272	E-mail, Renee Hoff, December 17, 2019	1
273	E-mail, Julie Prandi, December 17, 2019	1
274	E-mail, Brigitte Erbe, December 17, 2019	1
275	E-mail, Mary Anne O'Toole, December 17, 2019	1
276	E-mail, Mary Parks, December 17, 2019	1
277	E-mail, Diane Heizer, December 17, 2019	1
278	E-mail, Ruth Reagel, December 17, 2019	1
279	E-mail, Rev. James Hobart, Unitarian Universalist Church, Chicago, December 17, 2019	1
280	E-mail, Jennifer Livingston, December 17, 2019	1
281	E-mail, Debbie Montgomery, December 17, 2019	1
282	E-mail, Kathleen O'Laughlin, December 17, 2019	1
283	E-mail, Sunny and Tom Hall, December 17, 2019	1
284	E-mail, Donna Schiller, December 17, 2019	1
285	E-mail, Robert Bulanda, December 17, 2019	1
286	E-mail, Barbara Ghoshal, December 17, 2019	1
287	E-mail, Craig and Glenda Shaver, December 17, 2019	1
288	E-mail, Jerry Carden, December 17, 2019	1
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ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

PUBLIC HEARING

IN RE: NPDES PERMIT NUMBER IL0077666

HELD DECEMBER 18, 2019

ORIGINAL

RECORD OF PROCEEDINGS of the public hearing taken at Rent One Park Diamond Club, 1000 Miners Drive, Marion, Illinois, on December 18, 2019, at 6:00 p.m. before Lori A. Rogers, Notary Public/Illinois Certified Shorthand Reporter No. 084-002872.

HEARING OFFICER:

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Hearing Officer & Right to Know Coordinator
Illinois Environmental Protection Agency
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IEPA PANEL:
Darin LeCrone
Iwona Ward
Scott Twait
Stephanie Diers

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HEARING OFFICER: It's 6:00. Good evening, everyone. This is an informational hearing on the issuance of a water discharge permit for Williamson Energy at its Pond Creek Mine. Let the record reflect the time is now 6:01 p.m. My name's Christine Zeivel, and I am the hearing officer for the Illinois Environmental Protection Agency. On behalf of Director John Kim, I welcome you to tonight's hearing, and at this time, please silence all cell phones and other electronic devices if you have not already done so.

As I said, this is an informational hearing before the Illinois EPA in the matter of a renewal of a National Pollution Discharge Elimination System permit, which will be referred to generally as an N-P-D-E-S or NPDES permit, for Williamson Energy's Pond Creek Mine located in Franklin and Williamson counties. As part of this hearing proceeding, the Illinois EPA has prepared documents for public review that outline the major permit terms and conditions that are the subject of this hearing. And those documents are available for review at the registration desk

and also on the Illinois EPA's Public Notice web page.

The Illinois EPA is holding this hearing for the purpose of accepting comments from the public on the proposed renewal of the NPDES permit for Williamson Energy's Pond Creek Mine prior to taking final action on the renewal application. This public hearing is being held under the provisions of the Illinois EPA's procedures for permit and closure plan hearings which can be found at 35 Illinois Administrative Code, Part 166, Subpart A, which is in accordance with 35 Illinois Administrative Code Part 309 for public participation in NPDES Permit Applications. Copies of these procedures can be accessed on the website for the Illinois Pollution Control Board. That website is www.ipcb.state.il.us or if you do not have ready access to the internet, that can be obtained from me upon request.

An informational public hearing is not a contested case hearing but rather is meant as an opportunity for you to provide information to and ask questions of the Illinois EPA

concerning this specific permit. My responsibility as the hearing officer is to ensure that this proceeding comports with the procedural requirements and is conducted in a proper and fair but efficient manner.

Now I would like to explain how tonight's hearing is going to proceed. First, we will have the Illinois EPA staff located to my right introduce themselves. They will each identify their responsibilities within the agency in regard to the permitting action, and then a few of them will provide you a brief overview of information we believe is relevant to tonight's proceeding. This will be followed by additional instructions from me on how we will be taking oral comments during the hearing this evening, and then the public will be allowed to ask questions and provide comments utilizing the microphone and table located in between the aisles here in front of the panel.

We have a court reporter here who is taking a record of these proceedings for the purpose of creating a public record. Therefore, for her benefit, please keep the general

background noise in the room to a minimum so that she can hear and properly record everything that is said. Any comments or statements made from the audience without a microphone will not be recorded by the court reporter and will not be located and recorded in the transcript. Illinois EPA will post the transcript of this hearing on our web page in the same general place where the hearing notice and draft permit and other documents associated with this proceeding have been posted.

You are not required to provide your comments orally. Written comments are given the same consideration as oral comments made during this hearing and may be submitted to the Illinois EPA at any time during the comment period which ends January 17, 2020. All comments submitted by mail must be postmarked in sufficient time so as to arrive at the Illinois EPA no later than the closing day of January 17, 2020. Although we will continue to accept comments through that date, tonight is the only time that we will accept oral comments.

Any person who wishes to make oral

comments may do so as long as the statements are relevant to the issues at hand and the time allows. If you have not completed a registration card at this point, please head to the registration desk and complete a card making sure to check the appropriate box on the card if you desire to make comments at the hearing this evening. If you have lengthy comments, please consider giving only a summary of those comments at this hearing and then submitting the remainder and entirety of your comments to the Agency before the end of the comment period, and I will ensure that they are included in the hearing record. Please do keep your comments relevant to the conditions and requirements in the permit that Illinois EPA is proposing to renew. If your comments fall outside of the scope of this hearing, I may ask you to proceed to your next issue.

Each speaker will have the option of addressing questions to the Illinois EPA panel located to my right or making just a general comment, or you can do both. However, since we have a limited time in which to conduct this

hearing, Illinois EPA staff members will be responding to issues presented primarily for clarification purposes. We will be available to answer questions if those answers are readily available, but the Agency panel may respond by agreeing to defer the response to the responsiveness summary which will be posted following the close of the comment period. I will not allow speakers to argue, cross-examine or engage in prolonged dialogue with each other or with members of the panel, and I will also not allow members of the public to address comments to other members of the public. Comments from the public are to be addressed to the hearing panel located at the front of the room and the court reporter. We do have representatives of Williamson Energy here tonight, and they will be providing a statement for the record, but they will not be responding directly to questions or issues raised at this hearing tonight.

As the hearing officer, I intend to treat everyone in this room in a courteous, respectful and professional manner, and I ask that members of the panel and the public please

do the same. You may disagree with or object to some of the statements and comments that are made here tonight, but this is a public hearing, and everyone has a right to express their comments on this matter. However, I will only allow statements to be made tonight that relate to issues involved with this specific water permit. Statements and comments that are of a personal nature or reflect on the character or motive of a person or group are not appropriate at this hearing, and if statements or comments begin to drift into this area, I may interrupt the person speaking and ask them to move on to their next issue. While the issues tonight may justifiably invoke an emotional response, responsive noises such as applause, jeering, booing and other responsive noises are also not appropriate. It interfere's with the court reporter's ability to create a fair and accurate record of tonight's proceeding. And so I ask that everyone in the audience respect her time and ability to be able to provide a transcript that's accurate for both the benefit of the Agency and for the benefit of the public following this hearing. If the

conduct of persons attending this hearing should become unruly, I am authorized to adjourn this hearing should the actions warrant. And if that were to happen, the Illinois EPA would still accept written comments through the close of the comment period which is January 17, 2020.

In addition, I'd like to briefly stress that we want to avoid unnecessary repetition. As you can see, we have a full room tonight, and there are many individuals who have indicated their desire to provide comments, so if anyone before you has already presented what is contained in your comments, please skip over those issues when you speak. If someone speaking before you has already said what you desire to say, you can pass when I call your name to come forward. Once a single point is made, it makes no difference if that same point is made once or a dozen times. It will be considered, and it will be responded to in the responsiveness summary. Duplicative comments or sentiments will not lend weight to the Agency's decision in this matter.

All who legibly complete a

registration card or submit written comments during the comment period will be notified of the final decision in the matter and of the availability of the responsiveness summary. In the responsiveness summary, the Illinois EPA will respond to relevant issues that were raised at this hearing or submitted prior to the close of the comment period on January 17, 2020. Again, I will accept those written comments as long as they are received at the Illinois EPA in Springfield by that date.

While the record is open, all relevant comments, documents and data will be placed into the hearing record as exhibits. You can send all written documents to the attention of Barb Lieberoff in the matter as directed in the revised public notice which is available at the registration desk and on the Agency's public notice web page. The physical mailing address should you want to submit your comments via mail is located in that public notice. And if you wanted to send your comments via e-mail, that e-mail address is epa.publichearingcom. That's publichearingcom@illinois.gov. Please include

Pond Creek Mine NPDES or the permit number, which is IL0077666, in the subject line of the e-mail. Again, those addresses are located in the public notice that's available to you at the registration desk or on the web page.

At this time, I'm going to have the Illinois EPA staff present tonight introduce themselves and make a brief statement regarding the permit and tonight's proceeding. Afterwards, they'll return it to me, and I will provide further instruction on how we will be taking comments during this hearing, and then we will begin taking comments from the public.

MR. LeCRONE: Is it on? Not on? No, not on. Okay. I'll just go ahead and yell then. My name is Darin LeCrone. I'm the manager of the Industrial Unit, so I am the -- you can't hear me?

My name's Darin LeCrone. I am the manager of the Industrial Unit and the permit section, and so I am the one whose name is on the draft permit and have the supervisory responsibilities for not only coal mine permitting but other non-municipal-type

wastewaters.

MS. WARD: My name is Iwona Ward, and I am with the permit regulation unit for the agency and responsible for reviewing the coal mine applications and preparation of the coal mining EPA's permits.

MR. TWAIT: My name is Scott Twait. I'm the manager of the Water Quality Standards Section. I worked on the antidegradation assessment, the mixing zone, which is based on the CORMIX model, and water quality issues for the NPDES permit.

MS. DIERS: Hi. My name is Stephanie Diers, and I'm legal counsel for the Agency.

MS. WARD: Good evening, ladies and gentlemen. Again, my name is Iwona Ward, and I am the permit engineer for the Mine Pollution Control Program for the Environmental Protection Agency.

The purpose of this renewal and modified NPDES permit is to regulate surface discharges to the water of the state from the surface facilities of the existing underground Pond Creek Mine. The surface facilities of this

underground mining operation are located on approximately 986 acres and include drainage control structures.

UNIDENTIFIED SPEAKER: We can't hear you.

MS. WARD: I will try and speak louder. Will this be okay? Well, I will try again. The purpose of this renewal and modified NPDES permit is to regulate surface discharges to water of the state from the surface facilities of the existing underground Pond Creek Mine. The surface facilities of this underground mining operation are located on approximately 986 acres and include drainage control structures, nine sedimentation basins, and a coal preparation plant with a slurry disposal system that is operated as a closed circuit. The surface facilities at this operation also includes coal stockpiles, coal conveyors, a railroad loop, access roads, office and maintenance buildings.

Nine basins with eleven outfalls are identified in the NPDES permit which control runoff from these surface facilities. Receiving waters for the discharges from the facility are

identified as Pond Creek, unnamed tributaries to Pond Creek, and the Big Muddy River.

The following additional changes and modification have been incorporated into the current NPDES permit:

Three new discharges of Outfall 009 discharging to the Pond Creek, Outfall 009ES discharging to the unknown tributaries of the Pond Creek, and Outfall 011 discharging to the Big Muddy River;

Various mining operation and drainage control plan revisions;

About 229 acres incorporated for Refuse Disposal Area Number 3;

70.7 acres incorporated for the pipeline to the Big Muddy River;

About 145 acres for various IBR's for additional permit area;

Addition of bi-annual metals monitoring of discharges from Outfall Numbers 6, 7, 8, 9, 9ES and 11;

Incorporated previously issued Subtitle D Permits;

Mixing zone to the Big Muddy River is

approved with this permit. Excess water will be transported from the Pond Creek Mine to Outfall Number 011 located in the Big Muddy River through an HDPE pipeline. Water will be pumped from the water holding cell through approximately 12.5 miles of pipeline to the diffuser located at the mixing zone. The amount of water that could be discharged through the pipeline depends upon the chloride concentration in the discharge stream, the background chloride content, and the flow in the Big Muddy River. Maximum pumping rate is 5,000 gallons per minute from the facility.

I would like to thank you everyone for coming this evening and welcome you to the Illinois EPA public hearing. Thank you.

MR. TWAIT: Once again, my name is Scott Twait. I want to provide some background on the mixing zone issue as the Agency has received several comments on this topic. Mixing zones are allowed by the Clean Water Act and Board Regulations. Mixing zones are a defined area in the receiving stream which allows the discharger to design an effluent structure to mix their effluent with the receiving stream to meet

the water quality standards. This facility will have to calculate the chloride concentration at the edge of the mixing zone based on the upstream river flow and upstream chloride concentration and the effluent flow and the effluent chloride concentration. The maximum calculated chloride concentration at the edge of the mixing zone will then have to be reported on the DMRs, which is the discharge monitoring report, which is submitted to the Agency. Using the equation in Special Condition 14 and 16, they can only use 25 percent of the receiving stream for mixing. The facility will be installing conductivity meters upstream in the effluent pipe and downstream of the mixing zone. The conductivity meters will be correlated to the chloride concentration so that the facility will have continuous information of the chloride concentration in the stream (upstream and downstream) and the effluent. In addition to the calculated chloride concentration at the edge of the mixing zone, the facility will be required to install a conductivity meter downstream of the mixing zone that is correlated to the chloride

concentration. They will then be required to report the highest chloride concentration (correlated to conductivity) on the DMRs. This will ensure that the calculations for the mixing zone are being computed correctly and the water quality standard is being met for chlorides downstream of the mixing zone.

Also, I wanted to let you know that the company has provided additional information yesterday by e-mail with a paper copy to follow in response to the public comments that have been received. The information that the company provided includes: Supplemental information concerning the antidegradation document for Pond Creek Mine; the Big Muddy flood analysis; and modeling of the Big Muddy River chloride dispersion downstream of the proposed mixing zone regarding Pond Creek Mine.

The Agency has not had time to fully review these materials, but they will be added to the permit record and reviewed in considering comments and revisions to the draft permit.

Finally, the Agency has received a lot of comments about flooding and has prepared

the graphs shown on the easels over here. The first graph is Exhibit 239. The first graph shows the monthly mean flows of the Big Muddy River for the calendar years of 2005 to 2009 at the Plumfield Station, which is just upstream of the discharge. 2015 to 2019, sorry. This station is a few miles upstream of the proposed discharge location. The graph also shows a straight line at the bottom showing the maximum discharge from Pond Creek Mine of 11.1 cfs -- that's cubic feet per second. This is provided to indicate the relative magnitude of the maximum discharge of the Pond Creek Mine of 11.1 cfs to the monthly mean flow of the Big Muddy River at the upstream gauge station. Please note that the peak monthly mean on this graph is 4,893 cfs. When the Big Muddy River is flowing at this rate, the maximum discharge of the mine, 11.1 cfs, is 0.23 percent of the flow. Using the peak in 2015 monthly average flow of 2,122 cfs, the maximum discharge of the mine is 0.52 percent of the flow.

The second figure, Exhibit 240, shows the lowest monthly mean for each calendar year of

2015 to 2019 with a comparison to the maximum discharge rate from the Pond Creek Mine of 11.1 cfs. This graph shows that there is enough flow during the dryer portions of the year for the Big Muddy River to accept effluent and maintain the chloride water quality standard. Thank you for attending this hearing.

HEARING OFFICER: I will note that we had someone scheduled to be here tonight from the Agency's groundwater division, but she was unable to attend at the last minute due to health reasons. Any questions pertaining specifically to groundwater, which we acknowledge will be present by the comments received to date, those comments may be addressed in the responsiveness summary and not by tonight's panel. I apologize for the absence of our groundwater division representative tonight.

People who have requested to speak will be called upon in the order in which they registered to make a comment. I have that stack of cards here. For the purpose of allowing everyone to have a chance to comment and to ensure that we conduct this hearing in a timely

fashion, I'm going to have to impose a time limit of four to five minutes per speaker. We have had over fifty members of the public indicate their desire to speak tonight, and we'd like to give everybody an opportunity to come to the microphone. If everyone has had an opportunity to speak and we still have time, I may allow those who initially did not desire to speak to come to the microphone or those who have spoken to speak again if there's additional comments that they weren't able to fit in during their initial time. If we cannot accommodate everyone who desires to speak and make comments this evening, please submit your comments to us in writing. Each comment submitted is received, entered into the hearing record, and addressed in the responsiveness summary. Again, those comments are given the same weight as any comments made orally here tonight.

We will start with the first speaker at the microphone, as I said, that's located in the aisleway here beginning with Clayton Cross on behalf of Williamson with Foresight. Once he begins -- or before he begins, I will read the

name of the next speaker and ask that you come and stand behind them so that you can approach the microphone as soon as the previous speaker has finished. I recognize that this may be inconvenient for some, but by having you ready behind the speaker who is at the microphone, we'll be able to get people to the microphone quicker and be able to fit in as many speakers tonight as possible.

When it is your turn to speak, you should state your name and, if applicable, any governmental body, organization or association that you represent for the record. If you are not representing a governmental body, an organization or an association, you may simply indicate that you're a concerned citizen, resident or member of the public.

For the benefit of the court reporter, I ask that you spell your last name. If there are alternate spellings to your first name, and you know who you are, please provide the spelling -- the correct spelling of your first name for the benefit of the court reporter. And once you spell your name, we will start

timing and your time period will begin.

Mr. Twait referenced two graphs that have been provided today for visual representation. As he referenced, those graphs have been marked as Exhibit 239 and 240. If you have questions specific to those graphs or comments specific to those graphs, please reference the exhibit numbers. It makes it much more clear for the transcript and for the Agency reviewing the comments later exactly to what you were referencing.

UNIDENTIFIED SPEAKER: Can you name those exhibit numbers again?

HEARING OFFICER: Sure. It's Exhibit 239 is the graph that's closest to me, and Exhibit 240 is the -- that's farthest away to my left that shows the minimum mean flow.

I ask that while you're speaking, you direct your attention to the hearing panel at the front of the room and to the court reporter to ensure that an accurate record of your comments is made. If you're reading from a prepared statement, please read slowly so that all of your comments can be transcribed by the court

reporter. And also, please consider leaving a copy of your prepared remarks for the court reporter. You can just walk up here and provide them to this corner of the table when you're done speaking. That will help make sure that the transcription is as accurate as possible.

Before we get started, I would just like you to raise your hand if you cannot hear me or if you have not been able to hear us to this point. No? Wonderful.

As I said, Clayton Cross is with Foresight on behalf of Williamson Energy. Clayton will be giving a statement that's limited to the same period as any other member of the public, and then our next speaker following Clayton, if you wouldn't mind coming behind the microphone, is Clare Killman with Carbondale Spring. You will be up following Clayton's comments.

CLAYTON CROSS: Good evening. Is this on? Can you hear me? Hello? Okay. Good evening. My name is Clayton Cross, last name C-R-O-S-S. I am the Director of Engineering at Foresight and Williamson Energy. Williamson

Energy operates one of the safest and most productive mines in the entire world. This is no mistake. Williamson Energy has invested in the best people, best systems and best equipment to build this coal mine. In all, over $600 million has been invested into this property. We are responsible for employing 194 coal miners directly. Another 283 contractors work supplying, servicing and performing some other activity for our operation. This means almost 500 families in this area directly depend upon the success of this mine for their livelihood, to pay their mortgages, educate their children, and buy Christmas gifts. Furthermore, every year this mine directly or indirectly generates $78 million in state, county, and local revenues. The economic boost that this mining operation provides to southern Illinois is very, very significant.

Given the extensive coal reserve that we have the rights to mine, this mine could be operating for another 50 years at current production levels. We need this permit renewed to keep this mine open long term and operating in

an environmentally-responsible manner while ensuring that our coal miners are not exposed to the unnecessary dangers of excessive water. This mine has operated since 2006, and the purpose of this hearing is to take comments on the IEPA's decision to renew and modify our NPDES permit. Generally, the NPDES permit allows us to discharge water at our mining operation under certain conditions.

When we first started this mine in 2006, the mine was very dry, meaning that we had to import almost all of our water for various uses. In other words, the mine didn't make much water. Now, as our mine has expanded for 13 years, we have had to handle an increasing amount of groundwater that is seeping into our mine.

This groundwater infiltrating into our underground coal mine presents two main problems for us. First, we have to get it out of the mine, because the water has the ability to block our critical ventilation systems or flood escapeways out of the mine, any of which leads to serious risks to our miners. We have to get the water out of the mine. We do this with pumps

that bring the water to the surface and pipelines that convey it to our main facilities.

This brings me to the second problem. The groundwater that is infiltrating our mine has naturally-occurring sulfates and chlorides in it. So one nontechnical way to look at it, it's a little bit salty, what you might call "brackish" water.

Again, this little bit of saltiness is naturally occurring in the water. It is not caused by anything that we add or because the water comes into contact with our coal. But because it is relatively salty, we have to deal with it differently than normal water. Historically, we have stored the water in surface ponds or impoundments, but they have limited capacities. We recirculate and use as much of the brackish water as we can on site through various processes, but we still have an excess.

So as many of you know, the plan to deal with this problem long term involves Williamson Energy building a twelve and one-half mile buried pipeline to the Big Muddy River, installing a multi-port diffuser, and tying the

diffuser to real-time continuous monitors. All of these elements work together to strategically discharge the water through a mixing zone into a water body that can easily assimilate it without violating the water quality standard. We evaluated other alternatives -- reverse osmosis, evaporation, and crystallization, to name a few, but these methods consume a tremendous amount of energy and require the disposal of a concentrated cake to a separate landfill. It is not as simple as filtering the water. The salt is dissolved.

This mixing zone is not going to be just an open pipe dumping continuously into the river. There are very specific controls to make sure the discharges are compliant with water quality standards. Water quality standards are adopted and approved by both the US and Illinois EPA based on a rigorous scientific process that result in standards that are conservatively protective of aquatic life. In addition, we have reviewed the aquatic life present in the Big Muddy River in conjunction with academic experts, and they have concluded that our discharges will not adversely impact aquatic life in the Big

Muddy River.

We will install continuous water quality monitors upstream and downstream of the diffuser (or outfall structure). This will give us virtually continuous data on the chloride levels in the receiving water, the Big Muddy River. And if we see on these monitors that the Big Muddy is not capable of accepting our water without violating the water quality standard, then we will not discharge. Instead, we will hold the water until the river can receive it without violating the standard. This provides the ability to control the flow so that water quality standards will be met on a continuous basis.

Lastly, I wish to address the concern for increasing the flood risk. Our discharge will not have any practically-measurable impact to the surface water elevation and to the flood extent. For example, we had a large rain event in this area on October 26th of this past year. It produced nearly three and a half inches of rain. This is almost equivalent to a two-year 24-hour rain event for this area. The Big Muddy

River at the Plumfield Bridge monitoring station eventually crested at a height of almost 10 feet, flowing 834 cubic feet per second, which is 374,326 gallons per minute. Again, almost 375,000 gallons per minute. If we were to pump our max capacity of right at 5,000 gallons per minute, our contribution would increase the water elevation at the Route 13 Bridge in Murphysboro by 1.8 millimeters.

HEARING OFFICER: Mr. Cross, I'm going to have to ask you to wrap up.

CLAYTON CROSS: Yes, ma'am. This is equivalent to the thickness of a quarter, so it's not practically measurable.

Approving the requested mixing zone is the safest, most environmentally sound and most effective way for Williamson Energy to manage its excess water to ensure the miners' safety and enhance our ability to meet the mandated water quality standards. We are fully committed to operating this system within the legal limits of this permit. This long-term solution will allow our first-class operation to continue and support about 500 local families.

Thank you.

HEARING OFFICER: If you're providing your comments to the court reporter, we'll enter it as Exhibit 241. I believe those comments may have additionally contained pictures of the graphs that are provided to the right of the panel today. Any information you see to the right of the panel has been provided by Williamson and Foresight and are not products of the Agency. If you have any questions specific to those graphs, you can reference Exhibit 241 in your questions orally tonight or through your written comments.

Clare, you can proceed to the microphone, and next up is Thomas Finkenkeller. You'll be up following Clare.

CLARE KILLMAN: Thank you, Christine. My name is Clare Killman. That's spelled C-L-A-R-E, K-I-L-L-M-A-N just for the alternative spelling. Is it okay if I ask a few questions?

HEARING OFFICER: Absolutely.

CLARE KILLMAN: Okay. This first one is for Christine Zevil (ph)? Is that how you --

HEARING OFFICER: Zeivel.

CLARE KILLMAN: Zeivel?

HEARING OFFICER: Yes.

CLARE KILLMAN: Okay. Just for the point of clarification. Are you all acting as representatives of the EPA currently?

HEARING OFFICER: I am an employee of the Illinois EPA, and I have been designated by the Director as the Agency's hearing officer.

CLARE KILLMAN: Yes. Would you consider everyone on this panel to be acting currently in capacities as reps of the EPA or whatever capacity they're acting in?

HEARING OFFICER: Everyone is an employee of the Illinois EPA.

CLARE KILLMAN: Cool. Thank you, just for the video camera and all of that.

HEARING OFFICER: Absolutely.

CLARE KILLMAN: So you're all acting currently as the EPA, like representatives of that organization here today. And that would mean that you would be able to speak to the ethical considerations of the EPA as I understand.

This first question is for Mr. Twait.

Do you consider humans to be a part of the environment you are obliged to protect?

MR. TWAIT: Yes, we have human health criteria also.

CLARE KILLMAN: Do you think it's irresponsible for an EPA official to misrepresent written data and then need to be corrected by their hearing officer in a public hearing?

HEARING OFFICER: I provided him clarification, because I've seen the written comments beforehand. They were written accurately, but while he was reading, he misspoke, and so I wanted to make sure for the clarity of the record. So it was a mistake, a misspeak and not a purposeful misrepresentation.

CLARE KILLMAN: And do you find that to be irresponsible is the question?

MR. TWAIT: When I read the material, I made a mistake, and she corrected me.

CLARE KILLMAN: Cool. Thank you. This next question is for LeCrone, if you don't mind. Just pass the mike. Darin, the definition of a sellout is the betrayal of one's principles for reasons of expedience. And as I understand

it, this permit's on your desk, right? So should you approve this permit, would you consider yourself a sellout and the EPA sellouts or just unprincipled?

HEARING OFFICER: Miss Killman, I clarified in my opening comments that remarks of a personal nature that speak to an individual's character or otherwise wouldn't be appropriate for this hearing. We're here to address specifically the technical issues, terms and conditions related to the permit renewal.

CLARE KILLMAN: Sure.

HEARING OFFICER: I ask that you keep your comments to that.

CLARE KILLMAN: Sure. As I said earlier, that you are acting as the EPA, so maybe this isn't necessarily directed to LeCrone as an individual, but more as a representative of the EPA offering ethical considerations privy to his position, right?

HEARING OFFICER: But comments specific to individuals are inappropriate for this hearing, and your comments --

CLARE KILLMAN: Sure.

HEARING OFFICER: -- need to be directed to the matter of the permit, the permit conditions, issues and questions surrounding the permit itself.

CLARE KILLMAN: And if the permit is signed, do you consider yourselves sellouts or just unprincipled?

HEARING OFFICER: Miss Killman, if you continue with your line of questioning, I'm going to have to move on to the next speaker --

CLARE KILLMAN: Sure, I understand.

HEARING OFFICER: -- unless you have another issue that you feel is more relevant.

CLARE KILLMAN: Okay. I'm totally fine if you move on. Thanks.

HEARING OFFICER: Thomas Finkenkeller, you are up next to the microphone. And following Thomas, Nick -- and I apologize for any mispronunciations tonight. I'm doing my best. Nick Smalego (ph)? Smaligo? Thank you.

THOMAS FINKENKELLER: Good evening. My name is Thomas Finkenkeller. First name T-H-O-M-A-S. Last name F-I-N-K-E-N-K-E-L-L-E-R. I am a concerned citizen living in Carbondale,

Illinois. One of my concerns is about trace effluence from the mine discharges. Looking at a pollutant loading report for Pond Creek Mine for all the years, for at least seven years in the past, there was at least one year that had incomplete data points, and I want to reiterate or I want to stress that it must be made clear that it is not just sulfates and chlorides that are important to have complete data on, because there are many other different elements. Whether they are aluminum or boron or various transition metals, it can be toxic in relatively low concentrations. I must stress that the data must always be complete before any permit can be approved. Thank you all.

HEARING OFFICER: Nick, you will be next to the microphone. And following Nick is Keenan Bell, Sr.

NICK SMALIGO: Okay, hi. My name is Nick Smaligo, S-M-A-L-I-G-O. I feel a bit limited in terms of the ability to speak, because there's certain constraints that have been put on the discourse here. One of them, as you said, to focus solely on the permit and the discharge, but

the problem is is that's connected to a mining operation and that, as Mr. Cross said, this is necessary in order to sustain that mining operation. And you all as members of the EPA and all of us as environmentally-conscious people here understand that you can't really separate one thing out from the whole that it's a part of. You can for a moment, but if you just focus on that one thing, then you're making an error in your perception. So we can't discuss this and the health of the Big Muddy River, the ecosystems that it's connected to, southern Illinois as a whole unless we're also thinking about the effect of coal mining on climate change, on the two million people who die every year as a result of the burning of coal, fossil fuels. And so it feels very limiting to say, well, we can only focus just on this thing, because these things are connected. And I understand that institutionally you have to put up certain blinders in order to function within the role that you have as a job, but that's not sufficient for the moment that we're in.

There are scientists around the globe

ringing the alarm bells about human-caused climate change of which coal burning has had a tremendous contribution to. And we can't -- you know, you can't be an environmental protection agency unless you actually consider the ecological crises that we're in. And so it seems to be utterly irresponsible to even consider sustaining this industry which has destroyed the lungs and the land for a hundred years in this place. And it's pathetic to see the lackeys of that corporation come up here and give their reasoned arguments within this very narrow window while the companies that own them have been funding climate change denial for decades. That was recently revealed by when Murray Energy which went into bankruptcy last month had to make its records of its political contributions public. So this is a company that is actively obscuring scientific discourse and the ability for us to make an informed decision about how we want to develop in this region and how we can freaking live. And here you are as members of an environmental protection agency trying to give them one last chance to sustain this horrible

practice for another decade or so in an industry that is in terminal structural decline in this region. It doesn't have a future, and they're trying to take us down with it.

Foresight Energy is valued at 8 cents on the stock market as of last week. They're on the verge of bankruptcy, and you're trying to give them a way out here. And when they go into bankruptcy, by the way, you know they're going to take all of that money and they're going to fuck over their workers just like that coal mine did down in Kentucky where the workers, to their credit, blocked the coal train and eventually won a settlement there. But this is disgusting, and to echo my friend Clare's comments, like the procedure, the idea that we're all just going to like keep it very, very narrow here and not talk about the issues that are actually driving all of us here, but to pretend that we're all biologists or chemists, we're not. But we know that this industry can't go on, because we've listened to lots and lots of biologists and chemists.

And so this is an opportunity for you all to make one tiny dent in the right direction.

And rather than permitting the continuing destruction of the ecosystems on which the life on this planet depends, right, you can put your foot down and say, No, sorry, Foresight, you're going to have to go into bankruptcy, and you're going to have to shut this mine down. And the rest of us here, especially those families on whose livelihood depends on this mine, we're all going to have to really quick figure out how we are going to live going forward, and that's a question we're all asking. Those families are in the same boat as the rest of us. But right now, we can't keep going down this path. Thank you.

HEARING OFFICER: Mr. Keenan Bell, you're up to the microphone. And following Mr. Bell, Mike Ellet, E-L-L-E-T, I believe is your last name, sir? Keenan, whenever you're ready.

KEENAN BELL: Thank you. Peace and blessings to everybody here tonight. Thank you for coming out. I didn't know I was coming out, but, you know, I'm a member of the universe, and I come here to speak on behalf of all of those things who cannot speak for themselves like the

wildlife, like the children, like the children in the wombs. I mean, I mean, it gets really deep. I mean, everybody speaks about going to heaven, right? Everybody talks about going to heaven and Hell, but no one else understands about the kingdom of nature first. You have to first respect the earth if you are going to expect the earth to respect you.

Now, people wonder why there's earthquakes going on all around the world. They wonder why these things, these drastic things are happening. Okay. When you take blood from the human body, what happens? It collapses and dies. That's what's going on with the earthquakes, okay? I can give you an explanation. All right. First and foremost, I must start over. My name is Keenan Bell, Sr. My mother named me. I was born here in Carbondale Memorial Hospital, so that makes me a native here of this area and these lands. And I have a name given by God. I am Chief Yunio Benyaweh (ph), and I speak in the name of Yaweh and his son Yahshua or Christ. Now, Christ died for all of us. I don't know if you believe in him. I know this. It may not be

pertinent to this conversation or whatnot, but he's real, and he is coming back. And I hate to be doing some drilling or polluting his earth when he comes back. I mean, you guys are bringing a curse upon these lands. Don't you see it? 2020, 20/20 vision, 2020 Mad Dog, whatever you want to call it. You guys are opening up Pandora's box. Please stop, because if you don't, then there will be repercussions, and those things you guys aren't ready for. I mean, Gaia, Mother Earth, she's real. I mean, she feeds us; she clothes us; she shelters us. I mean, she's everything we need. Why do we continue and insist on destroying her? Why? You ask yourself that question when you go to sleep at night.

You know what? It's not about clean this and that. It's about money, and money is the root of all evil. You talk about all of these millions and these billions. Why isn't this money going to help these homeless people? I'm staying currently at this homeless shelter, because I'm a traveler, and I didn't know I would be here tonight. I'm going to wrap this up.

I'll tell you this. Decisions and the choices is what molds one's lives. See, your lives can be filled with happiness. Well, you could be doomed from all your sins and die, die, die.

Have a blessed night, everybody. And for the record, everybody, if you continue with this -- and I am just a messenger -- you will curse yourself and your families. Have a great night.

HEARING OFFICER: Mr. Ellet, you're up to the microphone. And following Mike, Lucia Amorelli -- Lucia, you'll be up following Mike's comments.

MIKE ELLET: My name is Mike Ellet. Last name is E-L-L-E-T. My credentials are I'm retired. I was a licensed -- under the Department of Health licensed state plumber. I started my occupation in 1964 in the Air Force as a plumber, went to plumbing school. After that, I've come through the apprentice program, got my license. I was in business 45 years. So a part of my license fell under the Department of Health, and my other part of my license fell under the EPA. I went through the Environmental

Resources Training Center in Edwardsville to become a cross-connection control device inspector, State Drinking Water Act. I see we're addressing the Clean Water Act here tonight.

Now I'm going to go back in a little bit of history why I'm here. I was raised on the Big Muddy River, that direction over there towards Hurst and Bush in a little community called Blairsville. In the early '50s, from '53 to '59, the Big Muddy River was poisoned twice. I don't know if Scott under the -- first name of Scott up there, Clean Water Act, I never knew. I'm not saying the mines done it, but it can happen. What had happened when I say "poisoned," the first time it come down, it was red water. And what I'm saying is it turned the Big Muddy red. And when someone was mentioning earlier the aquatic conditions of the river, it killed everything, all of the fish, wild animals, birds. My uncle had livestock that part of his fencing was the Big Muddy River, so he had to move the livestock away. And then in the latter part of the '50s, probably '58, '59, here come the green water. When I said the red and green water, I

mean it turned Big Muddy red and green and killed everything.

Now, again, my license fell under the Safe Drinking Water Act, and this is under the Clean Water Act. This can happen. I don't know if records was kept from the EPA or what happened then. Again, I'm not saying the mines done it, but I say it can happen. And, you know, remembering this as a child, we had people in Blairsville that would actually -- four commercial fishermen back then for a staple -- we didn't have all the money in the world, so these commercial fishermen sold fish to make a living, and myself, probably about ten years old, I done what we call trotlines, and I got to sell some of my fish to the commercial fishermen and then bring it home to our family. Not after this. I remember one of the things that for some reason it stuck in my mind, Blairsville Bridge a hundred yards upstream, and when the water would get low, there would be an island, go out in the middle, and there was actually mussels on the river, okay? We would see that in there, the oceans and whatever. After that happened, no, there were no

more mussels. And the other thing about this is back at that time -- and I'm kind of curious about that, what happened -- is several of the communities along Big Muddy -- Royalton, Murphysboro, Hurst, whatever -- that was their water source. So to say that this can't -- and the monitoring. I think what I've seen in the past the years that I was a plumber or worked with the EPA or whatever, the response comes after a disaster. And that's why I'm here, and I thank you for my time, okay?

HEARING OFFICER: Ms. Amorelli, you'll be up next to the microphone. Following Lucia, George Ellis. You can prepare yourself to follow Ms. Amorelli.

LUCIA AMORELLI: Okay. My name is Lucia Amorelli.

HEARING OFFICER: Lucia, I apologize for my mispronunciation of your first name.

LUCIA AMORELLI: That's all right. A-M-O-R-E-L-L-I is the last name. Lucia, L-U-C-I-A. I'm going to bounce around a little bit, just a couple of different topics. First of all, I am from Jackson County. I'm a concerned

citizen. I live five miles from the Big Muddy River, less than half a mile from one of the tributaries. I'm an avid hiker, kayaker, swimmer. I swim in these waters, I kayak, I do all kinds of things. That's why I live here. That's why I'm here. I've already submitted 16 pages of comments. I could have written a whole book on the issues and on the unanswered questions that I hope to get.

The first thing I want to address is just for everybody's information. According to information I found on the EPA violations, Williamson Energy between -- just between 2015 and 2017, just those two years, 45 outfall effluent violations. Two years. I haven't got the information for the other years. Eleven violations were sulfate and ten for chloride in Pond Creek, which brings me to issues of water quality. You say that we are not going to have problems with water quality, but they're repeatedly violating the standards, okay? So how can the water be safe if they're repeatedly violated?

The second issue of water quality,

and I'm sure other people will address this further, is that the standards for Illinois are some of the worst standards around. Our neighboring states -- so 500 milligrams per liter of chloride for Illinois, but surrounding states -- Indiana, Missouri, Iowa -- they have 250 milligrams of chloride. That's because the national quality water standard is like at 250 milligrams a liter for chloride, which is what they're saying is the acceptable level for aquatic life. So our standard is two times higher. And there could be up to 12,000 milligrams dumped into the river at a time to diffuse, 12,000 milligrams, just to say that.

In 2004, the Big Muddy River TDML report states that the Big Muddy River is compromised and impaired. And again in the 2019 report that just came out, the same thing. The Big Muddy River is already polluted. It's already impaired in part because of mining operations. It states that, and I quote, Abandoned coal mines should be identified in addition to other mining activities which contribute to manganese and sulfate

concentrations, which is exactly what the violations are for this company. So my question to the IEPA is does this mean that the IEPA is going against its own implementation plans by considering granting a permit for a pipeline which will infuse the river with more elevated levels of chlorides, sulfates, manganese and other pollutants? Does this not go against the Clean Water Act? So IEPA already says the river is polluted, but then they're allowing more pollutants to go in. Why is Pond Creek Mine not included in the draft permit? It's a polluted river, polluted tributary. It's not included in the permit.

I want to address Scott Twait about mixing zones. You said that they're following the mixing zones. But in Section 302.102 allowing mixing, mixing zones and ZIDs. Number 4, Section 4: Mixing is not allowed in water containing mussel beds, endangered species habitats, fish spawning areas, areas of important aquatic life habitats or any other national features. My question is has this been determined by the EPA or IDNR if there are

endangered species, mussel beds, because there's no mention of endangered species anywhere except for they won't be affected, any species, because the water qualities will be met, which is not true, because they violate all the time.

Second thing for mixing zone. No mixing is allowed when the water quality standard for the constituent in question is already violated. The water is already violated, which brings me to what I want to close with and then I have -- they're all my pages. Which I've been sick for a couple months primarily probably focusing on this, which is very, very upsetting. And I think someone else is going to be talking about the endangered species. The point I want to bring up that someone might not bring up very quickly is that this section of river is the exact section of river that the NRI, the National Rivers Inventory, by the national parks has listed as an outstanding remarkable value just south of Rend Lake exactly where this pipeline all the way 52 miles from the Southern Illinois Airport which is where I live close by. It says that it being a wild and scenic candidate river,

it's supposed to have protections from government agencies. It says if an NRI river segment could be affected by the proposed action, an environmental assessment or an environmental impact statement needs to be done. My question is why was there no mention that this is an Outstandingly Remarkable Value designated river? Nowhere no one has ever mentioned it. Why? It's the exact same section. We have this section of a river, and the EPA doesn't seem to care.

I want to finish with that I believe the rivers -- and this is starting to become worldwide, this thought, this philosophy, and it should be. Has the EPA considered that the river itself should have its own rights? It's already dammed and polluted. It's dammed at Rend Lake to create water for us, to create water for that mine. It's dammed. It already has a pipeline that's at Sugar Camp 12 miles north of this proposed pipeline. It's already being screwed by the stuff that's going to come out of that pipe, and now you're proposing to put another pipeline in it. How much more should the Big Muddy River endure? How dare we as humans treat the river as

a toxic dump?

HEARING OFFICER: Mr. George Ellis, you're up next to the microphone. Ms. Amorelli, thank you for your comments tonight. We are out of time to be able to answer at this time directly to the questions posed, but they have been recorded by the court reporter for the transcript, and responses will be provided in the Agency's responsiveness summary. Mr. Ellis, are you here this evening? So you're going to pass?

GEORGE ELLIS: Yeah.

HEARING OFFICER: Okay. Tabitha Tripp. Tabitha, if you're here tonight, you're up next to the microphone. Following Tabitha -- while she, perhaps, comes forward, following Tabitha will be Roy Sumner. Is Tabitha Tripp here this evening?

UNIDENTIFIED SPEAKER: She's coming.

HEARING OFFICER: Okay. I apologize for the short notice. Roy Sumner? Mr. Sumner, if you're available, you will be following Ms. Tripp at the microphone. Thank you.

TABITHA TRIPP: Tabitha Tripp, T-R-I-P-P, T-A-B-I-T-H-A. I am with Southern

Illinoisans Against Fracturing Our Environment. So I had a FOIA at the EPA office for what had been told to me a complaint had been made. And on first response, we were denied. And finally on the second response, my wording must have been correct. So in a field inspection report for compliance sampling dated 8/29/19, the EPA employee spoke to a nearby landowner who said the EPA should take samples on Saturdays or Sundays when the stream is rolling in dark gob water. The landowner was advised to then make a formal complaint to which he responded that the mine had given him such a hard time last time that he didn't want to make a complaint, a formal complaint. So my question to the EPA is what recourse do citizens have when they see a violation occurring and assume that risk of making a complaint, but yet the polluters are allowed to bully us, the citizens, in silence? If you at the EPA are not doing your jobs in enforcing the regulations that they are, and citizens who see the violations, they should be protected by you. You should uphold the law and stand with the citizens who are actually doing

due diligence and actually reporting those violations.

On 9/3, an IDNR inspector -- this is in the same report -- it cited in this report saying that he had received similar information from multiple resources about off-hour discharges. Are these off-hour discharges a reoccurring problem with this mine? The same reports state that despite the daily effluent of approximately 2.7 million gallons of underground water seeping into the mine, there have been no discharges monitoring reports since March of 2019. And that report goes on to say that the water max balance of effluent water and discharge water does not appear consistent. Seems a little weird to me, too, that there's 2.7 million gallons going into a mine today but nothing was documented coming out. Doesn't add up, does it?

Sample results show amounts of sulfites and chlorides greatly exceed the limit of permit water quality standards in this little report that I got. And then the report goes on to say monitoring violations, the analysis not conducted of discharges, inadequate frequency of

sampling, invalid underrepresented samples as required by permit. So I guess what my biggest concern here is it seems like you've got EPA employees saying one thing, but when we look at the EPA ECHO site, it's saying another thing. I thought it was really awkward that it went on the site on Sunday and it said that there were actual violations in a big yellow box on the ECHO site, and then today I went there, and the box had turned blue in two days, that there were no violations. So I'm curious what happened in the last two days that it went from there were violations cited to no violations? I took screen shots, because I was a little baffled that that just happened today.

So I'm a little concerned about the transparency that the EPA is sharing. I'm concerned about the authenticity of the information that you're sharing with the public. I am concerned that there is not adequate monitoring happening. I'm concerned that there's not inspections that are actually documenting what's really going on, and I'm really, really concerned, because what happens is when citizens

make a complaint, then they're bullied into silence. That's not acceptable. It's not acceptable that we don't have any recourse as citizens when we actually stand up and report something. You see something, say something. Isn't that what the cops are always telling us now? Isn't that what they tell us in the airport? You see something, say something. We are, and we're getting bullied. I don't have anything further to say.

HEARING OFFICER: Mr. Sumner, we're going to take just a moment to respond to a few of the points made, and then we'll bring you up to the microphone.

MS. WARD: We appreciate all of your comments and your concerns. Yes, you're completely right, you know. Yes, you should be our eyes in the field, and we all appreciate if you see anything, please report it to us. This is helping us to keep the company and all our environment protected. So I would like to -- you provided many, many questions, and I would like to answer all of them. I will provide you responses in the summary. All of my comments --

all of my responses will be in the responsiveness summary, but one of our questions or one of your questions I remember was -- so they did not disappear on the DMRs. On the ECHO system that you see one day and another day you have not that's because we actually review the DMRs also, and we realized that some of them was recorded with the wrong units, was recorded with milligrams per liter versus it should be recorded milliliters per liter. That's why some of them actually was not a violation, so they were actually mistakes again -- by our mistake was wrongly reported on the DMRs on the ECHO system.

UNIDENTIFIED SPEAKER: (Inaudible)

HEARING OFFICER: Any comments from the audience will not be taken by the court reporter and should be reserved for the time at the microphone.

MS. DIERS: I think one other thing I want to note about you talked about the violations that you saw. There's an ECHO system which is USEPA, and then you have ICIS is what IEPA does. So sometimes there's mistakes made at ICIS on our system or it doesn't get fed in

enough time to EPA, so sometimes they cross over. So if you see those instances where you guys are seeing something on ECHO, that is not on our ICIS or vice versa. So now that you have raised those issues about compliance issues numbers that you've seen, we are going back through the DMRs and looking to see if they've recorded correctly, if the numbers are correct. Like Ms. Ward mentioned about seeing that some of the parameters weren't recorded correctly, we are definitely looking into that and appreciate you guys raising that information with us.

HEARING OFFICER: Mr. Sumner, please come to the microphone. I appreciate your patience. Following Roy's comments, Georgia de la Garza, you will be up following Mr. Summer.

ROY SUMNER: Hello. I'm Roy Sumner, S-U-M-N-E-R. First name is R-O-Y. I have lived on Carbon Lake Road in Murphysboro for the last 25 years. I'm very close to the Big Muddy River. This last -- in 2019, I think from the end of January until May, the Big Muddy River lapped at the road. Late May into June, it was closed for two months. What I have observed in the 25 years

I've been out there is that it's more likely to see more frequent flooding that affects my road, and I notice it when I can't get out. But I'm also concerned about the poisons that they've mentioned in this water that's going to be discharged. And I haven't seen anything or heard anything so far that makes me comfortable accepting the plan before us. Thank you.

GEORGIA de la GARZA: Georgia de la Garza. Georgia is spelled like the state. de la Garza is D-E, space, L-A, space, capital G-A-R-Z-A. I'm president of Shawnee Hills and Hollers as a 501, and I'm also a organizer with Big Muddy River Rats over here in Zeigler at the point where they're going to be expelling these toxins in the water.

When I was first called by my home people over here to come and talk to them -- I've worked on the front lines of the coal industry now for fifteen years -- I put a presentation together, went over there, and the first question I asked them, because I grew up on the Big Muddy River. We had a house in town, but my dad wanted us to have that farm experience, so we were

raised on a farm on Big Muddy. We had a rope, jumped into the river, swam, learned how to make turtle soup, how to run troutlines, you know, catfish lines, how to canoe, make identifications of a poignant amount of bird life, scout mussels for soups. There was a lot of creatures and people and community that lived on that river and that still do live on that river and use that river. So the first question I asked them, because I used to throw a pole alongside many of them, was how many people in this room, which was a packed room, fish? Everyone -- little kids, moms, grandmas, everybody raised their hands. I said, How many of you lately have seen something wrong with the fish? The livers are enlarged. Their eyes are milky. The gills are messed up. How long has this been going on? Several years now. The mussels have declined substantially. How was I going to tell them that I'd just found the permit after looking through the 456 IDNR permit, this permit, looking at the data, looking at the science that Sugar Camp Mine had been dumping into Big Muddy since 2003. So we know that Big Muddy has a substantial amount of this

same water that's been being dumped in that river on a daily basis. There are documents that prove that. There are readings that prove that. So we know that if they're going to be dumping and allowing 3.5 million more gallons of water going on top of 2.6 million, we know what that river's going to look like. We know that whatever aquatic life that's there is going to go. We know that our way of life on the river is going to go.

And something that you need to consider, too, is, you know, the Big Muddy is not just a river. It's a major tributary, a major tributary of the Mississippi River. Right now, we have our local governments are looking at the issues that we're having on our rivers now. And this is detrimental to that whole Mississippi flow and resiliency that we're looking at as our communities are developing and preparing for these floods that we've been having and looking at climate change.

I work with Wash U students. I've been doing that for about seven years. And the last two years we've done a major study. I think

the EPA, you guys reached out to us last year to ask us to see that data which was pretty substantial. It's a lot more than just under a hundred violations. There are multiple clustered violations that we have in our areas. I think I was showing some of you some photographs of our water. We've done a lot of aerials here. We are surrounded right now with mercury ponds, aluminum ponds, heavy metal holding ponds, and I want you to take into consideration right now this is not just about a pipeline going into the river dumping 3.5 million gallons of toxic water. This is about whole communities that Pond Creek Mine is wiping out. You go over to that community, the houses are abandoned. People are being forced out of their homes. You can't do -- you can't farm the land, because it's caving in, because that's what longwall mining does.

If the coal miners -- 194 coal miners, let's compare that to the thousands of people in southern Illinois who are being diagnosed with cancer on a daily basis. One of our biggest industries here is health care, and it is because of these toxins that are being

emitted into the air making us sick. We have a cancer that is 1 in 28 million diagnosed in the USA. We have ten clustered cancers, a group over here of ten, mostly children, right over in that area surrounded by these toxins. Take a helicopter, I urge you, to go over. And say, you know, well, the violations we're taking in consideration. Here's our experience when we report violations. We've done this multiple times every year. Groups of students that come in from Wash U, Northwest, U of I, whatever, and communities that we -- community groups that we organized. You say if you see something that is a violation -- of course, we have the forms. Fill out your violation. We'll submit it to the EPA. We call the office over in Marion, and then we go and we sit and we wait to see how long it takes for someone from the EPA to come out. But guess what happens? The coal mine goes out there, and they clean it up really quick. Do they get a phone call? Do they get, you know, Hey, get over there and clean it out. We've got to come and check this out. And then a day or two after the coal miners leave, guess what? The

EPA comes in and, oh, interesting. We don't see anything. You mean, you don't see that 30-foot ditch pouring out of a 168-foot impoundment structure going into agriculture? No, it's not there. Well, we have video. So here's the other thing I want to -- two other points I want to make.

Now that we have scientists that work with us, we have -- I think I have ten of my students that I've worked with over hundreds over the last few years, ten of them are now environmental lawyers -- love it -- and they're all ready to work and jump in for us. We have found foundations that will support that effort. So right now, since we know the science, since we know, we're working right now connecting these toxins to our health risks. We've got the data we've worked on for two years. We're connecting it with new data that we're compiling and working very hard to get an epidemiology report. And we know, as you know, testing has become very clear right now.

HEARING OFFICER: Ms. de la Garza, I'm going to have to ask you to wrap up.

GEORGIA de la GARZA: Okay. It's become very clear right now when we make those connections, when you sign those permits, you're an accomplice to our murder. You're killing us here. We're dying from this industry. We're dying. It's not about the endangered species anymore. It's about us. I want to say one thing --

HEARING OFFICER: You've had eight minutes now, Ms. de la Garza.

GEORGIA de la GARZA: Praise to you, my creator, with all of your creatures, especially sir brother sun, who is the day, and through whom you give us light. You remember --

HEARING OFFICER: You have had eight minutes, Ms. De la Garza. I'm going to have to ask you to sit down.

GEORGIA de la GARZA: -- where our creation is. Praise to you. Water is life.

HEARING OFFICER: Amber Futch, you will be next. If you would come up to the microphone, and following Ms. Futch, Jan Thomas.

GEORGIA de la GARZA: (Untranslated chant.)

HEARING OFFICER: I'm going to have to ask you to sit down for the benefit of the panel. We have other citizens that want the opportunity to speak. I do not want to have to ask you to be escorted from the room, so can you please sit down, ma'am? Thank you. Amber, you're going to be up next to the microphone. Jan Thomas, you're going to follow.

AMBER FUTCH: As you know, I'm Amber Futch, Futch spelled F-U-T-C-H, and I didn't grow up around here. I grew up in Tennessee near plastic factories and such, and they were allowed to dump into the Duck River down in Tennessee. And they said they were within the -- reasonable with the EPA and everything. And we currently in Hickman County, Tennessee, do not have a viable water source from the Duck River. We have to go out further from the Duck River to get water. My concern is the same thing happening here if this is approved, because people, after working with corporations before, I know they are good at covering up what they do. They lie about their numbers, and that's a huge concern to me. Is it being digitally monitored and sent to you guys

and you guys are seeing it as live, or is it them reporting it to you? Because people can lie very easily on just a submit -- oh, it has to be at this. Well, we'll say it's this, without even checking. And that's a huge concern of mine, not to mention the way the wildlife is going to be impacted. Every little thing that we do to our environment comes back to us. When they tested Agent Orange in Hickman County, Tennessee, the same place I came from, they didn't understand the whole cancer risk with it. Yeah, it got rid of the brush, but at what cost? It killed parts of our environment, and we're still recovering today from it. I may be from a different area, and I may not understand everything that goes into it, but I want to know more information on it, more than what you provided, in plain English as well. I see on there that there would be a minimal amount of mercury allowed into the river, and mercury, period, is not healthy for river life and/or people. That's about all I have to say on the subject.

HEARING OFFICER: Ms. Thomas, you'll be next up to the microphone. And following Jan

Thomas, Cameron Smith, if you could please be ready to provide your comments.

JAN THOMAS: I'm Jan Thomas. That's T-H-O-M-A-S. I live in Murphysboro, and I would like to talk about a couple of things, and one has already been -- yeah, one has already been touched on. But, basically, it is the financial unreliability of this company which somebody mentioned its stock is worth $0.08 now on the New York Stock Exchange. About four years ago, it was worth $17. So as you can see, it's plummeting, and, in fact, all of the coal mines in the Illinois Basin are projected by the Institute for Energy Economics and Financial Analysis, they're all going down the tubes and pretty fast, too, because most of this coal goes to electricity generation, which companies are now switching to natural gas, because natural gas is cheap. We're fracking now, which is another whole issue. But a lot of the coal-burning power plants that Foresight Energy supplies throughout the Midwest and the Southeast, a very large percentage of them, according to this article, have indicated that they will be either closing

or severely reducing their production as coal burners within the next decade certainly. So all of this is just financially unsupportable. Foresight just missed a $24.4 million interest payment at the end of the third quarter of '19, and they have been given, so far, two, maybe we're even up to three now extensions from the SEC on paying this. But as a matter of fact, their total debt is like one and a quarter billion dollars, and yet we're talking about permitting them to build out an elaborate infrastructure which will keep tying this -- tying us to dependence on fossil fuel for an indefinite period of time. And they're bragging that they have 50 years worth of coal there, but the planet can't really handle 50 years more of burning coal. In fact, the writing is on the wall. Coal mines are done. And I'm afraid that the coal miners here are going to find themselves in the same state as those ones in Kentucky. Everybody heard about them camping out on the railroad tracks to stop that last shipment of coal from going out because their company was bankrupt and they hadn't been paid. And, as a

matter of fact, the paychecks they had recently gotten had bounced. So this is not a good financial risk.

And, by the way, there's not a severance tax on coal in Illinois, and it's been mined here for almost -- maybe even for two centuries, and there's still no severance tax on it. Every other state in the country has that.

Oh, and one more thing. In that category of Robert Murray, the CEO of Murray Energy, parent company of Foresight which just filed for bankruptcy, he took away $14 million when he left, and he also contributed $1 million to climate-change-denying groups. So these guys are not -- you know, the coal miners, I'm very sorry that they're in a stressful position, but we all know they're not really the people who get the money. The money goes to the CEOs. So that's my first point.

And my second -- this is really a question. I have not seen anything at all anywhere that's a solution to this saline water seeping into the mine from an underground aquifer. Why isn't it -- why hasn't it been

suggested that this saline water could be placed in the depths of the earth with these injection wells? We all know that the fracking industry does this all the time. And if this were fracked water with all the toxic chemicals added in order to make fracking work and with all the radioactivity and more salty stuff brought out from the deep earth, I would definitely not be advocating this. But the coal mine is telling us this water is just salty, so why aren't we asking them to reinject it in deep injection wells back into the earth? So I think you should deny this permit. Thanks.

MR. TWAIT: You asked the question about why they're not injecting the water. They are currently doing that at their Sugar Camp Mine. They're running it through reverse osmosis and developing a high concentration brine and reinjecting it in deep water wells. And the deep water wells haven't been able to continue to handle both -- the amount of water that's pumped down there, and so it's just not economical for them.

HEARING OFFICER: Mr. Smith, you're

going to be up next at the microphone with your comments. Following Cameron Smith, Connie Schmidt.

CAMERON SMITH: I'm Cameron Smith, S-M-I-T-H. I live in Murphysboro. I'm a SAFE member. I'm also a property owner, and I'm here not to take anybody's job away, but I'm here to protect my property. My wife and I co-own the historic Douglass School in Murphysboro. The Frederick Douglass School was first built in 1897, way before the building of the Rend Lake Dam. It was Murphysboro's segregated school, and it was built next to the Big Muddy, because they were the black kids. Anyway, back in the day when the Big Muddy was a navigable river, they hauled brick and coal down that river. Today, FEMA has classified our building as an AE Flood Zone. So it's not a matter of if it will flood; it's when will it flood.

On May 3, 2011, the Big Muddy reached its record high of forty and a half feet above flood stage, and that was at the gauging station on Route 127. At that time, the 127 bridge was closed and under water. The water was so high,

you could no longer see the guardrails on either side of the river. The Route 13 Bridge was also being threatened, but it remained opened and closely watched by IDOT. During this time, the flood water was so high and so strong, the water was vibrating the bridge, so it was decided by IDOT to rebuild the bridge and raise the level of the Route 13 Bridge. I wonder if IDOT had calculated for this increase of water flow from Pond Creek.

This spring we had standing water on our property for 148 days. I think the gentleman mentioned that. Most of the time, the flood water comes in and goes out as fast as it comes in. But this spring, the water stood there in our yard, and we could see hundreds, if not thousands, of minnows and tadpoles on the water's edge. So I have to wonder what these extra chlorides and sulfates will do to the population.

Mr. Cross mentioned that the amount of water at the time that will be released is only 5,000 gallons per minute, or that would be 83 gallons per second, and that would be the equivalent of 16 five-gallon buckets coming out

of those pipes in one second. That sounds like a lot of water to me. But my understanding is that the mine won't be allowed to increase the water discharge when the Big Muddy is high, and I have to wonder what that one percent of increased salty water will do to our historic building. And will the IEPA be monitoring how much comes out of that pipe at that time? How much longer will we continue to pollute our waters and not care? I ask the IEPA to deny or delay the permit to allow for further study for what impact it will have for the people of southern Illinois. Thank you.

HEARING OFFICER: Sir, if you give a copy of your comments to the court reporter right down here in front of me, it will be entered into the record. Connie Schmidt will be up next to the microphone, and following Ms. Schmidt, Galen Thomas, if you could be ready to provide your comments.

CONNIE SCHMIDT: Hi. My name is Connie Schmidt, C-O-N-N-I-E. Schmidt is S-C-H-M-I-D-T. Good evening. I serve as the Chairperson for the Executive Committee of Sierra

Club, the Illinois chapter. We are a big group. I represent 100,000 members and supporters across Illinois, and we are concerned with a clean and healthy environment for all residents of Illinois. This includes clean water, which is what brings me here today.

The request by the Pond Creek Mine owners for discharge of dirty wastewater carrying high concentrates of chloride and sulfate into the Big Muddy River is ludicrous at best. These pollutants impact aquatic life, both plants and organisms, by altering their ability to reproduce and killing many of them off, thus drastically impacting the ecosystem and all of the other species that depend on those life forms, which would include humans.

Dumping waste into a natural resource like the Big Muddy is harmful to southern Illinois and beyond. The Big Muddy carries water to the Mississippi eventually and on to the Gulf of Mexico. This is already an area in serious peril. In addition to the Big Muddy, it's very important to humans. It provides tourism. There is commercial and recreational uses of the water

both for visitors and local residents, not to mention a safe haven to countless fish and other species. This area is prone to flooding, so polluting the actual waters of the river would also harm the riparian watershed as well. Endangering these factors is like shooting a healthy resource in the foot.

The plan to monitor this discharge is flawed at best. The discharge would enter the river at its bed where contaminants are more difficult to detect, and the entry point is strategically placed downstream of a monitoring system. This river does not have a rock bottom that naturally can act as a filtration. By its very name, we know that mud lines the river basin trapping pollution within its banks. Even if the pollutants could seep through the river, they would enter -- undoubtedly enter an aquifer that would connect to human drinking water at some point. It is just not a good idea to allow pollution into a water source.

In conclusion, we ask you please deny this request to dump dirty wastewater from the mine into any water system sustaining life for

recreation or creatures of our environment. Thank you.

HEARING OFFICER: Mr. Thomas, you'll be up next. Following Mr. Thomas, David Freeman. Mr. Freeman, if you can be prepared to provide your comments.

GALEN THOMAS: Galen Thomas. Last name T-H-O-M-A-S. First name G-A-L-E-N. On behalf of the Southern Illinois Kayak and Canoe Club, I want to thank you for the opportunity to come and speak to the group. Although we have been assured that this discharge of 2.7 to 3.5 million gallons per day of mine water into the Big Muddy will not pose a hazard to individuals using the river for kayaking and canoeing, it's frankly difficult for us to believe that water with that quantity going into the Big Muddy will not create turbulence in that particular area that could pose a hazard to people that are kayaking or canoeing, especially if they are relatively new to the issue of trying to maneuver around hazards in the water. The map or the picture that they had up on the board earlier there showing the depth allegedly of the Big

Muddy is really a misrepresentation, because we were out very recently, thanks to Iwona Ward and her cooperation with the mines, to see the actual location and, in reality, the water level is on an embankment of 30 feet down to the water. So I would really like to know if anybody knows what the depth of the Big Muddy in that area is currently, because it surely isn't 30 feet deep for the diffusers to be pouring the effluent into the water. Three and a half million gallons a day would seem to create some turbulence. I don't care if it is directed to be on the bottom of the water or the bottom of the screen and it supposedly is on the side that the natural flow of the river is going to push all of that polluted water up against the one bank and, magically, it's not going to spread out over the entire flow of the water so that fish will conveniently swim down on the upstream part of it and not be impacted by that. That's what we're supposed to believe.

In addition to the turbulence issue, there is concern for the high concentrations of sulfates, chlorides and other pollutants that

might pose a danger to people if they fell into the river in that particular curve where the water is, because some of the individuals that have expressed concern on our website take their children out for kayaking and canoeing on the Big Muddy, and they're very concerned that this might be an added hazard for them.

We have concerns that the antidegradation assessment is deficient because it seems to totally be focused on the water quality issues while not giving any assessment to the impact on the recreational use of the Big Muddy and the potential economic impact on reducing the Big Muddy's contribution to the region as a tourism destination.

The assessment also identifies the Big Muddy, as others suggested, as being impaired due to sulfates, chlorides and several other factors, but ignores the fact that the plan will inevitably result in more contamination of the river. The reality is the proposed dumping would result in some increase in the TMDL, the total maximum daily load. Just because the diffusers are located near the bottom of the river out of

sight doesn't change the fact that dumping is occurring. At best, it minimizes the portion of the river that's immediately impacted and a plume may be not evident to observers, but nevertheless, it is there. We would hope that the IEPA is not saying that pollution is acceptable as long as the water quality limits are not exceeded. Does it have to exceed the 500 milligram level in order to cause alarm? I would hope not. It's still impairing the river more than what it's already impaired. Maybe rather than having the diffuser hidden under water and out of sight, it would be preferable to just have a pipeline that pumped directly into the Big Muddy so people could see when pollution is being dumped in rather than having it hidden near the bottom. Surely we're not saying if the Big Muddy is already impaired, what's a little more contamination?

How will the monitoring equipment be installed to ensure that it's secured when the water levels vary so drastically in that region? We were out there, like I say, 30 feet at least down at the water level, but during flood stage,

it's much higher than that. It's almost up to where we were walking. There aren't any bridges in that area or any real sturdy structures in order to attach the monitoring equipment there like it is at Murphysboro. So there's something going to have to be constructed there to shield and protect it from floating debris, trees and all the other things that come down during the floods.

How will the diffuser vents be protected from people continuing to use the location as a dumpsite for large objects? I assume that there's going to be a fencing off of that area, but currently as we saw, there were deer carcasses that had been dumped over the side, and in the past it's a historic dumpsite for larger objects that people just wanted to get rid of. So if somebody dumps a refrigerator or something off there, it has that potential of damaging the vents.

As far as the monitoring goes, our recommendation would be that the monitoring be done the same way the USGS service does in Murphysboro. Have it continuous. Have it

accessible to anybody that wants to look it up on the website. Right now, you can go on USGS and see sulfates and chlorides and turbidity and all of these things. Anybody can research that whenever they want. They don't have it be just the sole property of the mine and quarterly reports being made to the Illinois EPA.

Lastly, if the pipeline can be approved in spite of all the numbers and statistics that other people have documented, then how many more pipelines can be approved to dump into the Big Muddy as long as it's not a massive excessive amount that occurs at one particular time? I know the Sugar Camp Mine has already been approved for a pipeline. It has not been built yet, so they're not dumping yet. If this is approved also, that's two. How many more can be approved because it will just be an incremental degradation of the Big Muddy? Thank you.

HEARING OFFICER: I would like to let the record reflect that Mr. Thomas' comments specifically referenced a graphic provided by Williamson Energy. That graphic has been

provided and a scale available to be entered into the record that will be entered into the record as Exhibit 241.

Mr. Freeman, you will be up next to the microphone. And following David Freeman, we have Jean Sellar.

DAVID FREEMAN: Good evening. My name is Dave Freeman, F-R-E-E-M-A-N. I'm actually here because I love the Big Muddy River. I was born and raised within probably an eighth of a mile. I own property right now about three-eighths of I'll call it "oceanfront property" on Big Muddy, and I care very much about the Big Muddy. I've fished it and hunted it my whole life. I actually do some commercial fishing on the river, mainly a hobby, but I do put up my winter's meat -- flathead catfish -- but through the years, I've seen many fish kills. Especially, say, approximately thirty, thirty-five years ago, I saw -- well, the big ditch that comes out of Herrin, when we did have several businesses in the area. After a big rain, we'd have a lot of poisons washed into the river, and I've seen absolutely thousands of fish

die. Actually, now if I do take home a big channel, I cut it open, and the livers will have white spots on it, so there's poison in the river that's been put in there for years.

One thing that does scare me, right south of Zeigler, we have a sewage lagoon, and I know it's EPA regulated, evidently, but the runoff, actually, is very detrimental to the river. It stinks. A lot of times it's blue. It's full of bubbles and soap, and I don't understand why it could possibly be that way this day and time. I've seen many generations, several different generations from when I was a little boy I remember from grade school. I actually have seen the old foreigners -- we had a great influx of foreigners to come into Zeigler to the No. 1, Zeigler No. 1 mine, and I can remember the little men sitting down on the river on little old docks with a tripod and a net on it like a fulcrum, and they would catch their fish that way. They mowed -- with the old sickle mowers, they mowed through the woods on the banks of the Big Muddy River to the hickory nut trees, and they would mow underneath the hickory nut

trees, because that was their lives, their mainstay of having hickory nuts, and they also sold them.

I've seen paths. There used to be a path for a mile along the river well worn. Everyone used that. And the point being if we would have just a small computer glitch and the trucks shut down, we're all going to be depending on the Big Muddy River again. So we do definitely need to take care of it, and that's something we all need to think about. It's just we can't have any carcinogens going in there, because, you know, all of the fish live off the phytoplankton, zooplankton, etc., etc. I mean, if we damaged that little small part of our ecosystem, we will have the trickle-down or the trickle-up effect.

Before I start throwing spears at the coal company, I would like to say that my parents, my grandparents and, actually, my son-in-law are coal miners. I have had a love/hate relationship with the coal mines. Actually, Zeigler Coal Company owned -- don't quote me exactly on this -- approximately at one

time 23,000 acres around Zeigler and then probably 30 plus years ago, from a desk in Chicago they cleared 17,000 acres. And when they cleared this, they didn't do it in a very proper manner. They cleared out all the -- a lot of the trees in the waterways, and now we do have much more erosion involved than what we need. I do know that the -- eventually, they sold out to the area farmers, and now they put fescue, etc., etc., in those drains, so we do have less erosion into the Big Muddy River.

I've always lived -- my property -- also I have property where I do live right on the edge of Zeigler, and it's been right next to the No. 2, Zeigler No. 2 mines, and for 50 years, we've put up with gob piles there. Finally, a few years ago, they reclaimed the mine. They supposedly came in and put two to three foot of dirt on that property. But when I was a kid, we used to skate on this place called -- we called the rust pond, because it was a rusty color from all the bad chemicals that came out of that mine. There were several sections of Prairie Creek that ran for two miles that ran into Big Muddy River

that almost all of it, the big sections, will not even grow trees. They all died and fell over. That's from Zeigler Coal Company. I know a place down by No. 3 mine, Zeigler Coal Company No. 3 where there's several feet of shale that came in a big ditch for years. And at the lowest point of the river now, you can't hardly -- you have to get out of your boat and drag it because there's several feet of rock and shale from the coal company. Those gob piles that adjoins my property have smelled and have been such a danger for 50 years, and they finally took care of it. But they didn't cover it all up, and now there's also drains in different areas that's very detrimental to the Big Muddy River.

HEARING OFFICER: Mr. Freeman, I'm going to have to ask you to wrap up your comments.

DAVID FREEMAN: Okay. I will say one thing. The chemical companies will lie. I do between thirty-four and forty-five funerals a year. I'm on the Honor Guard. Our Vietnam vets are dying at a faster rate per capita than our Korean vets because of Agent Orange. The

chemical company lied to our farmers about the chemicals, and now they're causing lots -- and they told them they'd dissipate in two to three days. Now they're poisonous, finding out they're giving us, the human species, cancer. Thank you, very much.

HEARING OFFICER: Jean Sellar, you'll be up to the microphone next. And then following Jean, Beth Ann Roberts-Jacquot, you can begin.

BETH ROBERTS-JACQUOT: Jacquot.

HEARING OFFICER: Jacquot, thank you. Appreciate it. Jean, you can begin.

JEAN SELLAR: Hi. My name is Jean Sellar, J-E-A-N, S-E-L-L-A-R. I'm speaking as a concerned citizen and someone who spends a lot of time in the bottomlands of the Big Muddy River. My credentials are that I am a retired biologist retired from the U.S. Army Corps of Engineers. I have spent thousands of hours monitoring bottomlands, (indaudible), wetlands, rivers, lakes and streams.

UNIDENTIFIED SPEAKER: Talk louder.

JEAN SELLAR: Sorry. I'm trying not to shout.

HEARING OFFICER: Everybody would like to hear what you have to say.

JEAN SELLAR: Okay. I am a retired biologist from the U.S. Army Corps of Engineers. I have spent thousands of hours monitoring streams, rivers, wetlands, bottomlands for changes in ecosystem quality as a result of flooding and water quality issues. I want to make several comments, but first, I want to remind the Agency, as I'm sure you know, that you are required to consult on threatened and endangered species of Illinois. I want to report a bunch of numbers -- very dull -- but I hope important to a technical agency like you. There are nineteen -- or excuse me -- fifteen species that are threatened and endangered in Franklin County. There are twenty-one in Williamson County. In Jackson County, there are fifty-seven. In Union County, there are sixty. These are all species that are affected by the -- or most of them are species that are affected by the Big Muddy River. Of those species, there are thirty threatened and endangered plant species that live in bottomlands. I have a great deal of

personal experience that shows that rare species such as that are directly negatively impacted by flood water, especially polluted flood water. They are dying out. One of those species is only found in the bottomlands of Big Muddy River in Illinois, and it's rare outside of Illinois.

Two comments. One is that the mean flow is not very meaningful to other organisms. They care, as a number of other people mentioned, about the rare toxic events. It only takes a short time of exposure ranging from a few minutes to a few hours, possibly days, to poison and kill them. I think the agency needs to be looking at different numbers than mean base flow or mean peak flow even on a monthly level.

The other thing is that there are no -- and I repeat -- no thorough studies of the Big Muddy organisms. I've checked endlessly through professional documentation. It's a difficult river to study if you don't have a fair amount of money. I want to strongly encourage the Agency, the Illinois EPA, to require a thorough documentation of the species that actually live in the Big Muddy River. You're going to find a

number that are not listed already by the State. For example, the pallid sturgeon has been caught in the Mississippi River right outside the mouth of the Big Muddy. The Big Muddy provides a habitat that's perfect for the pallid sturgeon. The alligator snapping turtle, which is gradually increasing its population in Illinois partly but not totally due to reintroduction programs, is documented in some other streams in the vicinity. The Big Muddy habitat is fine for alligator snapping turtles. So I want to strongly encourage you to do that study with a responsible or a group of responsible, objective scientists. Thank you.

HEARING OFFICER: If you can give us just one moment.

MR. TWAIT: Just two I'll respond to you on the questions on T and E species. We do have to consult with Illinois Department of Natural Resources, their threatened and endangered species consultation, and they did look at this discharge and indicated that there were no T and E species that would be affected by this discharge.

HEARING OFFICER: Excuse me. We're going to have to wait for speakers with microphones; otherwise, it's not clear and able for the court reporter to create a transcript.

MR. TWAIT: However, they did indicate that there was numerous species that were in various need of conservation and provided some comments on that. And one of the comments was to ensure that the mine or the effluent monitoring requirements, according to the permit, were enforced.

HEARING OFFICER: Beth, you will be up next to the microphone to provide your comments. And then following Beth, just so that someone can be ready, is Jerry and Carolyn Worther? Worthen? You can be prepared to provide your comments following Beth.

BETH ANN ROBERTS-JACQUOT: All right. It's Beth Ann and then Roberts -- that's Robert with an S -- a hyphen, and then J-A-C-Q-U-O-T, pronounced Jacquot. All right. So first of all, I'm going to address the coal mine gentleman and tell him you're not in my county. You're not adding to our revenue. You're not adding to the

local revenue. I live in Murphysboro. You're going to pipe this garbage 70 miles to my back yard. I live on the Big Muddy. I have two acres on one side of the river and thirty-two on the other. We hunt. We fish. My grandkids play in the yard that gets flooded by this water spring, summer and fall here lately. Am I to the point where I can't let my grandkids play in the yard because I have to fear what's left over from him trying to make a profit? It's disturbing.

I don't know a lot, I'm not a biologist, but I am going to tell you a few things that this grandma managed to look up. All right. Runoff can change the pH to the same level as vinegar, runoff from coal mining. Coal releases heavy metals. Research shows that at nearly every level analyzed, there was a coal leachate that exceeded international water quality guidelines. For example, some metal samples from low sulfur western U.S. coal exceeded the Canadian water quality guidelines for protecting aquatic life. Combined efforts of chemical and physical stresses on stream ecosystems is a decline in ecosystem health loss

of biodiversity, which is fish, macroinvertebrates -- if I said that right -- and algae. Acid mining drainage has eliminated fish completely from some rivers and streams, and others support only a few acid-tolerant species. Coal mining practices not only destroy the streams and the rivers' beneficial uses, but the streams and rivers themselves by drastically altering their physical characteristics.

If an environmental disaster occurs, taxpayers will pay the costs of cleanup caused by the coal industry. Costs of pollution habitat destruction negate any benefit that may come from this. The economic impact is no longer positive, and the health effects only make it even more costly. Recent studies in Illinois found that coal mining in the state resulted in a net cost to the State of almost twenty million without even including any external factors. Twenty million dollars they're costing us. They're not bringing in money; they're costing us money.

Other industries will be affected because they depend on the ecosystems that coal

mining destroys. Tourism is one of those industries. I'm sure several of us have been on the wine trail. Don't let them kill that. Negative effects on the ecosystem lead to worse health in the population which has an impact on health care costs compounding the economic impact. One quick question and I'm going to give it to the lawyer. What does EPA stand for?

MS. DIERS: Environmental Protection Agency.

BETH ANN ROBERTS-JACQUOT: Can you say it a little louder?

MS. DIERS: Environmental protection agency.

BETH ANN ROBERTS-JACQUOT: Did everybody get that? Environmental Protection Agency. Thank you.

HEARING OFFICER: Jerry will be up to the microphone next. And then following Jerry, Amanda Pankau, P-A-N-K-A-U. You will follow Mr. -- is it Worther or Worthen?

JERRY WORTHEN: Worthen.

HEARING OFFICER: Worthen?

JERRY WORTHEN: Jerry Worthen,

W-O-R-T-H-E-N. And my wife, Carolyn, is with me, and we own a farm on the Big Muddy, and it's been in our family since our forefathers or my forefathers, I should say, since 1836. And it's a Centennial Farm. My dad never thought to take care of that, and we had it listed after my mother and my father died. But right now, we raise -- my son took over the farming, and he raises grain in a field that overflows just about every year anymore. And it -- because of flooding last year, he had an awful time getting the crops in and getting the crops out. But we feel that dumping their wastewater in the Muddy River is going to deteriorate the ground that we have. It's valuable ground as long as you can keep the water off of it.

Now, I've got a year's network that I read the river gauge at Sand Ridge every day. And from 1993, the river was six inches over the Muddy River -- the new Muddy River gauge or bridge. It was six inches over the deck on it. And now this one here, you would be surprised as to how far it was over it several times this year. It got up at one time to 360.62 feet.

That is sea level. And it went on that way for about four months. We drove out of our house to get out and go after our groceries with a tractor, because this water just kept coming up and coming up. And it was up for right at four months. And we couldn't stand any more water to be poured in the Muddy River. Right now this morning, I had read the gauge, and it was 340.09 is what it was this morning, and it's not going down very fast. Because if the Mississippi backs it up, it will back up on the Muddy, and it will run as fast backwards as it does forward.

I hope that you people see the light and you do not okay this permit to go through for this mine. I understand they need coal, but most of the time, the coal that we're seeing come out, and I've got friends that haul coal, and it's going overseas. It's going overseas to China and Japan. Now, if we want to check on that, you can check, because it's in writing.

And that's the last I've got. I appreciate your time, and I hope you reconsider and take this into -- well, take it into consideration that our farm has been in the

family for that long, and I don't want to lose it because of somebody that just wants to put water in the Muddy River. We used to didn't have any problems with the Muddy River, but they put 50 mile of wing dams in the Mississippi River in 1993, and that hurt us bad. And I thank you.

HEARING OFFICER: Thank you, Mr. Worthen. If you'd like to provide your comments to the court reporter, we'll be able to have a copy of the data set that you referenced in your comments today and that will certainly be reviewed and considered in our responsiveness summary.

Following Amanda, who is at the microphone now, we'll have Steve Maynor. Amanda, you can begin when you're ready.

AMANDA PANKAU: Okay, great. My name is Amanda Pankau, and I work with Prairie Rivers Network.

HEARING OFFICER: Can you spell your last name, please?

AMANDA PANKAU: P-A-N-K-A-U. Prairie Rivers Network is a state-wide nonprofit with a mission to protect water, heal land, and inspire

change. We have members in the Big Muddy watershed. And while I'm here tonight, if there's any representative of Prairie Rivers Network, I did want to note that I lived in southern Illinois for over 13 years. I still own property just over the hill from LaRue-Pine Hills that some folks have mentioned tonight. I wanted to thank you guys for holding this hearing and giving the public a chance to learn more and share their concerns.

Prairie Rivers has concerns about the additional harm that the facility may cause if the permit is issued as written tonight. I would like to share some of those concerns, but mostly I'm going to be asking clarifying questions that will help us prepare our post-hearing comments letter.

So to begin this, the antidegradation assessment prepared by the mine notes that the 90th percentile background level of chloride is 30 milligrams per liter, and the report states this number comes from the Illinois EPA. So we FOIA'd the last five years of water quality data from the Big Muddy at Plumfield just north of the

proposed discharge point. There the Illinois EPA monitors for chloride and other water quality parameters every six weeks as part of their ambient water quality network. We analyzed that data and found that the 90th percentile chloride concentration is actually 108 milligrams per liter, so I wanted to ask tonight how did the mine come to use 30 milligrams per liter as the 90th percentile?

MR. TWAIT: I don't know specifically what time period they used, but that could definitely make a difference. Their anti-deg was done, I believe, three years ago, so they might have looked at a larger data set.

AMANDA PANKAU: Okay. Would it not make sense to use the last five years of data as a better benchmark?

MR. TWAIT: Yes, it would.

AMANDA PANKAU: So my next question -- sorry I'm going to jump back and forth. I have three prioritized items given the limited amount of time. The anti-deg proposes to monitor downstream chloride concentrations in two ways: The calculated, you have a mixing equation as

well as physically with the downstream conductivity probe. So our question is, is the permit being violated if either of these values are found to be above 500 milligrams per liter of chloride?

MR. TWAIT: Yes, I believe here it would be a violation either way.

AMANDA PANKAU: Okay. And the way we read the permit, it does not seem to require the mine to report enough information to evaluate that mixing equation. So, for example, it doesn't appear that the direct measurement of effluent is required. So is the mine required to monitor and report the effluent discharge rates and chloride concentrations coming out of the pipe?

MR. TWAIT: On the DMRs they are reporting their maximum concentration, and I believe they have to keep records at the mine site for flows and concentration of the effluent.

AMANDA PANKAU: Okay. I think we would suggest that if they're required to meet that mixing zone, that they're recording the effluent concentration, the effluent discharge,

as well as the upstream concentration and upstream discharge.

So the permit proposes continuous monitoring of chloride via the conductivity upstream and downstream of the discharge given that multiple constituents impact conductivity. And I don't know that I want you to answer this question now, but we are curious of how will the mine develop that accurate calibration? Does the Agency have to approve that calibration curve derived by the mine? And are the calibrated values also reported on the DMR? So do we have all of that information that they're using to do that calibration?

MR. TWAIT: We have written into the NPDES permit that they've got to get the citing of those conductivity meters approved by us. That's something that we can consider as to approving their calibration curves.

AMANDA PANKAU: All right. Thank you. So as I demonstrated with these questions, the permit is written in a way that compliance will ultimately rely on the feasibility of the monitoring scheme per discharge Outfall 11. So

the availability and accuracy of upstream and downstream chloride concentrations as well as the effluent concentrations will be critical for any measure for public accountability. So an independent third party research institution would be much better suited to monitor this rather than the mine. The USGS routinely monitors these type of stations and have the best system for making that information available to the public. The mine should fund USGS, install gauging stations and make public the realtime data that the mines use to determine their allowable discharge.

We have further concerns about the impact on aquatic life. We're curious to know if there has been any in-stream monitoring for fish data, aquatic invertebrates, as well as mussels in Pond Creek or the Big Muddy River. The diffuser design document states that its effluent is expected to be negatively buoyant or try to sink to the bottom of the stream until adequate mixing has occurred. Given that the highest concentrations will be located on the river bed, we think that the river should be assessed for

mussels. Has a mussel survey been done on the Big Muddy River?

MR. TWAIT: When I looked through my documents, I didn't see that, so I don't think it has.

AMBER PANKAU: So again, we think that a fish survey, a mussel survey and a survey of invertebrates pre-construction as well as long-term monitoring post-construction would be or should be required.

HEARING OFFICER: Amanda, I'm going to have to ask you to wrap up.

AMANDA PANKAU: Okay. I think I might have more, but I guess a couple of last questions. I know I'm not supposed to speak to the audience, but I'm speaking to you guys as well. The Sugar Camp Mine has had a permit approved to build a similar pipeline to the Big Muddy River. Do you know if that pipeline will be constructed?

MR. TWAIT: They have a permit to discharge from the Agency. The permit to build the pipeline is handled by IDNR.

AMANDA PANKAU: So we've ran some

numbers that show if you have chloride coming out of that upstream proposed Sugar Camp discharge as well as this one, and we just want to make sure you guys are taking into account that potential, because you've already granted the permit.

MR. TWAIT: Yes. We've taken that into account. One of the things that we did was required the conductivity monitoring upstream, so their calculations had to take into account what's upstream already in the stream.

AMANDA PANKAU: Thank you.

HEARING OFFICER: Steve Maynor. Excuse me? No. Only those at the microphone can speak. It looks like right now we are going to be running out of time, and as it is, not everybody here that signed up to speak is going to have an opportunity. So I again ask that when I ask you to wrap up or keep your comments limited that we do so out of respect for your fellow residents who would like an opportunity to speak. Is Steve Maynor here to come to the microphone? If not, Barbara McKasson. Barbara, you're up next. And then following Barbara, Jane Cogie.

JANE COGIE: I think my point's been made, so I'll just submit them.

HEARING OFFICER: Okay. That would be great. Jane will submit her comments, her written comments to the Agency, and we will address those through the responsiveness summary. So following Barbara, Sienna. Your last name is not legible, so --

UNIDENTIFIED SPEAKER: Sorry. Yeah, I'll submit mine, too.

HEARING OFFICER: Okay. Sienna is going to submit her comments through the written comment period. Pat Wagner? Pat will submit her comments through the comment period. Thank you. Chuck Paprocki?

CHUCK PAPROCKI: Yes.

HEARING OFFICER: Are you here? Okay. You will follow Barbara when she's completed her comments.

BARBARA McKASSON: My name is Barbara McKasson, last name M-C, capital K-A-S-S, as in Sam, O-N as in Nancy. I am a native of the Big Muddy River and often visit natural areas that are impacted by the Big Muddy River when flooding

such as LaRue-Pine Hills National Natural Landmark and Little Grand Canyon. LaRue-Pine Hills is currently one of the most biologically diverse areas in the United States in competition with Smokey Mountain National Park. Little Grand Canyon is designated as a high-quality natural area with many Illinois threatened and endangered species. Both of these places are highly impacted whenever the Big Muddy River floods, and both of these areas have very important recreation areas. I think you should be taking this into consideration.

From reading all of the literature on this, it seems that the measurements for the effluent is very complicated. I'm wondering how will IEPA verify all of these calibrations, how they will work so that the effluent will stay within the limits of the regulations? And I'm wondering if that is why IEPA is allowing huge fluctuations of the sulfates and chlorides, sometimes far above the standards set by the regulations. Even with a diffuser, what gives Illinois EPA any confidence that there will not be acutely high concentrations that can gravely

harm the fish, macroinvertebrates, mussels, plants and other wildlife that depend on the Big Muddy River, especially near the O11 Outflow location?

Science has shown that organisms have trouble regulating osmosis through their tissues with such high concentrations of chlorides. How current are surveys of fish and macroinvertebrates in Pond Creek and the Big Muddy River? Shouldn't IEPA conduct these surveys before granting these permits so that you will be better prepared to know how much the aquatic life is being affected by this effluent?

The fact that the bond required for the discharge pipe into the Big Muddy River does not cover harm caused by the effluent is very concerning, so it looks like the people and the environment will pay the costs. Why isn't Williamson Energy not required to put up a bond for repairing damage that may be caused by their operations, that is damage to the Big Muddy River wildlife and the people who depend on the Big Muddy for recreation? What if there's a big fish kill? Can IEPA hold Williamson Energy

responsible and charge them reparations for the damage? Can Williamson Energy be held responsible for restoring fish populations? And as has been pointed out, the parent company, Murray, is in bankruptcy, and it looks like Foresight Energy is also close to bankruptcy. So we have to ask what is the financial status of Williamson Energy? Would they be able to ameliorate or mitigate any harmful events? Does the corporation and the Illinois EPA expect public funds and the environment to absorb the costs?

I'm concerned that the proposed location of the downstream monitoring probe is too far downstream to measure and evaluate the level of pollutants at the outfall. The permit specifies that, quote, This downstream monitoring shall be performed a sufficient distance downstream of the associated outfall to ensure that complete mixing has occurred, unquote. If the mine places the probe further downstream, they gain additional mixing. More dilution to the pollution. Why are they not required to monitor as close as possible to the edge of the

designated mixing zone, which is the point of compliance?

I am also concerned about the Outfall 009 which goes into Pond Creek, which has been designated in the past as impaired by chloride in the TMDL evaluations. Pond Creek is listed in the public notice and appears to be impaired already by chlorides. Why are you proposing to grant the mine a mixing zone for chlorides at the Pond Creek Outfall if the Big Muddy River is already impaired? Why was the level of chlorides in Pond Creek found by IEPA to no longer be of concern by the recent TMDL assessment when it already has been measured at or near the maximum of 500 milligrams per liter? According to the Pond Creek Watershed Inventory 2019 created by the Greater Egypt Regional Planning and Development Commission, page 74, quote, Pond Creek has been listed for chloride and sedimentation/siltation impairments since 2010 and dissolved oxygen since 2012. In 2008, the stream was listed for iron, manganese, pH, total suspended solids, and fecal coliform, unquote.

Methyl mercury is known to cause

serious nerve and organ problems in humans. Will the increased chloride and total dissolved solids levels in the Big Muddy River cause higher methyl mercury levels? Will the acid mine drainage allowed in this permit also increase the conversion of mercury to methyl mercury? Can IEPA assure us that it will not? We know there is commercial fishing and recreational fishing in the Big Muddy River. Because of bioaccumulation of heavy metals up the food chain, we are concerned that anyone eating catfish, bass or other predatory fish will be harmed. Has IEPA evaluated the possible harm to humans from increased methyl mercury that could be caused by granting this permit? According to sciencedirect.com, quote, Mercury speciation, which is affected by chloride, will impact mercury bioavailability to methylating bacteria, affecting subsequent methyl mercury production and bioaccumulation in these systems, unquote. Also, the Illinois Department of Public Health has issued a methyl mercury advisory for predator fish in all of the waters of the state, and this can be found on their website.

In summary, considering these concerns, I am opposed to IEPA granting this Permit Number Illinois 0077666 to Williamson Energy. Thank you.

HEARING OFFICER: Chuck, you'll be up to the microphone next to provide your comments. And following, we'll have Jacob Bolton. Jacob, if you're still here, you can make yourself prepared to follow Chuck.

CHUCK PAPROCKI: Hello. My name is Chuck Paprocki, P-A-P-R-O-C-K-I. I'm a member of SAFE and a member of Carbondale Spring. As you can see -- I hope you can see that the people of Carbondale are no fools. We understand and love our natural environments, and we know that we are asked to abide being poisoned because a private mining company is unwilling to clean up its own mess and protect its workers. Now, this is just me asking the question personally. According to what I understand about the EPA regulations regarding when you notify the public that a public waterway is being poisoned, you calculate that if chlorides and sulfates poisoning is above 250 milligrams per liter, that there's no reason

to tell the public that they're being poisoned because the taste is so bad and the water stinks so bad that there's no need to tell the people what is obvious. That's my understanding of your rules and regulations about not warning the public about these poisons.

Now, according to the parameters that I see in your documents for poisoning, you're allowing 1,250 milligrams per liter for sulfates, five times the poisoning level that people notice, and 500 milligrams per liter of chlorides, which is double the amount. And this is being added to our water supply every second, every hour, every week, every month, every year for as long as the mine is open. And I wanted to know if you really believe, this panel of EPA agents, that this is really safe for the people of southern Illinois?

I just want to make a statement. We, the people of southern Illinois, want the state of Illinois and the EPA to know that we hold you accountable as well as the mining companies for any destruction to any life form in our environment or to any adversity to human health

in southern Illinois as a consequence of granting these companies the right to pollute our environment knowing full well the potential risks of these actions. Thank you.

MR. TWAIT: Yeah, just for a clarification, you mentioned a sulfate standard of 250. That is for a public water supply intake, just to let everybody know. The water quality standard for sulfate is higher than that.

HEARING OFFICER: Jacob Bolton, you'll be up to provide your comment next. And following Jacob, Grant Depoy.

JACOB BOLTON: Hey, everybody. My name is Jacob Bolton, also known as "Treesus." I am the diplomat of trees.

HEARING OFFICER: Could you spell your name for the court reporter?

JACOB BOLTON: Bolton, like B-O-L-T-O-N. Michael Bolton is not my relative. I hold no positions on this issue and stand here as an honest broker. I am a forestry student at Southern Illinois University, and I've taken a watershed management class very recently, and I am in Intro to Water Resources right now to learn

about how to save the world. I am empathetic to all that is and every human, and I respect all of you. I value empirical evidence that is comprehensive to encompass complex socio-ecological issues, and I am a problem solver. So my first question, is Pond Creek considered under the CWA waters of the USA?

MR. TWAIT: Yes.

JACOB BOLTON: Thank you. What order stream is this creek?

MR. TWAIT: I don't know the answer to that.

JACOB BOLTON: But it's part of a watershed, and watersheds all drain to one area, and I am curious if this permit considers watersheds downstream.

MR. TWAIT: In what way?

JACOB BOLTON: In terms of the Mississippi River, you know, all of the larger watersheds on a larger scale.

MR. TWAIT: We looked at ensuring that the water quality standards will be met. And once they're met, they're expected to be met downstream where additional water comes in.

JACOB BOLTON: Got you. Since these are our common-pool resources and waters of the USA, I am curious if this has taken into consideration the compounding pollutants that were discharged downstream and also considerate of all the other industries that input into streams, because the Gulf of Mexico is currently under hypoxia during the summers, and there's fish die off, and this is a tributary to the Mississippi which discharges into the Gulf of Mexico. So I'm just curious if they will take -- if you guys and others will consider thinking comprehensively working together to consider these compounding pollutants and the life of all that is.

MR. TWAIT: We can consider that. If you have information as to how they are compounding, that would be helpful.

JACOB BOLTON: I suppose I'm curious -- I'm learning still. I'm a student, so I'm not smart -- I'm not like whatever it is. I'm very smart. I'm an intelligent human. You all are, too. And the metals, heavy metals, I don't see how they possibly dissolve in water. How does

that affect plant life and trees, as well as the animals that use those for habitation?

MR. TWAIT: The metals are -- some of them are particulate, and they will settle out in the stream continuum, and some of it is dissolved and it will continue going downstream.

JACOB BOLTON: Cool. Well, I think that the boundary delineations that we currently use ought to be reconsidered to include watersheds to help people focus on area-specific introductions of pollutants and their compounding issues downstream. I highly -- I know that there are, without even looking, that there are a lot of people introducing pollutants into the streams and the river. I feel that drugs (ph) is a large-scale issue that we can all work on together as 7.7 billion people trying to save the world. And we need site-specific community studies that involve more action with each other. I think that we have too much bureaucracy that could be reduced and maybe start focusing on problem solving quicker, because there is empirical evidence that climate change and other forms of not goodness in all of our lives, worse

case scenario, could end us in 80 years. I would like to live, and I would like everyone else to live, too. So thank you.

HEARING OFFICER: Grant, you'll be up next to the microphone. Carla Womack, you will follow Grant. And, Grant, if you could give me just one moment before you start.

Grant, you can begin, and if you wouldn't mind stating your name and spelling your last name for the court reporter. And then once Grant has finished, Carla Womack, if you are still here and present tonight, you will follow Grant.

GRANT DEPOY: Thank you. Grant Depoy, D-E-P-O-Y. I'm a concerned citizen, I'm concerned about the Big Muddy River, and I'm concerned about our future dealing with the consequences of our actions right now. I'm a lead facilitator in the Student Sustainability Coalition at SIU-C, and I'm also a forestry student. We have one of the top forestry schools in the nation where I study collaborative management, policy sciences, forest policies, and watershed governance under some of the best

professors in the nation. So, first, I want to say that I'm training right now to do the job you guys are doing. And like Jacob shared before, we have class discussions about the current contemporary issues we are dealing with in the field, one of those being the shortfalls of the EPA's framework for decision-making being that it relies on only one kind of way of understanding, one kind of knowledge, and we need to expand our field to take into consideration other ways of knowing being local experiential knowledge -- and I think we've heard from a number of people here today -- that they have knowledge regarding the locality of these issues that our framework is not prepared to address on this hyper-localized scale. The other perspective being traditional ecological values. So just one quick question I had was if in this decision-making there have been platforms made for the consideration of the indigenous people's values of this area.

MR. TWAIT: I don't think we've seen that information, so if you'd provide it for the record, we can take that into consideration.

GRANT DEPOY: So thank you. I think

it also would be well to consider a platform for the local people who live on that land and the land affected by the Big Muddy right now. I think it's clear in our field we need to move towards more of democratic ways of decision-making. I think if we were to collect wisdom from the people here, you can see very clearly that this decision has not been democratic. I don't think a lot of people here feel that their voices are being heard. And we're scared, because we don't know who is making the decisions. We don't know who is the one with the pen in their hand putting down the final "yes." So I need people in my field to look up to. This is going to be -- these issues I'm going to be working against my whole life to turn around these decisions made and have a real understanding of the consequences I'm going to have to deal with. So I'm scared for myself for the future. Like Jacob said, worse case scenario, who knows what we'll have in the future. I don't think we have room to be making -- to be taking these risks right now. I don't know who's benefitting from this other than

those 500 families that have been mentioned earlier, but we need to make a world that works for a hundred percent of humanity here and not just a handful of people. And if it's another 50 years, if this is ensured to be in production for another 50 years, that's also not a future I want to live in.

So I'm also a visual learner. I just wanted to leave this with if you're in this room and you don't support this, please stand up right now. Stand up if you don't support this. And if this passes, raise your hand up if you're going to keep fighting against this to turn this around. All right. Thank you.

HEARING OFFICER: Carla Womack, are you present with us tonight? I don't see you. Karen Frailey? Karen Frailey, if you're here, please approach the microphone.

UNIDENTIFIED SPEAKER: She'll submit a written comment.

HEARING OFFICER: Okay. Thank you very much. John Wallace? Mr. Wallace, it looks like he's still here and will be coming to the microphone. Following Mr. Wallace, there's no

first name. N. Tenney -- okay. N. Tenney Naumer. Okay. A hand raise back there. So, Mr. Wallace, whenever you're ready, you can proceed with your comments. Oh, who do we have at the microphone?

KARL FRALEY: Karl Fraley.

HEARING OFFICER: Okay. I have Carla with an A at the end, Carla Womack, Karen Frailey.

KARL FRALEY: Oh, I'm sorry.

HEARING OFFICER: That's okay. I think I called them twice. I called them back to back, and it may have been combined. So is Carla Womack here? She's gone, okay. Karen Frailey said she would submit her comments written. Then John Wallace. And following John -- okay. Great. Thank you.

JOHN WALLACE: John Wallace, W-A-L-L-A-C-E. John, J-O-H-N. I want to talk a little bit about this region a little more than I think other folks have, because the natural wonders, the incredible landscape that we have here, and the Big Muddy River downstream of the outflow pipe will actually enter -- this water

will pass through some of this unique area. Before I do that, something that caught my eye which -- and raised my dander, I might say, was a Southern Illinoisan article about this hearing coming up in which several people were quoted from the Illinois EPA. One in particular was a Kim Briggs, the media representative for your organization, and she made a comment that this meeting was not a popularity vote. I find that offensive. We live in a democracy. You all know that. You are -- I'm a retired public servant, and you all are public servants now. And when the public stands up and says "no," you need to listen.

Mr. LeCrone, you were quoted as well, and you made some comments about, you know, it's not a hearing that we're going to -- the chances are this isn't going to be a yes or no determination from your agency. I get that there are lots of steps in this process. I understand. But what's real important is for you all to understand the local folks down here, you know, barring a few that are associated and affiliated with the mining company, are bothered by this.

We've watched degradation take place too much. The Big Muddy is an impaired stream. But the Big Muddy is also a fascinating area. It passes through five natural -- or excuse me -- four different natural divisions in this region downstream of the outflow pipe.

You know, I really thought the diffusers were going to be something hard to comprehend. We have five different versions of PVC pipe, and that's going to appropriately diffuse this water, this degraded water? And then the -- let me get back to my natural divisions. It passes through the Southern Till Plain, then into the Shawnee Hills and into the Illinois Ozarks, the Ozark Plateau and the Mississippi River Bottomlands. So the Big Muddy passes through some really unique areas, areas that you don't have in Springfield or aren't found anywhere else in the state.

And as it passes through these areas, it also passes through a real important chunk of public land: The Shawnee National Forest. It is the largest single ownership of land in this state: 287,000 acres. And it's public land.

It's land that I use and many people around here use. And the Big Muddy is a stream that I have used and many of us around have used for recreational use, for just appreciating the scenic beauty of this area. And as it passes through this area, there are -- in Jackson County -- I've lived in Jackson County for about 25 years, and I still recreate in Jackson County. I own some land in Jackson County as well. But as it passes through the Shawnee National Forest, Little Grand Canyon was mentioned as again one of those national natural landmarks. LaRue-Pine Hills, it passes nearby. There are a number of different flood plains and different types of wetlands that the stream passes through. And I just want to make sure you understand this polluted water, this increase in flow is going to pass through a number of unique bends in the river, including Rawlins Bend, Cripps Bend, Dillon Bend, Mill Bend, Horseshoe Bend wherein you find Horseshoe Lake, and Horseshoe Bluff butts up against it. Turkey Bayou, Oakwood Bottoms Greentree Reservoir, Rattlesnake Ferry, all of these places are used by us. The Big

Bayou. I've canoed the Big Muddy with groups of people. I one time took a class of high school students and camped out in this flood plain in one of these bends on the national forest, so it was a very memorable time several years ago. I hope to do it again. But more importantly, what I hope is that those places are here after I'm gone so that other high school students, those high school students that I took will take some. When they have high school students, they'll bring them down to do the same thing.

HEARING OFFICER: Mr. Wallace, I'm going to have to ask you to wrap up.

JOHN WALLACE: This 2.7 million gallons of water average daily comes out to 360,455 cubic feet. That's like 144.2 feet by 50 feet by five stories tall of water a day that's going to be added to the river, and that water's compromised. It's polluted water. And no one mentioned yet the impacts from that flow on erosion. The Big Muddy River is already deepening in size. What's going to happen there? Can you guarantee that these places are going to be protected that are so important to us? These

National Natural Landmarks, the US Park Service --

HEARING OFFICER: Mr. Wallace, you are out of time. I apologize.

JOHN WALLACE: Please take careful consideration of what you're about to do here. Thank you.

HEARING OFFICER: Thank you for providing comments.

JOHN WALLACE: There's also some petitions for Governor Pritzker to protect the Big Muddy River that I would like to submit.

HEARING OFFICER: You can provide them to me and not to the court reporter. I cannot deliver these to Governor Pritzker. If you want to deliver them yourself, you should take them with you; otherwise they will be entered into the record for the public hearing. Just so you know, by providing them to me does not mean they will make it to Governor Pritzker. Instead, they will be entered into the hearing record. Okay. Well, thank you very much. I will ensure that they get entered into the hearing record.

UNIDENTIFIED SPEAKER: Thank you.
HEARING OFFICER: Absolutely. The next speaker will be Joyce Blumenshine.
UNIDENTIFIED SPEAKER: Joyce will submit written comments.
HEARING OFFICER: Okay. Albert Ettinger, you will be up to the microphone following the current speaker.
TENNEY NAUMER: For the record, my name is spelled T, as in Tom, E-N-N-E-Y. My last name is spelled N-A-U-M-E-R. Can you hear me now? Okay. So I live in Marion, and I was born and raised here in southern Illinois. My family's been here for over 150 years. I'm a CPA and a Certified Fraud Examiner, and I also studied finance at SIU a couple years at the doctoral level, so I know a little bit about analyzing financial statements. Question: What has the EPA, Illinois EPA done to analyze the financial condition of this company?
MR. TWAIT: That is not something that we look at for issuing NPDES permits.
TENNEY NAUMER: Oh, really?
MR. TWAIT: IDNR may do that when

they issue bonds, but that's not something that we consider.

TENNEY NAUMER: So they have a bond for five hundred thousand for reclamation of the pipeline area, but as I understand it, no bond for anything that might occur in the river; is that right?

MR. TWAIT: I don't know what their bond is.

TENNEY NAUMER: You guys don't know? You're analyzing this to see if you're going to permit this thing to go forward, and you don't know? Really?

MS. WARD: Yes, you are correct, ma'am. That's the bond for the pipeline.

TENNEY NAUMER: But not for the effluent?

MS. WARD: No, not for the effluent. That bond, that is only for reclamation by the company for construction of the pipeline.

TENNEY NAUMER: Okay. Is that enough?

MS. WARD: To reclaim the pipeline? I believe so.

TENNEY NAUMER: Twelve miles, is that enough?

MS. WARD: I am not actually an expert in calculating bonds. This is something with IDNR.

TENNEY NAUMER: IDNR, huh? We should be talking to them, huh?

MS. WARD: About bonds, yes.

TENNEY NAUMER: So it won't enter into your decision-making?

MS. WARD: No, ma'am.

TENNEY NAUMER: Really? So we've got a company that's going bankrupt here. They can't make their interest payments. Their stock price went down to seven cents. They've been de-listed from the stock exchange. What are they going to -- you know, what they're going to do here is try to extract here and leave all the external costs to the Illinois taxpayer. Isn't that a concern? Isn't that a concern? I've heard at least 20 people up here give reasons, any one of which should negate this project, any one of which. Yeah, nobody's looking at me. Okay.

So, furthermore, you know, Foresight

Energy hasn't paid any taxes to the federal government in five years or a dividend. Their accounts payable is just increasing rapidly. They're not going to have the money to do anything to help this place down here if something goes wrong. It's not going to happen. The parent company just declared bankruptcy. It's not going to happen, and you guys are just going to surely not rubber stamp this project. Surely not. You don't communicate with the IDNR on the finances of this thing?

MR. TWAIT: We do not communicate with IDNR on finances. Although we do communicate with IDNR, just not on finances.

TENNEY NAUMER: Huh, okay. Another interesting thing is that you've already approved a pipe outflow upstream, and somehow this one downstream is supposed to continuously monitor even though we know that people have complained about things that happen on the weekend that they get bullied out of -- we know that -- so they're going to continuously monitor down here the stream, and if something goes wrong up there, they're just going to shut everything down.

Really? You know what? It's like water rights in the west, you know, when you buy a piece of property, you get assigned a water right, and if you're further downstream, you get less and less and less, and you pay for those water rights upstream. You pay a lot of money to have first right on the water out west. You guys are just giving away the right to pollute. You're just freaking giving it away.

HEARING OFFICER: We're going to have to keep the comments to the speaker, one, to be respectful of their time; two, to be respectful of the court reporter.

TENNEY NAUMER: Right. And I noted that you said it's 5,000 gallons a minute maximum flow rate; is that right?

MS. WARD: That's right. That's correct.

TENNEY NAUMER: That's like 7.2 million a day. I think I used my calculator correctly. You never catch a CPA without a calculator. But I thought in the permit it said it was going to be 2.7 to 2.9 daily. How is that working out mathematically? Anyway, we've got

this Ohio millionaire, Bob Murray, who just paid himself $14 million out of the company before he declared it bankrupt, and Foresight is directly underneath that, and it's going bankrupt. If you look at the financials, which I have here, which I can enter into the record, they're going belly up. What are they going to do here when it's cleanup time? How are they going to pay for that? But you guys aren't looking at the finances. Wow. Seriously. You guys should be ashamed. Ashamed.

MR. TWAIT: IDNR is the entity that collects bonds for mining facilities to ensure cleanup.

TENNEY NAUMER: Ensure. Ensure like they do reclamation?

MR. TWAIT: That is not the Agency's -- that is not Illinois EPA's responsibility.

TENNEY NAUMER: Well, you know it now. It's going to go in the record.

HEARING OFFICER: I'm going to have to ask you to wrap up your comments.

TENNEY NAUMER: Okay. I'm done.

HEARING OFFICER: If there are any

documents you want us to put into the record, you can do that now. Mr. Ettinger, if you can give us just one moment.

MR. LeCRONE: Okay. I'd like to explain a little bit more about what our authorities are in response to her concerns about financial stability. The NPDES program is a federally-delegated program. The Illinois EPA is a delegated state to administer the USEPA's program. The NPDES permitting program does not contain any financial assurance requirements, and our agency does not have any authority either under the delegated program agreement or via the Illinois Pollution Control Board to require any financial assurance or for there to be a financial assurance analysis of the company. So we just have to follow the Pollution Control Board regulations for what we can and can't consider in the issuance of a permit.

ALBERT ETTINGER: Mr. LeCrone, can I -- excuse me. Mr. LeCrone, I beg to differ with you to some extent. I'm Albert Ettinger. I'm a lawyer. I represent the Sierra Club here. Under the Illinois Environmental Protection regulations

for antidegradation, you're only allowed to grant a new loading into a water body if it is reasonably necessary to accommodate important social or economic development. If this mine is going to go bankrupt shortly, this discharge is not necessary to accommodate important socioeconomic development. In fact, what it would do is create negative economic development. And what you are basing your decision on is an antidegradation analysis which has only considered what is good for the company and the economic development that it claims that it will create. You have not considered at all -- and I have read the antidegradation statement -- at all the damage that might be done particularly if they open this discharge and go bust six months later.

Now I have a question, though. And that is -- that's not -- that is within your authority. By the way, I'm a lawyer. I recognize when people have authority to do things. And, by the way, I believe the hearing officer has done a very good job today, and I have watched a lot of hearings. But I have a

question for Mr. Twait. I understand that the company produced some documents yesterday that are relevant to the comments that were made in August; is that true?

MR. TWAIT: Yes.

ALBERT ETTINGER: Are we going to get those comments? Are we going to get those documents before we have to comment on this permit?

MR. TWAIT: They're available by a FOIA now.

ALBERT ETTINGER: Yeah, and I don't get 30 days. We need those documents now, because we've got 30 days to comment. So we wish to see those documents ASAP. I have a question for Ms. -- I'm sorry, ma'am -- Ward?

MS. WARD: Yes.

ALBERT ETTINGER: You explained that there were corrections that needed to be made in certain discharge monitoring reports because of mistakes in decimal points?

MS. WARD: There was not a mistake in decimal points. There was a unit mistake. A different unit was recorded.

ALBERT ETTINGER: Who made those mistakes?

MS. WARD: I believe that our agency was recording the data in the ECHO with different units than it's supposed to be.

ALBERT ETTINGER: Okay. Well, are you aware of a pH reading of 3.3 in October of 2018? Was that recorded properly?

MS. WARD: I cannot recall off the top of my head. I am not saying that all of the numbers were recorded incorrectly. The majority of the numbers were.

ALBERT ETTINGER: The majority of the numbers were recorded incorrectly by the Agency or by the company?

MS. WARD: They were taking into consideration the wrong units.

ALBERT ETTINGER: Who was?

MS. WARD: The Agency was.

ALBERT ETTINGER: Okay. I have a couple of other little questions here. One is on mercury. I'm looking, first of all, this Table 2.1, is that -- what the company did, is that, in effect, the reasonable potential analysis that

was done for this permit, or did the Agency do another reasonable potential analysis?

MR. TWAIT: I'm not sure what you've got there. Where did that come from?

ALBERT ETTINGER: I've got Table 2.1 to the antidegradation analysis that was done in 2016 and was based on data between September 2016 and the first of November in 2016. It's that document that they have used to include that we don't need to worry about mercury or iron or several other constituents because, in their view, these numbers did not exceed the water quality standards.

MR. TWAIT: Offhand, I'm not sure that we used those numbers. I'm not positive that we were aware that they were in the document.

ALBERT ETTINGER: I'm sorry? You weren't aware of the antidegradation analysis? You didn't mean to say that, right?

MR. TWAIT: No, I'm saying I didn't know that those mercury data were in there. Let me pull it out and see.

HEARING OFFICER: I am going to have

to ask to reduce the amount of comments outside of the speaker at the microphone. We are going beyond the scheduled time. We are doing that as an opportunity to provide all of you as much time as possible to provide comments. But if it continues to --

ALBERT ETTINGER: I actually -- I have real questions here that I would kind of like to get answers to.

HEARING OFFICER: Absolutely. I would love for you to have that opportunity.

MR. TWAIT: I don't see that I looked at that data for the anti-deg purposes. And you said it was in Table 2.1?

ALBERT ETTINGER: Table 2.1 of the antidegradation analysis that was written by the company.

MR. TWAIT: Okay. We'll take a look at that.

ALBERT ETTINGER: Okay. Well, they used -- in order for them to conclude that there's no problem from mercury, they rely on this data which interestingly comes down to two point per trillion, which sounds really great,

but -- and they find there's no detects on two points per trillion. But as they note themselves, the water quality standard is half of what they measured down to. Has the agency done any work to assure that the reasonable potential for mercury has been measured down to where it would measure a violation of the mercury standards?

MR. TWAIT: It's my understanding that the company is continuing to take metals data for a determination of a reasonable potential, but we have not seen that data.

ALBERT ETTINGER: Wait a minute. Wait a minute. You're going to ask the public to comment on a permit when you haven't collected all of the data yet relative to the permit?

MR. TWAIT: They are collecting data due to comments received in the comment period.

ALBERT ETTINGER: One of my comments would be, then, that they should use clean mercury techniques in order so that they are not looking at a detection method which is well over the water quality standard. And as we are all aware, the Big Muddy River is impaired for

mercury, and it's black-letter law that you can't allow a mixing zone for a parameter in which there is already a violation; therefore this permit cannot be granted on the current record. Furthermore, did the Agency consider the IEPA -- sorry. Excuse me. Did the Agency use the or consider the USEPA technical support document in 1991 which is used in order to calculate a reasonable potential according to guidance from USEPA?

MR. TWAIT: We are aware of that document, and the mine is collecting additional data so we can use it correctly.

ALBERT ETTINGER: Okay. So we have six data points here. As you're aware under the technical support document that asks for a minimum of ten, so you're collecting more data at this point. Is that what we're hearing?

MR. TWAIT: That is my understanding.

ALBERT ETTINGER: Okay. I think those are all the -- oh, I have one more question, and this is really fascinating and could be interesting across the state. They're going to use conductivity probes in order to

determine the chloride level. Doesn't chloride as a percentage of conductivity vary under various conditions?

MR. TWAIT: It is something to -- that they can develop a concentration curve on, but, yes, it will have some variation.

ALBERT ETTINGER: But it hasn't been developed yet?

MR. TWAIT: The curve has not.

ALBERT ETTINGER: So we don't know what chloride is going to come out based on your conductivity readings currently, but you're going to develop that in the future?

MR. TWAIT: Yes.

ALBERT ETTINGER: Or rather the company is going to develop that in the future?

MR. TWAIT: Yes, and then we're going to look at it.

HEARING OFFICER: Next up to the microphone, Ann Wheeler. Ann Wheeler, are you still with us tonight? Amelia Robinson?

UNIDENTIFIED SPEAKER: She's gone.

HEARING OFFICER: Kay Rippelmeyer?

UNIDENTIFIED SPEAKER: Gone.

HEARING OFFICER: Karl Fraley? Karl Fraley up to the microphone. Before you start, Karl, let me call out a few other names and see who we still have with us tonight. Mark Malkovich?

MARK MALKOVICH: Here.

HEARING OFFICER: Excellent. You will follow Mr. Fraley.

KARL FRALEY: My name is Karl with a K, K-A-R-L, Fraley, F-R-A-L-E-Y. I'm 72 years old, and I've lived on the river all my life in Murphysboro. I've been a commercial fisherman since I was 15 years old. I am currently the president of the Southern Illinois Waterfowl Association which represents hundreds of water fowlers in the southern nine counties of Illinois. This river is the lifeblood of the region from Rend Lake to the Mississippi. The entire ecological system is being threatened by this proposal. All of the fish, waterfowl, wildlife, trees and adjoining lands will be decimated by this wastewater. The good Lord made this river for us, and I'm sure is he didn't intend for it to be turned into a sewer from many

coal mines. This poison water will kill fish.

Many bald eagles nest along the river. They'll fly down, feed on these fish, take these fish back to their young in their nests and wipe out generations of eagles. All species of waterfowl use this river year-round. Especially in the spring they feed on the invertebrates in the water to get the protein to sustain their northward migration. Extended periods of high water will kill trees and ruin farmland. The coal mines need to build their own wastewater plants and not be allowed to ruin our beautiful river. I pray that government agencies will not allow this to happen. In God we trust.

HEARING OFFICER: Mark, you'll be up to the microphone next, and then Dennis Conley, are you still with us? Okay. Mr. Conley will submit his comments in writing. Thank you for being with us tonight. Reth Dagraty (ph)? Looks like R-E-T-H --

UNIDENTIFIED SPEAKER: Retha Daugherty.

HEARING OFFICER: Retha. Is she still with us? She's gone? Katie Purcell?

UNIDENTIFIED SPEAKER: She's gone.

HEARING OFFICER: Sarah Depuy, D-E-P-U-Y.

SARAH DEPUY: Yes.

HEARING OFFICER: You're still with us? All right. You will follow Mr. Malkovich when he's completed.

MARK MALKOVICH: Hello. My name is Mark Malkovich, M-A-L-K-O-V-I-C-H, and I currently own property that runs a half mile on both sides of the Big Muddy, and we use this for recreation, fishing, we swim in it, and it's a big part of our life. And today I'm going to talk about mine acid drainage, and the reason that I have a different perspective on this is I worked in the coal mines for thirteen years. And the products that are pumped out of the mine have a lot more to do than just salt, chlorine, saline. Many, many other problems, and the main one is they call it fool's gold, you know, and it's called iron pyrite. And this iron pyrite is a significant part of the acid that can break down these heavy metals, and that when I worked in the mine, I could see that they had also a lot

of things -- they would pump this water into big pits. These pits would be covered with oil and grease and no telling what else. Also now, the implement of diesel mining, that diesel fuel would again come on top of those pits, and then when they pumped that water out, it would all go to the same place. So I have an article here, and it's from the United States Environmental Protection Agency, and it talks about acid mine drainage.

Acid mine drainage is currently the main pollution of surface water in the mid-Atlantic region. Acid mine drainage is caused when water flows over or through sulfur-bearing materials forming solutions of net acidity. Acid mine drainage comes mainly from abandoned coal mines and currently active mining. Acid mine drainage degrades more than 4,500 stream miles in the mid-Atlantic region with a loss of aquatic life, restricts stream use for recreation, public water drinking, and industrial water uses.

And they say, Well, what is mine drainage? Mine drainage is the metal-rich water

formed from chemical reaction between water and rocks containing sulfur-bearing materials. The runoff formed is usually acidic and frequently comes from areas where coal mining activities have exposed rocks containing pyrite, which is the fool's gold. And anybody that's ever worked in mining, it's in the coal seam itself. You see a lot of times they come up with these like little -- they call them gold dollars, and it's pure iron pyrite, and that is one of the main ingredients.

And so it says, How does the mine drainage occur? Mine drainage is formed when pyrite, an iron sulfide, is exposed and reacts with air and water to form sulfuric acid and dissolved iron. Some or all of this iron can precipitate to form red, orange or yellow sediments in the bottom of streams containing mine drainage. The acid runoff further dissolves heavy metals such as copper, lead, mercury into ground and surface waters. As this here gets pumped into this, these minerals get absorbed into the water, and mercury is one of the main ones that has the ability to really, really

poison our water system. And the rate or degree by which the acid mine drainage proceeds can be increased by the action of certain bacteria. Certain bacteria can also increase that action from the acid.

Now, some of the problems associated with mine drainage are contaminate our water -- our drinking water, and they disrupt the flow of reproduction of aquatic plants and animals, and especially like the ones that live on the bottom. Since I did there with the Big Muddy River that comes across me, we used to see mussels, different washboard and other flat mussels, almost none around anymore, but there used to be a lot of them. So that affects it quite a lot. Also its corroding effects of acid on parts of infrastructure such as bridges and other metal structures.

The results of acid drainage, acid mine drainage is one of the region's most serious water pollution problems. It is only an economic and ecological concern to the states -- it's not only a ecologic concern to the states, but it's also an economic concern as well.

A region impacted by mine acid drainage often has a decline in valued recreational fish species such as trout and other -- we don't have trout here, but also the catfish. The predatory fish can eat the smaller fish and get this concentration of mercury. And then as we catch the fish and we eat them, we're eating that mercury in a concentrated form. Because over the years they eat all of those little fish, that mercury stays with that predatory fish. And so as they eat those fish, we in turn get that.

A regional impact by acid mining [sic] often has a decline in the value of recreational fish species as well as a general decline in outdoor recreation and tourism along with contamination of groundwater drinking supplies.

And I see, you know, people need a job. But every mine that I've worked at is gone. It's gone, and they left a huge, huge mess, and the EPA had to come in -- it took many, many years -- to do reclamation, cover up the old gob piles, and this is something that's going to

happen to this mine over here one day. It's going to happen. It happens to all of them. And so that in order to -- you know, this problem with pollution is a long, long-term problem whereas problem with employment is a short-term problem. We have to think about the future, so I thank you very much.

HEARING OFFICER: Sarah, your turn to the microphone. So we have under 15 minutes left before we're going to have to close the record, so I ask all remaining speakers to just keep that in mind of your fellow residents who would still like an opportunity to speak. However, you will still -- anybody up to the microphone in the remaining time will have the allotted time as anybody else, and then we'll just have just maybe about a 30-second wrap up at the end before we adjourn for the evening.

So, Sarah, you'll be up to the microphone. And then following Sarah, Roberta. Would you still like to provide comments tonight? Okay. You'll be after Sarah. Sarah?

SARAH DePUY: Okay. My name is Sarah DePuy, D-E, capital P-U-Y, and I just have a few

quick questions, actual questions. Just a point of clarity, a lot of the information from the IEPA about the data that they looked at when making this decision, it seems like what I heard is that a lot of data is being compiled by the mining corporation itself, and I'm just wondering is there additional data that the IEPA has found on its own or with other third parties in regard to the watershed analysis or water, things like that, or is most of the data around this decision coming from the mine and what they've collected so far and continue to collect?

MR. TWAIT: The Agency collects stream data and goes out and does biological surveys. IDNR does some mussel surface -- or not IDNR.

UNIDENTIFIED SPEAKER: INHS.

MR. TWAIT: Thank you. INHS does the mussel surveys. And but most of the data, if not all of the data, of the effluent is coming from the facility.

SARAH DePUY: Okay. And does the IEPA have any plans to conduct its own analysis like as -- like as the effluent comes out and

then the IEPA just does regular analyses and tests further on is its regular practice. Is that going to be something that the IEPA will include as a point in future documents?

MS. WARD: We are collecting the samples during our field inspections. And also IDNR collects the samples during the inspections.

SARAH DePUY: Okay. And, I mean, is there any plans for after to do like monitor it through IEPA, or is it simply through the monitoring from the coal mine? Like the monitoring that the coal mine will be doing, will that be the only monitoring that the IEPA has access to is that?

MS. WARD: The coal mine will continuously monitor the discharges, but we can go any day and take our own samples.

SARAH DePUY: Okay. And then my final question is on the data that the instruments will be collecting, will this data which I assume that the coal mine will have first access to, obviously, will this data be available to the public in some form? And if something happens to the instruments, will the public be

alerted? Just, basically, who has access to the data?

MS. WARD: I understand your concerns. Well, if anything is going to go wrong, the pipeline's not going to be able to discharge. And the downstream measurement at the very edge of the mixing zone is going to be reported daily on the DMRs to the agency.

SARAH DePUY: So just will the public have access through the IEPA? Like will there be --

MS. WARD: The public has the access to see the DMRs on the ECHO.

SARAH DePUY: Okay. Thank you.

HEARING OFFICER: Roberta, and then is Thomas Grant still here with us? Would you still like to provide comment, Mr. Grant? Okay. You'll follow Roberta.

ROBERTA DePUY: Roberta Deason DePuy, D-E-P-U-Y, and the Deasons have been in southern Illinois since 1835 and so on. I speak to you as a person who consumes water. I live in Marion. I'm married to a retired federal hydrologist soil scientist, 37 years experience. I concur with

the concerns that the monitoring data is submitted by the for-profit agency that wants to do -- that benefits of the permit -- I'm sorry -- because I never saw that happen before, at least at the federal level for EPA. I'm greatly concerned.

I also, as I speak about water, you know, the watershed is extensive. We've talked about the tributaries that creates the wetlands. They are a sponge. And our drinking water in southern Illinois was created in the 1940's and '50s by our lake construction from the rivers. Crab Orchard Lake is -- it has the Wildlife Refuge. All of these things were created to provide our drinking water, and the wetlands is soaking everything up. So my one question is what is the date of the last watershed analysis, and how extensive is it that you have used and its impact on the water source for drinking water for southern Illinois?

MR. TWAIT: The Big Muddy River is not used as a water source for any --

ROBERTA DePUY: But it's part of the watershed. It is the watershed. All of the

creeks -- Google a map. It's the watershed. This is how all of this was created. The lakes came from the creeks from the rivers. The Big Muddy is a tributary of the Mississippi, but it also goes into all of the creeks. You follow it on a map. You look at the wetlands on I-57 as you drive by even. It's a watershed. So what's the date of the latest watershed analysis that you're considering for this? They were started in the 1980's in government, you know, the United States.

MR. TWAIT: We do a basin survey. I believe it's on a five-year cycle. I'm definitely not an expert on when was the last time that we did that basin assessment.

ROBERTA DePUY: And they're not used for any --

MR. TWAIT: We can address that in the responses somewhere.

ROBERTA DePUY: -- other agency's information?

MR. TWAIT: Yes, but I can't tell you the last time they were out there.

ROBERTA DePUY: Because usually as

EPA statements come up, they dovetail with all kinds of, you know, agencies like US Geological's been mentioned, the Clean Water Act has been mentioned. But there's information out there, and I'm just wondering how much consideration and scientific input are you, not the mine company, and how current is it, because this is our drinking water. So I'm just speaking as a citizen in opposition to this permit, because the people here drink the water, and it is in our watershed. Any other response to how you're considering the impact into the water shed? Look at the history of how our lakes were created. They're from the rivers and the creeks, so --

MR. TWAIT: Yeah, we use the 2016 integrated report for our assessments.

ROBERTA DePUY: From --

MR. TWAIT: From Illinois EPA.

ROBERTA DePUY: And --

MR. TWAIT: And IDNR and --

ROBERTA DePUY: And how extensive is it? How far off does it go?

MS. DIERS: We don't have anyone on the panel right now that works in that. We will

definitely answer in the responsiveness summary. He's just not the right person. I apologize, but we will definitely respond to that.

ROBERTA DePUY: Okay. I mean, it's a real question. I mean, and my husband did watershed analysis. He had to quantify rocks, you know, how many trees were hanging over for temperature for the fish before any kind of like road construction began for a private company or any private company wanted to use something that impacted the public. So it's a valid question.

MS. DIERS: Absolutely.

ROBERTA DePUY: I appreciate -- and, again, as a citizen, I am in opposition to this, because it's our water. Thank you.

HEARING OFFICER: Mr. Grant, if you could come to the microphone, you may be our last speaker this evening. We'll see where we are on time when you finish.

THOMAS GRANT: First of all, thank you for coming out and listening to us and our concerns. I appreciate your time. I'm a citizen of Carbondale, Illinois. I've been watching this for a while, and I'm glad we're having this

hearing. I just want to be on the record as being adamantly opposed to this permit. A couple of things. The -- and I used to work for the City of Carbondale, and I used to have the ability to issue a NPDES permit. I didn't have to deal with waterways, so I feel for you people. But the very name of it, National Pollution Discharge Elimination System, is problematic. We're not eliminating. We're taking it down to what we believe is a safe level, but we're not eliminating. I think you have the ability and authority -- and I might be wrong, but we can ask the lawyer from the Sierra Club or this lawyer -- to actually require that the mine company treat the water on site, extract the problem chemicals and the heavy metals before it is even discharged into the stream and can go into the stream at a cleaner level than the stream itself, which is how wastewater treatment plants are treated in this state, including every small town and city that has one in this state. So I believe you have that authority, and I thank you for your time.

HEARING OFFICER: Thank you,

Mr. Grant. Christina Krost, are you still here? Christina, you'll come to the microphone and, unfortunately, I apologize to the remainder of those in the audience who put in your names to provide comment tonight. Unfortunately, we are out of time. If you please stick around for following Ms. Krost's comments, I'll give additional information as to how you can ensure that your comments are entered into the record.

CHRISTINA KROST: Thank you for staying. We appreciate it. My name is Christina Krost, K-R-O-S-T, spelled with a C-H, C-H Christina. I'm the Southern Illinois Outreach Coordinator for Faith in Place, an interfaith creation care and environmental justice organization. I live here in Harrisburg, and I do outreach and organizing all over southern Illinois. I am a person of faith, I am a mother, and I am a concerned citizen.

Thank you for holding this hearing tonight, and I appreciate the chance to explain why I'm opposed to the approval of the Pond Creek Mine permit, because I feel the activities at the mine threaten human health and the environment

for all Illinoisans and the plants and animals living in the Big Muddy River watershed.

Water is life. Without it, we cannot survive. This truth echoes through the generations and across all faiths and cultural backgrounds. People have also long known that everyone is downstream or downwind of someone, so it is important to steward the land, air and water where you live so you do not adversely affect your neighbors.

This permit includes a 12.5-mile pipeline for discharge of millions of gallons of high chloride and sulfate water to dump directly into the Big Muddy River. As a parent and concerned citizen, I did research about the public health impacts of chloride and sulfates in water. It turns out these pollutants can cause gastrointestinal tract problems such as diarrhea, nausea, inflammatory bowel disease and consequent dehydration from these conditions, and it's a threat to public health.

I also learned that chloride can increase the corrosivity of water and reacts with metal ions increasing levels of metals in

drinking water. I am acutely aware of the dangers of heavy metal poisoning as I grew up not far from Flint, Michigan. But we don't have to go very far to see the effects of this in Illinois. In 2016, one in five Chicago homes tested had high levels of lead even after running the water for 3 to 5 minutes before using the water. What we've learned from Flint is that when the public is kept in the dark about these issues like this mine permit, terrible things can happen and then be covered up.

My research also led to a better understanding of how water travels from the Big Muddy River. The Big Muddy basin includes Kinkaid Lake, Rend Lake, Crab Orchard Lake, Devil's Kitchen Lake, Little Grassy Lake, and Cedar Lake. Of particular concern to me is Little Grassy Lake.

My husband is a United Methodist pastor, and my family has been attending camp at Little Grassy United Methodist Camp for many years. To learn that this mine discharge could affect my family's beloved camp was deeply concerning. I've watched countless families and

young adults deepen their spiritual relationship with their creator through their time at Little Grassy. That place changes lives. I cannot stand by and let this place be harmed because of a company's pursuit of profit at the expense of a beautiful natural resource.

As a mother and a person of faith, I must speak out about potential harm to my children and my neighbor's children. As a southern Illinois resident, I must ask you to consider the impact of this mine discharge on our shared land, air and water and the people and the wildlife that are sustained by it. As an environmental justice advocate, I urge you to assure that communities are not abandoned by polluters who refuse responsibility for their pollution should a disaster occur or a bankruptcy occur. Please consider cumulative impacts of pollution on vulnerable communities and on the plants and animals that call the Big Muddy River their home.

You have a chance to assure safe drinking water for my children and your children and the next generation to come. Please do not

approve this permit. Thank you for hosting this hearing.

HEARING OFFICER: We are out of time for this evening. If you did not get a chance to speak, please submit your comments to the Agency in writing as directed in the public notice. There are copies of the public notice at the registration desk if you don't have one; otherwise, you can find it on our web page. Any written comments submitted will be included in the record and reviewed by the Agency as the responsive summary is prepared. As we bring this hearing to a close, I need to remind everyone that the record in this matter closes on January 17, 2020. You can send any comments to the attention of Barb Lieberoff as noticed in the public notice or the website as provided in the public notice. The repository of documents for the permitting action is available at Illinois EPA's office. There are other additional documents that have been referenced here tonight as being recently received by the company. You can obtain those through a FOIA request to the Illinois EPA. That can be done through our

website. You can also contact the Agency if you need help in crafting your request. I know someone referenced tonight that one request was denied, and a second request was worded differently and you received responsive documents. If you're concerned about receiving the documents that you're seeking, please feel free to contact the Agency, and we will do what we can to help you craft a query so you can be provided those documents as quickly as possible in order to help you develop any additional comments or questions that you may have regarding the draft permit.

Thank you for your participation and your cooperation tonight. The time is 9:34 p.m., and this public hearing is adjourned.

* * * * * *

STATE OF ILLINOIS)
) SS
COUNTY OF FRANKLIN)

REPORTER'S CERTIFICATE

I, Lori A. Rogers, do hereby certify:

That the said proceeding was taken before me at the said time and place and was taken down in shorthand writing by me;

That I am a Certified Shorthand Reporter of the State of Illinois, that the said proceeding was thereafter under my direction transcribed into computer-assisted transcription, and that the foregoing transcript constitutes a full, true, and correct report to the best of my ability of the proceedings which then and there took place.

IN WITNESS WHEREOF, I have hereunto subscribed my hand this 6th day of January, 2020.

Lori A. Rogers, CSR/Notary Public
IL CSR #084-002872

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