BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

MIDWEST GENERATION, LLC	)	
	)	
Petitioner,	)	
	)	
v.	)	**PCB**
	)	**(Adjusted Standard - Land)**
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY	)	
	)	
	)	
Respondents.	)	

NOTICE OF FILING

To: Division of Legal Counsel
Illinois Environmental Protection Agency
1021 N. Grand Avenue East
P.O. Box 19276
Springfield, IL 62794-9276
Epa.dlc@illinois.gov

Don Brown, Assistant Clerk
Illinois Pollution Control Board
James R. Thompson Center
100 West Randolph Street, Suite 11-500
Chicago, IL 60601

PLEASE TAKE NOTICE that I have today electronically filed with the Office of the Clerk of the Pollution Control Board Midwest Generation LLC's Petition for an Adjusted Standard and Finding of Inapplicability for the Powerton Station with supporting documents, and the Appearances of Susan M. Franzetti, Kristen L. Gale, and Molly Snittjer, a copy of which are herewith served upon you.

Dated: May 11, 2021

MIDWEST GENERATION, L.L.C.

By: /s/ Kristen L. Gale
One of Its Attorneys

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CERTIFICATE OF SERVICE

The undersigned, an attorney, certifies that a true copy of the foregoing Midwest Generation LLC's Petition for an Adjusted Standard and Finding of Inapplicability for the Powerton Station with supporting exhibits, and the Appearances of Susan M. Franzetti, Kristen L. Gale, and Molly Snittjer, on May, 11, 2021 with the following:

Division of Legal Counsel
Illinois Environmental Protection Agency
1021 N. Grand Avenue East
P.O. Box 19276
Springfield, IL 62794-9276
Epa.dlc@illinois.gov

Don Brown, Assistant Clerk
Illinois Pollution Control Board
James R. Thompson Center
100 West Randolph Street, Suite 11-500
Chicago, IL 60601

and that true copies were filed to the Agency by FedEx, delivery charge prepaid, and electronic mail, and the Board electronically on May 11, 2021 to the parties listed above.

/s/ Kristen L. Gale

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BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

MIDWEST GENERATION, LLC Petitioner,	)	
	)	PCB
v.	)	(Adjusted Standard - Land)
	)	
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY Respondent.	)	

ENTRY OF APPEARANCE OF SUSAN M. FRANZETTI

NOW COMES Susan M. Franzetti, of Midwest Generation, LLC, and hereby enters her appearance as counsel in this matter on behalf of Midwest Generation, LLC. This appearance shall also serve as consent to service via email.

Respectfully submitted,

__/s/Susan M. Franzetti________________

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BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

MIDWEST GENERATION, LLC Petitioner,	)	
	)	PCB
v.	)	(Adjusted Standard - Land)
	)	
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY Respondent.	)	

ENTRY OF APPEARANCE OF KRISTEN L. GALE

NOW COMES Kristen L. Gale, of Midwest Generation, LLC, and hereby enters her appearance as counsel in this matter on behalf of Midwest Generation, LLC. This appearance shall also serve as consent to service via email.

Respectfully submitted,

__/s/Kristin L. Gale
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BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

MIDWEST GENERATION, LLC	)	
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ILLINOIS ENVIRONMENTAL	)	
PROTECTION AGENCY	)	
Respondent.	)	

ENTRY OF APPEARANCE OF MOLLY SNITTJER

NOW COMES Molly Snittjer, of Midwest Generation, LLC, and hereby enters her appearance as counsel in this matter on behalf of Midwest Generation, LLC. This appearance shall also serve as consent to service via email.

Respectfully submitted,

__/s/Molly Snittjer________________

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BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:

PETITION OF MIDWEST GENERATION FOR AN ADJUSTED STANDARD FROM 845.740(a) AND FINDING OF INAPPLICABILITY OF PART 845	**AS 21-** **(Adjusted Standard-Land)**

MIDWEST GENERATION, LLC'S PETITION AN ADJUSTED STANDARD AND FINDING OF INAPPLICABILITY FOR THE POWERTON STATION

Midwest Generation, LLC ("MWG") petitions the Illinois Pollution Control Board ("Board") for an adjusted standard from the Part 845 Illinois Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments at 35 Ill. Adm. Code 845 ("Illinois CCR Rule"). MWG seeks this regulatory relief for four basins at its Powerton Station in ("Powerton" or "Station") in Pekin, Tazewell County, Illinois: the Ash Surge Basin, Metal Cleaning Basin, the Bypass Basin, and the Service Water Basin. An adjusted standard is needed for the Ash Surge Basin, Bypass Basin, and Metal Cleaning Basin to allow the decontamination and retention of the existing liners in the three basins rather than the liners' removal as provided in the Illinois CCR Rule. For the Service Water Basin, MWG seeks an adjusted standard finding that Part 845 of the Board rules is inapplicable because it is a process water basin that does not accumulate CCR.

The Illinois CCR Rule regulates the Ash Surge Basin, Metal Cleaning Basin, and the Bypass Basin as Coal Combustion Residual ("CCR") surface impoundments. MWG plans to close the three basins by removing the CCR and converting the basins to non-CCR surface impoundment basins. The Ash Surge Basin and Metal Cleaning Basin will be used as low-volume waste ponds to hold the Station's process water and the Bypass Basin will become a

Recycling Cooling Water Basin as a passive cooling pond for the water from the new concrete tanks installed to manage the bottom ash. MWG seeks to reuse the basins' high-density polyethylene ("HDPE") liners, because the liners are in good condition and, after decontamination, can continue to serve the intended purpose as a liner. The CCR surface impoundment closure by removal requirements under the Illinois CCR Rule instead requires removal of the liner in a CCR surface impoundment. By comparison, the federal CCR rule does not require removal of a liner when a CCR surface impoundment is closed by removal. Because the liners in the Ash Surge Basin, Bypass Basin, and Metal Cleaning Basin are in good condition and can be effectively decontaminated, consistent with the federal CCR rule, MWG is requesting an adjusted standard from Section 845.740(a) to allow the continued post-closure use of the three liners.

The Service Water Basin is not a CCR surface impoundment. Instead, it operates as a "service water basin" or "process water basin". In December 2019, the Illinois Environmental Protection Agency ("Illinois EPA") determined, without consultation with MWG, that the Service Water Basin was a CCR surface impoundment and issued an invoice for the initial fee pursuant to Section 22.59(j) of the Illinois Environmental Protection Act ("Act"). 415 ILCS 5/22.59(j). However, the Service Water Basin does not collect CCR as part of its operations and has never collected CCR ash part of its operations. Because it does not fall within the definition of CCR surface impoundment under Section 3.143 of the Act, MWG is seeking an adjusted standard finding that the CCR rules are inapplicable to the Service Water Basin. 415 ILCS 5/3.143. 415 ILCS 5/3.143.

This Petition sets forth the factual and legal bases for MWG's requested relief. In further support of this Petition, MWG submits the affidavit of Dale Green and the affidavit and expert opinion of David Nielson, P.E., attached as Exhibits 1, 2, and 3 respectively and along with additional supporting documents.

I. Background

On July 30, 2019, Illinois enacted the Coal Ash Pollution Prevention Act ("CAPP Act") to regulate CCR surface impoundments and ordered the Illinois EPA and the Board to draft and implement regulations, including a permit program, to regulate CCR surface impoundments at electric generating stations. Illinois Public Act 101-0171. Pursuant to the CAPP Act, a "CCR surface impoundment" means "a natural topographic depression, man-made excavation, or diked area, which is designed to hold an accumulation of CCR and liquids, and the surface impoundment treats, stores, or disposes of CCR." 415 ILCS 5/3.143. The CAPP also created a new Section 22.59 of the Act for CCR surface impoundments. In relevant part, Section 22.59 requires an owner or operator of a CCR surface impoundment to pay an initial fee to the Agency six months after the effective date of the CAPP Act. 415 ILCS 5/22.59(j)(1).

A. Illinois CCR Rulemaking on Liners

Pursuant to Section 22.59 of the Act, Illinois EPA filed proposed new standards for the operation, maintenance, and closure of CCR surface impoundments as new Part 845 of the Board's Rules. *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845,* PCB 20-19. The proposed CCR rule closely mirrored the federal CCR rule, and the Illinois EPA claimed that the desired purpose was to obtain federal approval of the program. *Id.*, Illinois EPA Statement of Reasons, March 30, 2020, p. 10. To follow that purpose, the original language for closure by removal in the proposed CCR Rule included the same language as in Section 257.102(c) of the federal CCR Rule:

> "An owner may close by removing and decontaminating all areas affected by releases from the CCR surface impoundment. CCR removal and decontamination of the CCR surface impoundment are complete when the CCR in the surface impoundment and any areas affected by releases from the CCR surface impoundment have been removed.
> Proposed 35 Ill. Adm. Code 845.740(a).

Throughout the hearing process, including pre-filed questions, pre-filed answers, and two hearings held in August and September 2020, the Agency maintained this proposed language and gave no indication that it was considering revising it.

By comparison, in the proposed Section 845.770 requirements for retrofitting a CCR surface impoundment, Illinois EPA included a requirement to remove the liner even though the federal CCR rule required only that the CCR and any contaminated soils and sediments be removed. 40 CFR 257.102(k). MWG provided expert testimony by David E. Nielson that plastic liners like those in its impoundments could be effectively decontaminated, dispensing with the need for removal. *See* Ex. 4, Pre-filed Expert Testimony of David Nielson, p. 12. Geomembrane liners are flexible membranes manufactured of polyethylene (i.e., plastic) and are defined by the ASTM International as "an essentially impermeable geosynthetic composed of one or more synthetic sheets." Ex. 4, p. 12; ASTM D4439. They "are very low-permeability plastic products that are nonabsorptive," meaning they are unlikely to absorb the CCR constituents. Ex. 5, 9/30/2020 Tr., p. 199:7-8. Based on the conservative assumption that geomembranes could have small holes, the U.S.EPA nevertheless determined that a liner did not have to be removed as part of retro-fitting a CCR surface impoundment. Ex. 6, MWG Pre-Filed Answers, p. 44-45, 40 CFR 257.102(k). Relying upon the ASTM standard and these U.S.EPA conclusions, Mr. Nielson's expert witness testimony demonstrated that a liner may be decontaminated, without requiring the entire liner to be removed. The Board subsequently inquired in its pre-filed questions whether

Section 845.770(a)(1) could specify that only "contaminated liners" would need to be removed, which MWG agreed was acceptable and Mr. Nielson supported. Ex. 6, pp. 1, 47.

In the Agency's post-hearing comments, for the first time and without any prior indication or explanation, it presented new requirements for closure by removal. Ex. 7, Agency Final Comment, pp. 86-87. Without any technical support, the Agency submitted that an owner/operator must also remove "containment system components such as the impoundment liner and contaminated subsoils, and CCR impoundment structures and ancillary equipment." Ex. 7, p. 87. The Agency merely offered its belief that the modifications were required to comply with the Part B *proposed* federal CCR rule. Ex. 7, p. 86-87. MWG objected because the federal CCR rule does not require removal of the liner. Ex. 8, MWG's Response, p. 3. The applicable federal CCR rule as well as the proposed federal CCR rule the upon which Agency relied, only require that materials which contacted CCR be decontaminated. *Id.* There was no evidence in the rulemaking record to demonstrate that a liner contaminated with CCR cannot be effectively decontaminated. *Id.*, p. 3-5. In fact, Illinois EPA admitted it was simply assuming, without any scientific or other support, that all liners became contaminated and could not be decontaminated. *Id.* citing 8/25/2020 Hearing Tr., pp. 73:20-23, 76:14-17, attached as Ex. 9. Moreover, the expert testimony during the rulemaking stated precisely the opposite. *Id.* at 4. MWG's expert explained that synthetic liners (or "geomembrane liners") do not absorb CCR. Hence, synthetic liners are not likely to be contaminated merely because of contact with CCR. *Id.* But even where a geosynthetic liner has been contaminated by CCR, it can be decontaminated so that it is suitable to reuse as part of a CCR surface impoundment retrofit. *Id*.

B. Illinois CCR Final Rule

On February 4, 2021, the Board issued its Second Notice Order and Opinion for the Illinois CCR Rule. The Board adopted the Illinois EPA's requested changes to the closure by removal requirements that required removal of a liner and all associated equipment regardless of the condition. Feb. 4, 2020 Order, pp. 95-96. The Board reasoned that these changes were required to be consistent with the proposed federal CCR rule. *Id*. The Board did not address or discuss MWG's objections to this modified language. *Id.* But the Board agreed with MWG that when retrofitting a CCR surface impoundment, a competent plastic liner could be reused as long as the owner or operator demonstrated that the liner was decontaminated. The Board stated that "Midwest Generation has raised a valid concern about removing competent, uncontaminated existing synthetic (geomembrane) liners while retrofitting CCR surface impoundments." Opinion, p. 99.

The Board's Opinion also addressed areas where a regulated party disputed Illinois EPA's position on whether an area qualified as a CCR surface impoundment under Section 3.143 of the Act. The Board stated that a party could seek a regulatory relief mechanism, such as an adjusted standard, to resolve the dispute. *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845,* PCB 20-19, Order (February 4, 2021), p. 14.

C. Powerton Station Background

The Powerton Station is located in an industrial and agriculture area and began operations in the late 1920s. Ex. 1, ¶¶ 4, 5. MWG began operating the Powerton Station in 1999. *Id.*, ¶5. For its operations, Powerton has various environmental permits, including an NPDES permit for its wastewater discharges. *See* NPDES Permit, attached as Ex. 10.

1. Powerton CCR Surface Impoundments

Powerton has two active federal and Illinois CCR surface impoundments - the Ash Surge Basin and the Bypass Basin – and one Illinois CCR surface impoundment – the Metal Cleaning Basin located on the northern side of the Station.[1] Ex. 1, Ex. 11. All three basins are operated as part of the Station's NPDES permitted ash management system. Ex. 10. The Ash Surge Basin is the primary CCR surface impoundment, and the back-up basin is the Bypass Basin, which is used when MWG is emptying the Ash Surge Basin. *Id.*, ¶14. The majority of the CCR from the Station is captured by the dewatering bins that are located next to the Station building. *Id.*, ¶9. The CCR fines that do not drop out of the transport water in the dewatering bins, flow into the Ash Surge Basin or the Bypass Basin for settlement. *Id.*, ¶10. Both basins were built in 1978 with at least 12-inches of poz-o-pac liner on the bottom and a plastic liner on the sides. *Id.*, ¶11. Both CCR waste streams and non-CCR waste streams are directed to the Ash Surge Basin, or the Bypass Basin, depending on which is in service. *Id.*, ¶13. Neither of the basins are permanent disposal locations, instead, MWG routinely empties the basins. *Id.*, ¶15.

The Metal Cleaning Basin is not a part of the ash sluice system and was also constructed in 1978 with a 12-inch poz-o-pac liner on the bottom and a plastic liner on the sides. Ex. 1, ¶17. It is not a federal CCR surface impoundment because it is not used to hold an accumulation of CCR and liquids at the same time. *Id.*, ¶18. Instead, the Metal Cleaning Basin is used to hold dry ash when either an ash silo fails, or during ash silo maintenance of the ash silos. At other times, the Metal Cleaning Basin is used to hold process water when a boiler is washed. *Id*. Other than

[1] The Powerton CCR surface impoundments are also the subject of an enforcement action in front of the Board. *Sierra Club v. Midwest Generation, LLC*, PCB 13-15. The enforcement action alleges violations of the Act and Part 620 of the Board Rules, and is unrelated to MWG's request for Part 845 regulatory relief here.

the basins described herein, there is no other basin at Powerton that is designed to hold an accumulation of CCR and liquids. *Id.*, ¶22.[2]

a) Relining of the CCR Surface Impoundments

In 2010, MWG relined the Bypass Basin and the Metal Cleaning Basin with an HDPE liner system, and relined the Ash Surge Basin with the same HDPE liner system in 2013. Ex. 1, ¶¶ 23, 24. The relining construction activities were conducted pursuant to construction permits issued by the Illinois EPA. Exs. 12, 13. The liner systems consist of six layers of materials (from bottom to top): the original poz-o-pac, a geotextile cushion, the HDPE liner, a geotextile cushion, a 12-inch thick sand cushion layer, and a 6-inch limestone warning layer. The Construction Documentation Reports demonstrating the liner systems installed in each pond and the quality control measures taken during installation are attached as Exhibit 14 (Bypass Basin and Metal Cleaning Basin) and Exhibit 15 (Ash Surge Basin). Each layer in the liner system has a purpose. The purpose of the sand cushion layer is to avoid punctures on the geomembrane when equipment is on the liner. Ex. 1, ¶26. The purpose of the limestone warning layer, which is white and contrasts with the dark color of coal ash, is to act as a warning to operators when they are removing the ash so that they do not contact and cause any damage to the liner. *Id*. MWG retained the poz-o-pac liner because it served as an additional barrier and provided additional support for the overall life of the liner system. *Id.*, ¶25. Finally, as part of the measures to protect the liner from damage, MWG installed marker posts along the edge of the base of the basins to mark the sides for the operators when the basins are dredged. *Id.*, ¶28.

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[2] Powerton also has one inactive federal and Illinois surface impoundment, the Former Ash Basin. Ex. 1, ¶21.

b) Groundwater Monitoring Around the CCR Surface Impoundments

MWG has been monitoring the groundwater surrounding the CCR surface impoundments for over ten years and is currently monitoring the groundwater under two different state and federal programs. Beginning in 2010, MWG began monitoring the groundwater upgradient and downgradient of the Powerton CCR surface impoundments. Ex. 1, ¶36. In 2013, MWG entered into a Compliance Commitment Agreement ("CCA") with the Illinois EPA, which provided for continued monitoring for the constituents in 35 Ill. Adm. Code 620.410. *Id.*, ¶37, and CCA, attached as Ex. 16. Pursuant to the federal CCR rule, MWG installed additional groundwater wells in 2015, and also began monitoring the groundwater upgradient and downgradient of the CCR surface impoundments. Ex. 1, ¶38, Ex. 11, 40 CFR §257. As part of the federal CCR rule, MWG conducted an Alternate Source Demonstration ("ASD") for the Ash Surge Basin and the Bypass Basin, which demonstrates that neither are a source of constituents in the groundwater. The ASD is attached as Ex. 17. Because, the Metal Cleaning Basin is not a federal CCR surface impoundment, MWG there is no alternate source demonstration applicable to this basin.

2. MWG's Plans for Reuse of the Ash Surge Basin, Bypass Basin, and the Metal Cleaning Basin

In compliance with the federal CCR rule and now also the Illinois CCR rule, MWG is closing the Ash Surge Basin, the Bypass Basin, and the Metal Cleaning Basin by removing the CCR. But the closure deadline under the federal CCR rule would leave the Powerton Station without the ability to handle the bottom ash generated by the Station while an alternative management approach is implemented. Hence, on November 30, 2020, the Powerton Station sought an extension of the deadline for closure of the Ash Surge Basin by submitting a Demonstration for a Site-Specific Alternative Deadline to Initiate Closure of the Ash Surge

Basin ("Demonstration") to U.S.EPA. The Demonstration Report, without the supporting documents is attached as Ex. 18.[3]

The Demonstration also evaluated options for future management of the CCR and non-CCR waste streams at Powerton. Ex. 18. Based upon the available options, MWG is proposing to replace the Ash Surge Basin and the Bypass Basin with a concrete ash-settling tank. *Id.* at 1-17. Powerton will continue to use the dewatering bins to collect approximately 98% of the CCR. *Id.* and Ex. 1. The remaining approximately 2% of the CCR fines will settle out of the CCR transport water in the concrete tank, via two separate cells that are in series. *Id.* at 1-17 – 1-18. Most of the CCR fines will settle out of the water in the primary concrete cell, and the second "surge cell" will capture the final sedimentation of CCR. *Id.* The water leaving the concrete tanks, which no longer contains a measurable amount of CCR, will be discharged to the Bypass Basin, which will be repurposed as a Recycle Water Cooling Basin to cool the water. *Id.*, Ex. 2, ¶5. The Recycle Water Cooling Basin will not accumulate CCR. Ex. 2, ¶5. U.S.EPA stated in its preamble for the 2015 federal CCR rule that cooling water ponds are not "CCR surface impoundments" and thus are not regulated under the federal CCR Rule. 80 F.R. 21357. In consideration of the proposed Illinois CCR Rule, MWG reported to U.S.EPA that it would remove the HDPE liner from the Bypass Basin. *Id.* at 1-19. However, allowing MWG to reuse the competent HDPE liner will not only remove the unnecessary and wasteful disposal of a still useful geosynthetic liner, but also will reduce the amount of time required to convert the Bypass Basin to its new use. Ex. 2, ¶7.

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[3] The supporting documents are not included due to their size. The complete report is publicly available at: http://3659839d00eefa48ab17-3929cea8f28e01ec3cb6bbf40cac69f0.r20.cf1.rackcdn.com/POW_ASB_CPCX.pdf, and MWG can provide the complete document upon request.

For both future operational flexibility and compliance with the Clean Water Act Steam Electric Power Generating Effluent Guidelines and Standards (40 CFR Part 423, the "ELG Rule") for non-CCR wastewater, MWG plans to repurpose the Ash Surge Basin and the Metal Cleaning Basin as low-volume waste ponds for non-CCR waste streams. A low-volume waste pond is a pond that collects "low volume waste sources" which are defined in the ELG Rule as

> "wastewater from all sources except those for which specific limitations or standards are otherwise established in this part. Low volume waste sources include, but are not limited to, the following: wastewaters from ion exchange water treatment systems, water treatment evaporator blowdown, laboratory and sampling streams, boiler blowdown, floor drains, cooling tower basin cleaning wastes, recirculating house service water systems, and wet scrubber air pollution control systems whose primary purpose is particulate removal. Sanitary wastes, air conditioning wastes, and wastewater from carbon capture or sequestration systems are not included in this definition." 40 C.F.R. § 423.11(b).

The Ash Surge Basin and the Metal Cleaning Basin will be used for temporary storage of large volumes of non-CCR water until the water can be treated and discharged pursuant to the Station's NPDES permit. Ex. 3 and Ex. 18, p. 1-16.[4] For example, to avoid flooding at the Station during significant rainfall events, both ponds would be available to collect the stormwater until it can be treated and discharged. Ex. 3. Similar to the Bypass Basin, in consideration of the proposed Illinois CCR Rule, MWG reported to U.S.EPA that it would remove the HDPE liner from the Ash Surge Basin. *Id.* at 1-19. However, because the both the Ash Surge Basin and the Metal Cleaning Basin each have an HDPE liner that is in good condition, and can be decontaminated, MWG plans to reuse the HDPE liner instead of removing and replacing the liner.

[4] Because the Metal Cleaning Basin is not a federal CCR surface impoundment, U.S.EPA did not require a discussion on the future use of the Metal Cleaning Basin.

3. The Service Water Basin is not a CCR Surface Impoundment

The Service Water Basin receives process water after ash is collected in either the Ash Surge Basin or the Ash Bypass Basin, and the process water is either sent to the cooling water pond and recycled for plant use or discharged. Ex, 1, ¶40, and Ex. 10. Because the Service Water Basin is a process water basin and does not accumulate CCR, it is not a federal CCR surface impoundment. Ex. 1, ¶41. In the 2015 preamble of the federal CCR rule, the U.S.EPA stated that it revised the definition of CCR surface impoundment to exclude units that "present significantly lower risks, such as process water or cooling water ponds because, although they will accumulate any trace amounts of CCR that are present, they will not contain the significant quantities that give rise to the risks modeled in EPA's assessment." 80 F.R. 21357. The U.S.EPA continued by stating that "CCR surface impoundments do not include units generally referred to as cooling water ponds, process water ponds…" *Id.*

Since its construction in 1978 and continuously until 2013, the contents of the Service Water Basin were never emptied because it only received process water, not ash. Hence, there was never a need to remove material from the basin for over thirty years. Ex. 1, ¶¶39, 42. The Service Water Basin was emptied for the first time in 2013 when MWG relined the basin with a new HDPE liner. *Id.*, ¶43. When it was emptied, there was less than a foot of material accumulated in the basin and that material was not CCR. It was soil and biologic debris that had collected over the decades of use. *Id.*, ¶44.

a) Investigation of the Material at the Base of the Service Water Basin Shows There is Not an Accumulation of CCR

To demonstrate the absence of accumulated CCR in the Service Water Basin, MWG conducted a multi-faceted investigation of the basin. The investigation found there was little to no material present in the Service Water Basin. Based on a comparison of the calculated volume of material at the base of the Service Water Basin to the expected volume of material that would fall into the Service Water Basin from air dispersion and stormwater flow, the basin material is consistent with the latter. The volume calculations show that the amount of material present in the basin is almost equal to the contributions of material expected from those two non-CCR sources. Accordingly, the results of the technical investigation of the basin prove that the Service Water Basin is not a CCR surface impoundment because it does not contain CCR.

The multi-faceted investigation also included conducting a bathymetric survey of the bottom of the Service Water Basin. The bathymetric survey showed that material was either marginally present or not present at all at the bottom of the basin. Exs. 19, 20. A bathymetric survey calculates the depth from the water to the bottom of the surface impoundment, using an electronic depth finder from a boat floating in the pond. *Id.* The bathymetric survey found that the average bottom elevation was only 0.2 feet, or about 2.4 inches of material. *Id*. Based upon the size of the pond, MWG's consultant, KPRG & Associates, LLC ("KPRG") calculated that the total volume of material in the pond was only 52 cubic yards ("CY"). Based upon the guideline that 2 tons/acre/year falls onto the land, KPRG calculated that approximately 23.7 tons of non-CCR material fell into the basin from air deposition and stormwater runoff since it was emptied in 2013.[5]

The basin investigation also included collecting a sample of the material at the base of the Service Water Basin to evaluate the grain size, weight-to-volume relationship, and the contents

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[5] The estimate of two tons per acre per year is based upon the U.S. Dept. of Agriculture Report soil loss equation in the Department's "Predicting Rainfall Erosion Losses", December 1978. The 2 tons per acre per year is the maximum amount of erosion (soil loss tolerance) that can be tolerated without losing the long term functionality of the soil to grow a crop. According to the soil loss equation, the lost soil is replaced by natural processes at a rate that is the same or greater than the tolerance level of two to five tons per acre per year. Ex. 21. Michigan has codified this atmospheric rate of deposits in its Solid Waste Landfill Rules, to ensure that the slopes and covers of landfills are sufficiently maintained. See Michigan Dept. of Environmental Quality, Solid Waste Management, Part 115, R 299.4425 (8), attached as Ex. 22.

of organic material. Ex. 19. The weight-to-volume relationship analysis showed that the material in the Service Water Basin was 48% water and 52% solids. *Id.* Of the 52% solids, approximately 92% was non-organic matter. Accordingly, based upon the total volume of 52 CY, 24.8 CY is non-organic material, which is approximately 28.7 tons. *Id.* Moreover, if MWG were to empty the pond, there would only be on average approximately 1 inch of material (52% of 2.4 inches).

The grain size comparison showed that material at the base of the Service Water Basin was not similar to CCR. KPRG compared the CCR from the Joliet 9 Station to the material found in the Service Water Basin at the Powerton Station, because the Joliet 9 CCR and Powerton CCR are effectively the same.[6] Ex. 19. The material in the Service Water Basin was black/gray silty sand and 46% fine sand and fines. *Id.* In comparison, the Joliet 9 CCR was classified as brown sand and was 80% gravel and course to medium sand.

The results of the extensive investigation and analysis of the Service Water Basin clearly show that it is not a CCR surface impoundment. The 23.7 calculated tons of material from air dispersion, coupled with the sediments deposited from stormwater runoff, and the different classification and grain size of the basin material explain the sources of the 28.7 tons of material found at the basin's base and supports the conclusion that none of the material is CCR. Ex. 19, 20.

D. The Board has the Authority to Determine that Board Rules are Inapplicable.

The Board has the authority to determine that the Service Water Basin is not a CCR Surface Impoundment within the meaning of the CCR Rule. On prior occasions, the Board has

[6] The MWG coal-burning stations like Joliet 9 and Powerton burn the same coal. Both the Joliet 9 Station and the Powerton Station generate electricity and burn coal using cyclone boilers. Because the stations burn the same coal using the same method, the resulting CCR is so similar that CCR data from one station can be used comparatively as it was here. Ex. 19.

granted a petition for an adjusted standard and issued a finding that certain Board Rules are inapplicable. *See In the Matter of: Petition of Apex Material Technologies, LLC for an Adjusted Standard from Portions of 35 Ill. Adm. Code 807.104 and 810.103, or, in the Alternative, a Finding of Inapplicability,* AS15-2, slip op. pp. 51-52 (June 18, 2015); *In the Matter of: Petition of Westwood Lands, Inc. for and Adjusted Standard from Portions of 35 Ill. Adm. Code 807.104 and 35 Ill. Adm. Code 810.103 or, in the Alternative, a Finding of Inapplicability,* AS09-3, slip-op at 16 (Oct. 7, 2010); *In the Matter of: Petition of Jo'Lyn Corporation and Falcon Waste and Recycling for an Adjusted Standard from 35 Ill. Adm. Code Part 807 or, in the Alternative, a Finding of Inapplicability*, AS 04-2, slip op. at 13-14 (Apr. 7, 2005). With one exception, in each of these petitions, after evaluating the fact-specific petitioner operations and subject material, as well as prior Board and court opinions, the Board determined that the rules at issue were inapplicable to the petitioners. Even in the one instance where the Board denied a petitioner's request for inapplicability, the Board did so not because it lacked the authority to find the rule inapplicable, but because the Board's site-specific factual and legal analysis concluded that the petitioner had failed to make the required showing of inapplicability. *See In the Matter of: Petition of Apex Material Technologies* AS15-2, slip op. pp. 51-52.

II. Application of Automatic Stay

Section 28.1(e) of the Act provides that if a petition for an adjusted standard is sought within 20 days of the effective date of a rule or regulation, the operation of the rule or regulations is stayed as to such person pending disposition of the petition. 415 ILCS 5/28.1(e). On April 15, 2021, the Board issued its Opinion and Order adopting the Final Illinois CCR Rule, and establishing the effective date as April 21, 2021. *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845,* PCB 20-19, April 15, 2021, p. 5. Because MWG has filed its petition within 20 days of the effective date of the CCR Rule, the requirement to remove the liners in the Ash Surge Basin, Bypass Basin, and the Metal Cleaning Basin for closure by removal is stayed, and the operation of the CCR Rule is stayed as to the Service Water Basin at the Powerton Station.

III. Analysis and Petition Content Requirements

The Board requires that certain information be included in each petition for an adjusted standard. 35 Ill. Adm. Code §104.406. In this case, MWG is seeking an adjusted standard for four ponds on two different issues: (1) an adjusted standard from the requirement to remove the liner in the Ash Surge Basin, Bypass Basin and Metal Cleaning Basin when they are closed by removal of the CCR; and (2) an order finding that the Part 845 Rules are inapplicable to the Service Water Basin. The Section 104.406 petition requirements are set forth under individual headings below. Within each heading, the required information for the three basins that MWG plans to reuse, and the Service Water Basin are presented.

a) Standard from which Adjusted Standard is Sought

Ash Surge Basin, Bypass Basin and Metal Cleaning Basin: The rule-of-general applicability for which MWG requests an adjusted standard is at 35 Ill. Adm. Code Part 845.740(a). Because a competent geosynthetic liner may be decontaminated and the federal CCR rule allows that decontamination, MWG is requesting that the Board grant an adjusted standard from the Illinois CCR Rule to allow decontamination instead of a removal of the liner in each basin when closed by removal.

Service Water Basin: The rule-of-general applicability for which MWG requests an adjusted standard is at 35 Ill. Adm. Code Part 845.100. Because the Service Water Basin is not a CCR surface impoundment, MWG is requesting that the Board grant an adjusted standard from the CCR Rule stating that the CCR Rule finding the rule inapplicable to the Service Water Basin.

b) Whether the regulation was promulgated to implement the CWA, Safe Drinking Water Act, Comprehensive Environmental Response, Compensation and Liability Act, or the State programs concerning RCRA, UIC, or NPDES

Part 845 implements Sections 12, 22 and 22.59 of the Act. 35 Ill. Adm. Code 845. Section 22 of the Act provides the Board authority to adopt regulations to promote the purpose of Title V, Land Pollution and Refuse Disposal, the Title implementing the requirements of RCRA. Part 845 was not promulgated to implement the state RCRA program, which is Section 22.4 of the Act. *Big River Zinc Corp. v. Illinois EPA.*, 1991 Ill. ENV. LEXIS 350, PCB 91-61 (May 6, 1991), p. *12 (Regulations or rules adopted pursuant to Section 22.4 implement the state's RCRA program).

c) Level of Justification as Specified by the Regulation

Part 845 does not include a specific justification for an adjusted standard. Because there is not a specific level of justification, the applicable level of justification are the following factors identified in Section 28.1 of the Act:

> (1) factors relating to that petitioner are substantially and significantly different from the factors relied upon by the Board in adopting the general regulation applicable to that petitioner;
>
> (2) the existence of those factors justifies an adjusted standard;
>
> (3) the requested standard will not result in environmental or health effects substantially and significantly more adverse than the effects considered by the Board in adopting the rule of general applicability; and
>
> (4) the adjusted standard is consistent with any applicable federal law.
>
> 415 ILCS 5/28.1.

d) Nature of Petitioner's Activity that is the Subject of the Proposed Adjusted Standard

Description of Powerton Station: The Powerton Station employs approximately 88 people and has operated since the 1920s. Ex. 1, ¶¶4, 6. As a coal fired electric generating station, Powerton generates two types of coal ash from the burning of coal, fly ash and bottom ash. *Id.*, ¶7. Fly ash consists of lightweight particles and is collected via dry system using electrostatic precipitators. *Id.*, ¶8. Bottom ash consists of heavier particles that fall to the bottom of the furnace and is mixed with transport water and conveyed out of the plant to the dewatering bins located next to the Station. *Id.*, 9.

Bottom Ash Management at Powerton Station: Approximately 98% of the bottom ash is collected in the dewatering bins. Ex. 1, ¶9. The transport water and the fine bottom ash that remains in the transport water is sluiced into the Ash Surge Basin, the primary CCR surface impoundment for the accumulation of bottom ash at the Station. *Id.*, ¶10. The fine bottom ash settles out of the water into the Ash Surge Basin, and is temporarily stored in the basin until the pond is full and the bottom ash is removed. *Id.*, ¶10, 15. During bottom ash removal from the Ash Surge Basin, MWG uses the Bypass Basin to accumulate the bottom ash. *Id.*, ¶14. Once the fine bottom ash settles out of the water into one of the basins, the transport water flows into the Service Water Basin where it either is recycled back to the Station for further use or discharged through a permitted outfall, pursuant to the station's NPDES permit. *Id.*, ¶, 39,40 and Ex. 10. The Metal Cleaning Basin is used to hold dry ash during maintenance, or to hold process water from washing the Station's boilers. Ex. 1, ¶18.

None of the impoundments are permanent disposal sites, instead, since they were built, the bottom is routinely removed. Ex. 1, ¶15, 19. When ash is removed from the impoundments at Powerton Station, MWG is careful prevent the pond liners from being damaged. *Id*., ¶29. The CCR surface impoundments have markers to alert the ash removal machine operators, and MWG ensures that before each dredging event, all operators in the ponds know to avoid contact with the liners. *Id.*, ¶¶27, 30. Only specifically trained personnel from the Station are allowed to operate the ash removal machinery inside the basins. *Id.*, ¶31. All of the operators in the pond are careful and methodical to ensure the liners are not damaged. *Id.*, ¶32. The machine operators leave ash material on the slopes of the liners and on the bottom above the warning layer to avoid any liner damage. *Id.*, ¶33. When removal of ash from a basin is completed, MWG inspects the basin to verify that the ash was removed without damaging the liner, and only after the inspection confirms there has no damage to the liner is the basin placed back in service. *Id.*, ¶34. Bottom ash removed from the basins is typically beneficially used for mine reclamation. *Id.*, ¶28.

Pursuant to the CCAs entered into with the Illinois EPA in 2013, MWG is monitoring the groundwater upgradient and downgradient of the Ash Surge Basin and the Bypass Basin. Ex. 1, ¶37. Additionally, following passage of the federal CCR rule, MWG also began conducting groundwater monitoring around the Ash Surge Basin and the Bypass Basin. *Id.*, 38. The Alternate Source Demonstration for the Ash Surge Basin and the Bypass Basin demonstrate that the basins are not a source of ash constituents in the groundwater. Ex. 18. Because the Metal Cleaning Basin is not a federal CCR surface impoundment, it has not conducted an Alternative Source Demonstration.

Ash Surge, Bypass Basin and Metal Cleaning Basin: The Ash Surge Basin is approximately 8 acres, the Bypass Basin is less than an acre in size, and the Metal Cleaning Basin is approximately 1.5 acres. Ex. 1, ¶12, 16. In compliance with the federal and Illinois CCR rules, MWG is closing all three basins by removing the CCR. Ex. 1, ¶20, Ex. 23. In compliance with these rules as well as the federal ELG Rule, for its future operations, MWG will separate the CCR and non-CCR waste streams. Ex. 19, p. 1-21. The CCR waste streams will be managed by the concrete tank system. *Id.* The supernatant water from the concrete tanks will discharge into the Bypass Basin, which will be renamed the Recycle Water Cooling Basin to allow the water to cool. *Id.* at 1-18. *Id.* The non-CCR waste streams, including stormwater, will be managed in the Ash Surge Basin and the Metal Cleaning Basin that will serve as low-volume waste ponds.

All three basins have recently installed HDPE liners. The Bypass Basin and Metal Cleaning Basin were relined in 2010. Ex. 1, ¶23, Ex. 14. The Ash Surge Basin was relined in 2013. Ex. 1, ¶24, Ex. 15. Because all three basins have relatively new HDPE liners that are in good condition, and can be decontaminated, MWG plans to reuse the HDPE liners instead of removing and replacing them.

<u>Service Water Basin:</u> The Service Water Basin is approximately 2.02 acres in size and is located in the northern area of the Station at the end of a gravel road that runs between the Ash Surge Basin and the Metal Cleaning Basin. Ex. 1, ¶41, Ex. 11. The Service Water Basin receives process water after ash is collected in either the Ash Surge Basin or the Bypass Basin. The process water that enters the Service Water Basin is either sent to Powerton Cooling Lake for recycling for plant use or discharged Ex, 1, ¶40, and Ex. 10.

MWG conducted an investigation to evaluate whether the Service Water Basin collected any material, and if that material was CCR. Exs. 19, 20. The investigation found there was little to no material present in the Service Water Basin. Ex. 19. The bathymetric survey found that there was a total of 28.7 tons of material in the basin, with an average bottom elevation of only 0.2 feet, or about 2.4 inches of material, about half of which was water. If MWG were to empty the pond, there would only be on average approximately 1 inch of material remaining in it. *Id.* Also, the material at the base of the pond had different grain sizes than the CCR generated by Powerton, In sum, the investigation results show that the Service Water Basin does not accumulate CCR.

e) Efforts to Comply with Regulation

Ash Surge Basin, Bypass Basin and Metal Cleaning Basin: Compliance with the Illinois CCR rule for closure by removal requires removing the liner instead of reusing it. Liner removal entails significantly higher costs, including the total waste of a completely good, competent geosynthetic liner, with no added environmental benefits. Closure by removal of all of the CCR and liners would entail demolishing these basins, after removing the CCR for resale and beneficial use. Because the planned removal is not a "clean closure", some CCR will remain on the slopes and in the base of the basins before demolition begins. Ex. 2, ¶8. In the absence of the requested adjusted standard relief and to assure compliance, it must be conservatively assumed that the demolition process would leave behind some CCR when the liner is removed. This residual CCR would require not only excavation of the HDPE liner, but also the poz-o-pac liner beneath, as well as approximately six inches of soil below that liner. *Id.* Following removal and disposal, MWG would have to replace the liner with a new HDPE liner essentially the exact same liner currently lining all of the basins. The following is a table of the volume of material removed to be from each basin, the approximate cost of the removal and disposal of the removed material, and the approximate cost of relining the ponds with the same HDPE liner. Ex. 2, ¶¶10-11, 13, 16-17, 19, 22-23, 25.

Basin	Approx. Volume of Liner, Poz-o-Pac and Soil for Removal and Disposal	Approx. Cost of Removal and Disposal	Approx. Cost of Relining	Total
Ash Surge Basin	13,350 cubic yards ("CY")	$1,475,822	$312,570	$1,788,392
Bypass Basin	725 CY	$36,224	$53,609	$89,833
Metal Cleaning Basin	4,500 CY	$464,868	$107,218	$572,086
Total	18,575 CY	$1,976,914.00	$473,397.00	$2,450,311.00

Service Water Basin: Compliance with the Illinois CCR Rule for a pond that does not contain CCR entails significant costs, with no added environmental benefits. CCR is not sluiced to the Service Water Basin. MWG's investigation determined that the very small amount of material at the base of the basin is not CCR. Absent the requested adjusted standard relief, many of the Illinois CCR Rule requirements are practically impossible. For example, the initial operating permit application must include an analysis of the chemical constituents within the CCR that will be placed in the CCR surface impoundment and an analysis for the chemical constituents of all waste streams, chemical additives and sorbent materials entering or contained in the CCR surface impoundment. 35 Ill. Adm. Code 845.230(d)(2)(B), (C). Because no CCR enters the Service Water Basin, and CCR waste streams are not directed to it, neither of these requirements are applicable to the Service Water Basin. Ex. 1, ¶39. MWG cannot conduct an analysis of the chemical constituents within the CCR that will be placed in the Service Water Basin because no CCR exists in the pond. Similarly, the initial operating permit must also include a fugitive dust plan and an inflow design flood control system plan. 35 Ill. Adm. Code 845.230(d)(2)(H), (R). Because the Service Water Basin contains only water no "fugitive dust" is emitted. Hence, there is no need or purpose served by, preparing a Fugitive Dust Plan for an area that does not receive or otherwise handle CCR and does not generate CCR dust. Ex. 1, ¶39. Also, because CCR flow is not directed to the Service Water Basin, the CCR Rule's requirement to have a plan to manage the inflow during and following any peak discharge is not applicable. *Id.* The cost of conducting all of this essentially valueless work to meet the operating permit application requirements is estimated to be $57,200. Ex. 1, ¶45.

Similarly, under the CCR Rule, MWG would also have to prepare a construction permit application for "closure" of the Service Water Basin. The information required for a construction permit application is also impractical for a process water pond that only contains water. For example, the Design and Construction Plan required to be included in a construction permit application, requires a "statement of purpose for which the CCR surface impoundment is being used, how long the CCR surface impoundment has been in operation, and the types of CCR that have been placed in the CCR surface impoundment." 35 Ill. Adm. Code 845.220(a)(1)(B). The application must also contain a description of the "types of CCR expected in the CCR surface impoundment, including a chemical analysis," the rate at which CCR waste streams enter the impoundment, and the length of time the impoundment will receive CCR. 35 Ill. Adm. Code 845.220(a)(2)(A), (C), (D). Because the Service Water Basin does not contain CCR, does not receive CCR, and will not receive CCR, MWG cannot provide the type of CCR expected in the surface impoundment, including the chemical analysis, the rate of the CCR into the ponds, and the length of time the ponds will receive CCR. Ex. 1, ¶39. The estimated costs for preparing the construction application are $125,000. Ex. 1, ¶46.

Additionally, if the Service Water Basin is a CCR surface impoundment, which it should not be, then MWG would also have to pay the initial and annual fees pursuant to Section

22.59(j) of the Act. The total fees due for 2020 and 2021 are $100,000, and the annual fee of $25,000 would continue. 415 ILCS 5/22.59(j).

f) Proposed Adjusted Standard and Efforts Necessary to Achieve the Proposed Standard

Ash Surge Basin, Bypass Basin, and Metal Cleaning Basin: MWG's requested adjusted standard includes the same rule language that the Illinois EPA originally proposed for liners, which in turn is effectively the same language in the as the federal CCR rule.[7] In consideration of the Board's requirement to conduct visual inspection and analytical testing for reuse of a liner to retrofit a CCR surface impoundment in Section 845.770(a), MWG is also proposing a similar requirement here for the reuse of the liner. The proposed adjusted standard language is:

> MWG may close the Ash Surge Basin, Bypass Basin, and the Metal Cleaning Basin at the Powerton Station by removing and decontaminating all areas affected by releases from the three units. CCR removal and decontamination of the Ash Surge Basin, Bypass Basin, and the Metal Cleaning Basin is complete when the CCR in the Ash Surge Basin, Bypass Basin and the Metal Cleaning Basin and any areas affected by releases from the CCR surface impoundment have been removed. MWG must conduct visual inspection and analytical testing to demonstrate that the geomembrane liner in the Ash Surge Basin, Bypass Basin, and Metal Cleaning Basin is not contaminated with CCR constituents. MWG must submit the results to Illinois EPA.

To reuse the HDPE liner, MWG will follow the same established procedures for CCR removal that it has used for years to remove CCR for beneficial reuse. Once the CCR in the basin is removed, MWG will engage a contractor to conduct a multi-step process to carefully remove the CCR from the slopes and base of the ponds that was left in place during the initial CCR removal to protect the integrity of the liner. Ex. 1, ¶35. The multi-step process will include using an excavator with a rubber surface on the edge of the bucket to pull down most

[7] Illinois EPA's proposed CCR language had some minor non-substantive differences to the federal CCR rule. *Compare* Proposed Illinois EPA 35 Ill. Adm. Code 845.740(a) and 40 C.F.R. §845.102(c).

of the material from the slopes. *Id.* A vibrating plate will be used to shake the rest of the material loose on from the slope. *Id.* Either an excavator or front end loader with a rubber surface on the edge of the bucket will be used to carefully remove any remaining CCR material from the base of the pond. *Id.* The slopes and base of each basin will then be power-washed. The power-washing step will collect the mixture of ash and water and remove it from the basin. Upon completion of the power-washing step, wipe samples from the slopes will be collected to confirm that the HDPE liner has been decontaminated of CCR. Ex. 3. The approximate cost to clean and decontaminate each basin, is: Ash Surge Basin - $85,330, Bypass Basin - $9,297, and Metal Cleaning Basin - $18,959. The total approximate cost is: $111,500. Ex. 2, ¶¶ 14, 20, 25.

Mr. Nielson's expert opinion explains that competent geomembrane liners, including HDPE liners, may be cleaned and decontaminated. Ex. 3. With support from an international study, he explains that a geomembrane is "an essentially impermeable geosynthetic composed of one or more synthetic sheets." *Id*. Mr. Nielson did not find "any evidence that geomembrane liners, such as HDPE become contaminated with waste products that are present in CCR," and he was "not aware of a study that shows that polymer liners become saturated with CCR constituents." *Id.* To provide assurance that the HDPE liner was not contaminated, Mr. Nielson recommends that MWG conduct visual inspections and collect wipe samples of the HDPE liner to confirm that the HDPE liner was decontaminated. *Id.* In fact, Mr. Nielson identified a study of an HDPE liner, in which the pond owner repurposed an HDPE lined impoundment from holding landfill leachate to holding clean water. *Id.* Mr. Nielson's expert analysis demonstrates that the liners in the Ash Surge Basin, Bypass Basin, and Metal Cleaning Basin may be effectively decontaminated for reuse instead of being removed and disposed.

The Board has already found that a competent, uncontaminated existing geomembrane liner may be reused. In its Opinion and Second Notice Order, the Board stated that MWG had raised a valid concern about removing competent, uncontaminated liners, and that it saw "no reason for requiring removal of these liners if they can be used as a supplement to the liner system required by this Part." *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845,* PCB 20-19, Feb. 4, 2021 Order, p. 99. The Board found that the existing liner may be left in place if the owner or operator demonstrates that the liner is not contaminated with CCR constituents. *Id.* Consistent with the Board's direction, MWG has included in its proposed adjusted standard language a requirement that MWG conduct visual inspections and conduct analytical testing to confirm that the liner is not contaminated with CCR constituents.

Because all three Basins are subject to the Illinois CCR Rule, MWG will monitor groundwater surrounding the three basins for at least three years, if not longer depending on the results of the groundwater monitoring. 35 Ill. Adm. Code 845.740(b).

<u>Service Water Basin:</u> MWG's proposed adjusted standard relief is a finding that the Service Water Basin is not a CCR surface impoundment and is not subject to Part 845, Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments.

The proposed language is:

> Part 845 of the Illinois Pollution Control Board Regulations does not apply to the Service Water Basin, located at the MWG Powerton Generating Station, 13082 East Manito Road, Pekin, Tazewell County, IL 61554.

g) Description of Impact on the Environment of Complying with the Regulation vs. Complying with the Adjusted Standard

Ash Surge Basin, Bypass Basin, and Metal Cleaning Basin: Allowing decontamination of a competent geomembrane liner has a more favorable environmental impact than removing and disposing of it along with underlying soil that may have been in contact with CCR. Disposal of the three liners in a landfill regardless of their condition is a waste of landfill space. Ex. 3. Additionally, the underlying soil will also be removed and disposed in a landfill because of the assumption that the soil may have mixed with or otherwise made contact with the CCR during the demolition process. The need to remove the liner and any associated soil that contacted CCR during liner removal process, also unnecessarily increases the volume of material that would be disposed in a landfill.

By comparison, if the liner is reused, then there is no landfill disposal of either the liner or the associated soil. Also, because the liner is in good condition, and the Ash Surge Basin and the Metal Cleaning Basin will only be used for retention of low-volume wastewater (*i.e.* – process water), there is little risk of groundwater contamination from the reuse of the liner. Similarly, the Bypass Basin will be converted to the Recycling Cooling Water Basin, which will also contain non-CCR liquid. Even though the Recycling Cooling Water Basin is in series with the dewatering bins and the concrete tanks that collect the CCR, the Recycling Cooling Water Basin will not accumulate CCR Ex. 2, ¶¶4,5. Instead, the dewatering bins and the two concrete tanks, remove the measurable quantities of CCR. *Id.* The supernatant flowing from the concrete tanks into the Recycling Cooling Water Basin will not contain a measurable quantity of CCR. *Id.*

Also, the Board has already found that reuse of a competent liner is acceptable for retrofitting a CCR surface impoundment. *In the Matter of: Standards for the Disposal of*

Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845, PCB 20-19, Feb. 4, 2021 Order, p. 99. Because the Board found that a competent liner like the liners in the three basins may be decontaminated and reused as part of a retrofitted CCR surface impoundment, there is no reason to believe that a competent liner cannot be reused to repurpose the three basins to hold non-CCR liquids.

Service Water Basin: Neither the generally applicable rule nor the proposed adjusted standard that would remove the Service Water Basin from the applicability section of Part 845 have a more favorable environmental impact. The purpose of the CCR Rule is to regulate surface impoundments that contain CCR. Here, the Service Water Basin does not contain CCR – it only contains water. Ex. 1, ¶39. The water is process water that either is recycled back into the Station through the cooling lake or discharged as allowed in the Station's NPDES permit. *Id.*, ¶40. Because the Service Water Basin is not a CCR surface impoundment, does not contain CCR, and is regulated by the Station's NDPES permit, there is no environmental benefit to requiring the applicability of the Illinois CCR rule to the basin.

h) Justification of Proposed Adjusted Standard.

Because Part 845 does not include a specific justification for an adjusted standard, the applicable level of justification are the factors identified in Section 28.1 of the Act, set forth in Section III.C. above. Each of the Section 28.1 factors is addressed below for the Ash Surge Basin, Bypass Basin, Metal Cleaning Basin, and the Service Water Basin.

Ash Surge Basin, Bypass Basin, Metal Cleaning Basin: In its CCR Rule Opinion, the Board did not identify the factors it considered in requiring removal of the liner, other than referencing the Illinois EPA's statement that the proposed federal CCR rule includes that requirement. In addition to the fact that the federal CCR Rule "proposal" is not binding, it does not require removal but instead proposes to allow either removal or decontamination. MWG is reasonably proposing an adjusted standard that adopts the proposed federal CCR Rule's decontamination alternative.

Allowing decontamination of a competent liner as opposed to its removal and disposal regardless of liner condition will not result in environmental or health effects substantially and significantly more adverse than the effects that may have been considered by the Board. Reuse of a competent liner is more environmentally beneficial than disposal of three liners and the underlying soil, only to be replaced by virtually identical liners. Finally, because the federal CCR rule allows decontamination of a liner, allowing MWG to decontaminate and reuse the liners in the Ash Surge Basin, Bypass Basin, and the Metal Cleaning Basin is consistent with federal law. 40 C.F.R. §257.102(c).

Service Water Basin: The factors relating to the Service Water Basin are substantially and significantly different than the factors relied upon by the Board in consideration of Part 845. The Illinois CCR rulemaking focused on active CCR surface impoundments, including their operations and construction for the primary purpose of containing CCR. Here, MWG has demonstrated that the Service Water Basin does not contain CCR. Thus the factors the Board considered to regulate CCR surface impoundments are not applicable.

Finding that the Service Water Basin is not a CCR surface impoundment will not result in environmental or health effects substantially and significantly more adverse than the effects considered by the Board. The Illinois CCR Rule specifically considered the potential environmental effects of CCR surface impoundments, which is inapplicable to the Service Water Basin because it does not contain CCR. Also, finding that the Service Water Basin is not a CCR surface impoundments is consistent with federal law. In the 2015 preamble to the federal CCR Rulemaking, the U.S.EPA specifically stated that it revised the definition of CCR surface impoundment to exclude units that "present significantly lower risks, such as process water or cooling water ponds because, although they will accumulate any trace amounts of CCR that are present, they will not contain the significant quantities that give rise to the risks modeled in EPA's assessment." 80 F.R. 21357. The U.S.EPA continued by stating that "CCR surface impoundments do not include units generally referred to as cooling water ponds, process water ponds…" *Id*.

i) **Reasons the Board may Grant the Proposed Adjusted Standard Consistent with Federal Law**.

As stated herein, the Board may grant the proposed adjusted standards for the Ash Surge Basin, the Bypass Basin, the Metal Cleaning Basin, and the Service Water Basin because the proposed adjusted standards are consistent with federal law. The applicable federal CCR rule and the proposed federal CCR rule on closure by removal each allow for decontamination of a liner and does not require removal. 40 C.F.R. §257.102(c) and *proposed* 40 C.F.R. §257.102(c). Similarly, the applicable federal CCR rule does not apply to process water ponds. 80 F.R. 21357. Also, there are no procedural requirements applicable to the Board's decision on the petition that are imposed by federal law and not required by the Board regulations.

j) **Hearing on the Petition**.

MWG requests a hearing on the Petition.

k) As required by 35 Ill. Adm. Code 104.406(k) and (l), MWG has provided the citations to relevant supporting documents and legal authorities and has provided required information as applicable to its request the Board's finding of inapplicability.

IV. Conclusion

For the reasons stated, MWG requests the Board enter an Order which states that MWG may close the Ash Surge Basin, Bypass Basin, and the Metal Cleaning Basin by removal of the CCR and decontamination of the liner. MWG also requests that the Board enter an order which states that the Part 845 regulations do not apply to the Service Water Basin.

Respectfully submitted,
Midwest Generation, LLC

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BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:

PETITION OF MIDWEST GENERATION FOR AN ADJUSTED STANDARD FROM 35 ILL. ADM. CODE PARTS 811 and 814	**AS 21-** **(Adjusted Standard)**

INDEX OF EXHIBITS FOR MIDWEST GENERATION, LLC'S
PETITION FOR ADJUSTED STANDARD FOR THE POWERTON STATION

Exhibit 1	Affidavit of Dale Green, Powerton Station Manager
Exhibit 2	Affidavit of David Nielson, P.E.
Exhibit 3	Opinion of David Nielson, P.E.
Exhibit 4	Pre-filed Expert Testimony of David Nielson on behalf of Midwest Generation, LLC, *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845*, PCB 20-19
Exhibit 5	Excerpt of September 30, 2020 Hearing Transcript, *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845*, PCB 20-19
Exhibit 6	Excerpt of Midwest Generation, LLC Pre-Filed Answers, *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845*, PCB 20-19
Exhibit 7	Excerpt of Agency Final Comment, *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845*, PCB 20-19
Exhibit 8	Excerpt of Midwest Generation, LLC's Response Comment, *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845*, PCB 20-19
Exhibit 9	Excerpt of August 25, 2020 Hearing Transcript, *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845*, PCB 20-19

Exhibit 10	NPDES Permit for Powerton Station
Exhibit 11	Map of Powerton Station
Exhibit 12	Illinois EPA Construction Permit for Liner Replacement of Relining Bypass Basin and Metal Cleaning Basin
Exhibit 13	Illinois EPA Construction Permit for Liner Replacement of Ash Surge Basin
Exhibit 14	Construction Documentation for Liner Replacement of the Bypass Basin and Metal Cleaning Basin
Exhibit 15	Construction Documentation for Liner Replacement of the Ash Surge Basin
Exhibit 16	Compliance Commitment Agreement for Powerton Station
Exhibit 17	Alternate Source Demonstration for the Ash Surge Basin and the Bypass Basin, March 25, 2019
Exhibit 18	Demonstration for a Site-Specific Alternative Deadline to Initiate Closure of the Ash Surge Basin, Excerpt, Nov. 30, 2020
Exhibit 19	Evaluation of Sediment Quantities in Joliet Generating Station's Pond 1 and Pond 3 and Powerton Generating Station's Service Water Basin, Nov. 19, 2020
Exhibit 20	Sampling Location Discussion as part of Evaluation of Sediment Quantities in Joliet Generating Station's Pond 1 and Pond 3 and Powerton Generating Station's Service Water Basin, Feb. 26, 2021
Exhibit 21	"Predicting Rainfall Erosion Losses", U.S. Dept. of Agriculture, Dec. 1978
Exhibit 22	Michigan Dept. of Environmental Quality, Solid Waste Management, Part 115, R 299.4425 (8)
Exhibit 23	Closure Plan, Ash Surge Basin and Bypass Basin, Powerton Station, Oct. 2019

EXHIBIT 1

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:

PETITION OF MIDWEST GENERATION FOR AN ADJUSTED STANDARD FROM 845.740(a) AND FINDING OF INAPPLICABILITY OF PART 845	**AS (Adjusted Standard)**

AFFIDAVIT OF DALE GREEN

I, Dale Green, being first duly sworn on oath, depose and state as follows:

1. I am over the age of 18 years and am a resident of Illinois.

2. The information in this Affidavit is based on my personal knowledge or belief in my capacity as Station Manager of the Powerton Station ("Powerton" or "Station") and I would testify to such matters if called as a witness.

3. The Powerton Station is located at 13082 East Manito Road, Pekin in Tazewell County, Illinois.

4. Powerton was built in the late 1920's and has been a power plant ever since.

5. MWG began operating the Powerton Station in 1999, and the area around the station is industrial and agricultural.

6. Approximately 88 people work at the Powerton Station.

7. Powerton generates two types of coal combustion residuals ("CCR") from the burning of the coal to generate electricity, fly ash and bottom ash.

8. Fly ash consists of lightweight particles and is collected via a dry system using electrostatic precipitators.

9. Bottom ash consists of heavier particles that fall to the bottom of the furnaces and is mixed with water and conveyed to the dewatering bins located on the Station Property. The dewatering bins collect approximately 98% of the CCR.

10. The fine CCR that did not drop out of the transport water in the dewatering bins, flows into the Ash Surge Basin or the Bypass Basin for settlement.

11. The Ash Surge Basin and Bypass Basin are federal CCR surface impoundments, were built in 1978 with at least 12-inches of poz-o-pac liner on the bottom and Hypalon liner on the sides.

12. The Ash Surge Basin is approximately 8 acres and the Bypass Basin is less than an acre in size.

13. Both CCR waste streams and non-CCR waste streams were directed to the Ash Surge Basin, or the Bypass Basin, depending on which is in service. Pursuant to the federal CCR rule, the Bypass Basin service was taken out of service and does not accumulate CCR and liquid.

14. The Ash Surge Basin is the primary basin that accumulates the CCR. When MWG is emptying the Ash Surge Basin, MWG uses the Bypass Basin for accumulation of CCR.

15. MWG routinely empties both the Ash Surge Basin and the Bypass Basin.

16. The Metal Cleaning Basin, which is approximately 1.5 acres in size, is an Illinois CCR surface impoundment, but it is not a part of the ash sluice system.

17. The Metal Cleaning Basin was built in 1978 with a 12-inch poz-o-pac liner on the bottom and a Hypalon liner on the sides.

18. The Metal Cleaning Basin is not a federal CCR surface impoundment because it is not used to hold an accumulation of CCR and water at the same time. Instead it is used to hold dry ash if an ash silo fails, or during maintenance of the ash handling system. Also, on other

occasions, the Metal Cleaning Basin is used to hold the process water when the boilers at the Station are washed.

19. MWG routinely removes the dry CCR or process water from the Metal Cleaning Basin.

20. MWG intends to close the Metal Cleaning Basin by removal of the CCR.

21. The Powerton Station has an inactive CCR surface impoundment, the Former Ash Basin, which is located on the northern most edge of the Station.

22. There are no other basins at Powerton that hold CCR and liquid.

23. In 2010, MWG relined the Bypass Basin and the Metal Cleaning Basin with an HDPE liner, and additional layers of material to protect the liner during removal of the CCR.

24. In 2013, MWG relined the Ash Surge Basin with the same HDPE liner system as in the Bypass Basin and the Metal Cleaning Basin.

25. The HDPE was lain over the poz-o-pac on the base of the Ash Surge Basin, Bypass Basin, and Metal Cleaning Basin, because the poz-o-pac base is an additional barrier and provides additional support to the HDPE liner.

26. Over the HDPE liner in the Ash Surge Basin, Bypass Basin, and the Metal Cleaning Basin, there is a sand layer and a limestone layer. The purpose of the sand cushion layer is to avoid punctures on the geomembrane when equipment is on the liner. The purpose of the limestone warning layer, which is white and contrasts with the dark color of coal ash, is to act as a warning to the operators when the operators are removing the ash so that they do not reach the liner.

27. The Ash Surge Basin, Bypass Basin, and Metal Cleaning Basin have markers to notify the machine operators of the sides when the ponds are being dredged.

28. The Powerton CCR is removed from the ponds and is generally beneficially used for mine reclamation.

29. When ash is removed from the impoundments at Powerton, MWG takes specific care to prevent the pond liners from being damaged.

30. Before the dredging begins, the Powerton Station has a meeting to discuss the project and lay out the safety objectives, including being aware of the liner to avoid any damage to the liner.

31. Trained MWG operators operate the machinery to remove the CCR inside the basins.

32. All of the operators in the pond are careful and methodical to ensure the liners are not damaged.

33. The machine operators leave ash material on the slopes of the liners and on the bottom above the warning layer to avoid any damage to the liner.

34. Once MWG has completed removing the ash from a basin, MWG inspects the basin to verify that the liner was not damaged and only after the inspection is the basin placed back in service.

35. To clean and decontaminate the Ash Surge Basin, Bypass Basin, and the Metal Cleaning Basin for reuse, once the CCR is removed per its prior practice, MWG will engage a third party contractor to use a multi-step process to carefully remove the remaining CCR from the slopes and base of the pond and decontaminate the liner. An example of the multi-step process that the contractor could employ would be the contractor will first use an excavator with a rubber surface on the edge of the bucket to pull down most of the material from the slopes. The contractor would then use a vibrating plate to shake the rest of the material down to the bottom of the slope, for further removal. Then the contractor would use an excavator or front end loader with a rubber

surface on the edge of the bucket to carefully remove the excess material from the base of the pond. Finally, the contractor would power-wash the slopes and base of all three ponds.

36. Beginning in 2010, MWG began monitoring the groundwater upgradient and downgradient of the Powerton CCR surface impoundments.

37. In 2013, MWG entered into a Compliance Commitment Agreement ("CCA") with the Illinois EPA. The CCA requirements included a requirement to continue conducting the groundwater monitoring in the wells around the CCR surface impoundments.

38. MWG also conducts groundwater monitoring surrounding the Ash Surge Basin and the Bypass Basin pursuant to the federal CCR Rule, 40 C.F.R. 257.

39. The Service Water Basin at the Powerton Station is a process water basin that does not receive CCR. The Service Water Basin receives the transport water from the Ash Surge Basin or the Bypass Basin.

40. The transport water in the Service Water Basin either is recycled to the Station for further use or discharged through a permitted outfall pursuant to the Station's NDPES permit.

41. The Service Water Basin is not a federal CCR surface impoundment and is approximately 2.02 acres in size.

42. The Service Water Basin was constructed in 1978. Between 1978 and 2013, there was never a need to empty the Service Water Basin.

43. The Service Water Basin was emptied for the first time in 2013 when MWG relined the basin with a new HDPE polymer liner.

44. When the Service Water Basin was emptied in 2013, there was less than a foot of material accumulated in the basin that was not CCR, but rather soil and biologic debris that had collected for over thirty years.

45. The cost of conducting the work to prepare an operating permit application for the Service Water Basin required in Section 845.230 of the Illinois Coal Combustion Residual Rule would be approximately $57,200.

46. The estimated cost for preparing the construction permit application for the Service Water Basin required in Section 845.220 of the Illinois Coal Combustion Residual Rule would be $125,000.

Under penalties as provided by law pursuant to Section 1-109 of the Code of Civil Procedure, the undersigned certifies that the statements set forth in this instrument are true and correct, except as to matters therein stated to be on information and belief and as to such matters the undersigned certifies as aforesaid that he verily believes the same to be true.

FURTHER AFFIANT SAYETH NOT.

Dale Green

Subscribed and Sworn to before me
On May 6, 2021.

Notary Public

My Commission Expires: 7/5/2021

"OFFICIAL SEAL"
KIMBERLY M MARRON
Notary Public, State of Illinois
My Commission Expires 7/5/2021

EXHIBIT 2

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:

PETITION OF MIDWEST GENERATION FOR AN ADJUSTED STANDARD FROM 845.740(a) AND FINDING OF INAPPLICABILITY OF PART 845	**AS (Adjusted Standard)**

AFFIDAVIT OF DAVID E. NIELSON IN SUPPORT OF MIDWEST GENERATION LLC'S PETITION FOR AN ADJUSTED STANDARD AT THE POWERTON STATION

I, David E. Nielson, being first duly sworn on oath, depose and state as follows:

1. I am over the age of 18 years and am a resident of Indiana.

2. The information in this Affidavit is based on my personal knowledge or belief in my capacity as an Illinois licensed professional engineer, and as Sr. Consultant and Sr. Manager with Sargent & Lundy headquartered in Chicago, Illinois. I would testify to such matters included herein if called as a witness.

3. In my employment with Sargent & Lundy, I have had primary responsibility for providing engineering services to Midwest Generation, LLC ("MWG") relating to the requirements of the federal Coal Combustion Residual ("CCR") rule (40 C.F.R. 257) and the Illinois CCR rule (35 Ill. Adm Code 845) for modifications of the CCR management systems at the MWG Station located in Powerton, IL ("Powerton Station" or "Station"). I assisted in preparing the Demonstration for a Site-Specific Alternative Deadline to Initiate Closure of the Ash Surge Basin submitted to U.S.EPA which describes the alternatives available and unavailable to the Powerton Station for storage of bottom ash, and the intended CCR management system that will be installed. Based on this work, I have significant experience related to the compliance requirements for the CCR management systems at the Powerton Station.

4. The CCR management system proposed in the Demonstration for a Site-Specific Alternative Deadline to Initiate Closure of the Ash Surge Basin submitted to U.S.EPA was to replace the Ash Surge Basin and the Bypass Basin with a concrete ash-settling tank. The concrete ash-settling tank will collect the ultra-fine CCR that did not settle out of the transport water in the dewatering bins. Most of the fine ash CCR will settle out of the water in the primary concrete cell, and the second "surge cell" will capture the final sedimentation of CCR. The supernatant flowing from the concrete tanks will not contain a measurable amount of CCR.

5. The supernatant from the concrete tanks will flow into the Bypass Basin that is converted into a Recycling Cooling Water Basin. The Recycling Cooling Basin will not accumulate CCR.

6. Exhibit 3 to the Petition for an Adjusted Standard for the Powerton Station is my expert opinion that a geomembrane liner of a CCR surface impoundment does not need to be removed. Instead, a geomembrane liner can be decontaminated such that it may be used for another purpose, such as for use as a low volume waste pond.

7. Allowing reuse of the HDPE liners at Powerton will reduce the amount of time required to convert from its CCR management through a CCR surface impoundment to using the concrete tanks.

8. If MWG is required to remove the liners in the Ash Surge Basin, Bypass Basin, and Metal Cleaning Basin, due to the presence of the CCR in the ponds when demolition of the liners begins, it would be assumed that during the demolition CCR would escape from the ponds when the liners are removed, thus requiring excavation of the liner, the poz-o-pac, and approximately six inches of soil below the liner.

9. The total volume of liner, underlying poz-o-pac and CCR impacted soil removed from the Ash Surge Basin would be approximately 13,350 cubic yards ("CY"), which would be hauled off-site for disposal in a landfill.

10. Hauling a total quantity of 13,350 CY of soils offsite the Station would require 890 trucks based on a 15 CY per truck capacity.

11. The total cost for excavation, transportation and disposal of the liner, poz-o-pac, and soil from the Ash Surge Basin, including the labor and material costs, would be approximately $1,475,822.

12. The new liner that would be installed in the Ash Surge Basin would be almost the same as the liner currently lining the Ash Surge Basin.

13. The cost to install a new liner in the Ash Surge Basin would cost approximately $312,570.

14. The approximate cost to clean and conduct confirmatory wipe samples of the Ash Surge Basin would be $85,330.

15. The total volume of liner and soil removed from the Bypass Basin would be approximately 725 cubic yards ("CY"), which would be hauled off-site for disposal in a landfill.

16. Hauling a total quantity of 725 CY of soils offsite the Station would require 48 trucks based on a 15 CY per truck capacity.

17. The total cost for excavation, transportation, and disposal of the liner and soil from the Bypass Basin, including the labor and material costs, would be approximately $36,224.

18. The new liner that would be installed in the Bypass Basin would be almost the same as the liner currently lining the Bypass Basin.

19. The cost to install a new liner in the Bypass Basin would cost approximately $53,609.

20. The approximate cost to clean and conduct confirmatory wipe samples of the Bypass Basin would be $9,297.

21. The total volume of liner and underlying poz-o-pac soil removed from the Metal Cleaning Basin would be approximately 4,500 cubic yards ("CY"), which would be hauled off-site for disposal in a landfill.

22. Hauling a total quantity of 4,500 CY of soils offsite the Station would require 300 trucks based on a 15 CY per truck capacity.

23. The total cost for excavation, transportation and disposal of the liner, poz-o-pac, and soil from the Metal Cleaning Basin, including the labor and material costs, would be approximately $464,868.

24. The new liner that would be installed in the Metal Cleaning Basin would be almost the same as the liner currently lining the Metal Cleaning Basin.

25. The cost to install a new liner in the Metal Cleaning Basin would cost approximately $107,218.

26. The approximate cost to clean and conduct confirmatory wipe samples of the Bypass Basin would be $18,959.

FURTHER AFFIANT SAYETH NOT.

____
David E. Nielson

Subscribed and Sworn to before me
On May 10th, 2021.

Brandon Decker
Notary Public

My Commission Expires: 11/15/2022

NOTARY PUBLIC STATE OF TEXAS
BRANDON DECKER
Notary ID #131798198
My Commission Expires
November 15, 2022

This notarial act was an online notarization via two-way webcam and audiovisual technology

EXHIBIT 3
Part 1

Expert Opinion of David E. Nielson In Support of Midwest Generation, LLC's Petitions for an Adjusted Standard to Reuse the Polyethylene Liners in the Coal Combustion Residual Surface Impoundments

My name is David E. Nielson I am a Sr. Consultant and Sr. Manager with Sargent & Lundy (S&L). S&L is an Illinois-based engineering firm with over 125 years of history focused on the design of electric power generation and transmission systems. I have over 30 years of professional experience as a geotechnical and civil engineer. I have been a licensed professional engineer (civil) in the state of Illinois in good standing since 1993. My professional career has included services associated with coal combustion residuals (CCR), industrial waste surface impoundments, industrial waste landfills, and municipal solid waste (MSW) landfills in numerous states and regulatory environments since 1990. My curriculum vitae is attached (Attachment G).

I have been retained by Midwest Generation, LLC ("MWG") to provide expert testimony on MWG's Petitions for Adjusted Standards from Section 845.740(a) of the Illinois Coal Combustion Residual rule, Part 845 of the Illinois Pollution Control Board's ("Board") rules. Specifically, I am providing testimony supporting the closure of a CCR surface impoundment, by removal of the CCR with decontamination of the geomembrane liner, so it may be reused as a low-volume wastewater pond liner.

In 2020, I was retained by MWG to review and comment on the Illinois Environmental Protection Agency's ("Illinois EPA") proposed Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments as the new Part 845 of the Illinois Pollution Control Board's Rules. *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845*, PCB 20-19 ("Illinois CCR rule"). In that proceeding, I provided written testimony and oral testimony, including my opinion that a competent geomembrane liner may be reused as part of retrofitting a CCR surface impoundment. *Id.* My opinion here is similar to and consistent with my opinion that I provided *In the Matter of: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: Proposed New 35 Ill. Adm. Code 845*, PCB 20-19.

I. Background

- The Illinois CCR Rule - Section 845.120 states:
  “"Retrofit" means to remove all CCR and contaminated soils and sediments from the CCR surface impoundment, and to ensure the surface impoundment complies with the requirements in Section 845.410.”

  The Illinois CCR Rule - Section 845.410 details and references the requirements of a composite liner for new and laterally expanded CCR surface impoundments.

- Section 845.770(a)(4) of the Illinois CCR Rule states
  “An owner or operator may request the Agency to approve the use of an existing competent geomembrane liner as a supplemental liner by submitting visual inspection, and analytical testing results to demonstrate that the existing liner is not contaminated with CCR constituents.”

  Thus, the Illinois EPA and Board have established that existing liners can be considered supplemental liners provided that adequate visual and analytical test results demonstrate it is not contaminated with CCR constituents.

- Section 257.102 of the Federal Rule presents the requirements for closure of CCR impoundments by removal. 257.102(c) states “An owner or operator may elect to close a CCR unit by removing and decontaminating all areas affected by releases from the CCR unit. CCR removal and decontamination of the CCR unit are complete when constituent concentrations throughout the CCR unit and any areas affected by releases from the CCR unit have been removed and groundwater monitoring concentrations do not exceed the groundwater protection standard established pursuant to §257.95(h) for constituents listed in appendix IV to this part."

This Federal rule does not require the removal of any decontaminated liner systems.

- Section 845.740 of the Illinois Rule requires removal of liner systems for closure by removal as stated:
  "…containment system components such as the impoundment liner and contaminated subsoils, and CCR impoundment structures and ancillary equipment have been removed."

II. Geomembrane Liners in CCR Surface Impoundments Can be Decontaminated and Reused for Low-Volume Waste Ponds

In my opinion the reuse of geomembrane liners from CCR Surface impoundments that are properly decontaminated and undamaged can enhance the protection of health and the environment when they are repurposed for non-CCR impoundments, including low-volume waste ponds. My opinion is made to a reasonable degree of scientific certainty. This opinion is based on the following:

1. A low-volume waste pond is a pond that collects "low volume waste sources." "Low volume waste sources are defined in the Steam Electric Power Generating Effluent Guidelines and Standards as "wastewater from all sources except those for which specific limitations or standards are otherwise established in this part. Low volume waste sources include, but are not limited to, the following: Wastewaters from ion exchange water treatment systems, water treatment evaporator blowdown, laboratory and sampling streams, boiler blowdown, floor drains, cooling tower basin cleaning wastes, recirculating house service water systems, and wet scrubber air pollution control systems whose primary purpose is particulate removal. Sanitary wastes, air conditioning wastes, and wastewater from carbon capture or sequestration systems are not included in this definition." 40 C.F.R. § 423.11(b).

2. A low volume waste pond has an unmeasurable amount of non-CCR material because it holds the water required for the station operations and also stormwater. A power generating station uses the low volume waste ponds for temporary storage of large volumes of non-CCR waste streams until the water can be treated and discharged pursuant to the station's NPDES permit. For example, stormwater at a station would be directed to a low volume waste pond to avoid flooding a station and to also avoid discharge of stormwater from the station before treatment.

3. Geomembrane liners are flexible membranes that are manufactured of resins such as polyethylene (HDPE, LLDPE, LDPE) and polyvinyl chloride (PVC), which are energy intensive to manufacture and very low permeability. ASTM International defines geomembrane as "an essentially impermeable geosynthetic composed of one or more synthetic sheets." (Attachment A, p. 3).

4. Geomembrane liners, including HDPE, are used worldwide, including hazardous waste landfills, municipal solid waste landfills, hazardous waste impoundments, non-hazardous waste impoundments, tailings ponds, dams, and stormwater management ponds.

5. My research has not found any evidence that geomembrane liners, such as HDPE become contaminated with waste products that are present in CCR. In fact, I am not aware of a study that shows that polymer liners become saturated with CCR constituents. Thus, there is no basis to conclude that a geomembrane liner would be saturated with CCR constituents such that it cannot be decontaminated for reuse.

6. To clean a CCR surface impoundment, first the CCR is carefully removed from the surface impoundment. Following removal, the sides and base of the CCR surface impoundment are methodically cleaned with a high pressure power-washer to remove the residual CCR from the geomembrane. Visual inspections for any damage would also occur, and any potential damage found would be repaired.

7. Performing analytical testing on wipe samples to verify suitable decontamination of the exposed surface of undamaged HDPE liner systems is considered a reasonable

path forward to allow existing liners to be repurposed for non-CCR impoundments. The wipe samples would be obtained for the metal and other constituents regulated by the Illinois CCR Rule (845.600(a)(1)).

I suggest the sampling and testing consist of:

- In accordance with ASTM D6966-18 (Attachment B) perform a systematic and repeatable wipe sampling,
- Analytical chemistry testing to quantify the concentrations of the regulated metals and other chemical constituents.

It is my opinion that performing 1 set of wipe samples and tests per acre is an appropriate testing frequency. This opinion is based on the USEPA guidance that one permeability test should be performed per acre per lift of compacted clay liner (Attachment C, Section 2.8.4.3).

8. Geomembrane liners have been successfully cleaned for reuse for an alternative purpose. In 2018, a geomembrane lined landfill leachate pond was cleaned so the pond could store clean water. The geomembrane liner had been in use for approximately 25 years. Because the geomembrane liner would be exposed, the owner conducted an analysis of the condition of geomembrane after over two decades of use. The analysis showed that the geomembrane was in good condition with little signs of degradation, and the owner continued using the impoundment for clean water. Attachment D.

9. When considering a 60 mil HDPE liner that is 10 acres in extent, it contains over 120,000 pounds or about 60,000 kg of HDPE resin. The energy demand for manufacturing of the resin requires over 76 MJ/kg or 72,000 BTU/kg. (Attachment E, p. 11). Therefore, it is estimated that to manufacture the resin for 10 acres of 60 mil HDPE liner requires over 4,300,000,000 BTU of energy. This includes the energy value of the oil and natural gas products used to make the resin. This does not include the energy required to extrude the resin into sheets,

transportation, deployment, or seaming. Thus, I conclude that the energy intensive requirements to replace decontaminated, undamaged HDPE liner are not warranted.

10. Pond 1 at MWG's Joliet 29 station has a HDPE liner that was repurposed for the existing non-CCR impoundment. Ongoing groundwater testing validates that CCR constituents have not adversely impacted the groundwater. Attachment F.

11. When HDPE liner is removed from an impoundment it is not typically rolled to reduce the volume of waste to be transported to a landfill. Instead it is often removed with an excavator and loaded into dump trucks. Because removal of the liner is a demolition project, there would be no need for the excavators to carefully remove the liner. Instead, when the liner is removed, the CCR material that remained in the CCR surface impoundment would likely mix with the underlying soil. To confirm that all sub-soils were removed of CCR, at least 6 inches of subsoil would have to be removed and disposed of as well as the liner.

12. It is recognized that the zero air void volume of a typical liner for a 10 acre pond only occupies about 80 cubic yards of volume. However, when the material is placed in a dump truck with an excavator along with the nominal 6 inches of subsoil, it would likely require approximately 500 dump truck loads of the waste liner and subsoil to be hauled to a landfill. Additionally, about 5 over the road tractor trailer loads would be required to transport the new liner material from the factory to the site. In my opinion it is not prudent to require about 500 truck trips per 10 acres of lined impoundment to remove and replace an undamaged decontaminated existing liner.

13. Additionally, removing the liner and the subsoil, and installing a virtually identical liner to hold low-volume wastewater will take a significant amount of time compared to removing the CCR and decontaminating the liner. In the Demonstrations for a Site-Specific Alternative Deadline to Initiate Closure of the basins at the MWG Stations that MWG submitted to the U.S. EPA pursuant to the federal CCR rule, MWG committed to providing alternative disposal of the CCR as soon as technically

feasible. *See* Demonstration for a Site-Specific Alternative Deadline to Initiate Closure, Powerton Station, p. 3-5; Demonstration for a Site-Specific Alternative Deadline to Initiate Closure, Waukegan Station, p. 3-5. Because it is technically feasible to decontaminate a geomembrane liner, by removing the CCR and decontaminating the liner, MWG would be fulfilling its commitment to provide the alternative capacity for CCR and non-CCR wastestreams as soon as technically feasible.

III. Conclusion

I recommend that MWG be granted an adjusted standard from the Illinois CCR Rule requirement to remove the geomembrane liner of a CCR surface impoundment for closure by removal of CCR. A competent geomembrane liner does not become saturated with CCR constituents, and can be cleaned and decontaminated for another purpose. Additionally, wipe samples will be taken to confirm that the decontamination cleaning was successful. As previously noted the adjusted standard as requested is in accordance with the USEPA CCR Rule.

Digitally signed by David E. Nielson
Date: 2021.05.09 18:40:37 -05'00'

David E. Nielson, P.E.

ATTACHMENTS

A. ASTM International, Standard Terminology for Geosynthetics, ASTM D4439 - 20, January 2020.

B. ASTM International, Standard Practice for Collection of Settled Dust Samples Using Wipe Sampling Methods for Subsequent Determination of Metals, ASTM D6966-18, November 2018.

C. https://geosyntheticsmagazine.com/2019/02/01/a-leachate-pond-geomembrane-after-25-years-of-service/

D. Daniel, D. E. and R. M. Koerner. Technical Guidance Document: Quality Assurance and Quality Control for Waste Containment Facilities, EPA/600/R-93/182 (NTIS PB94-159100), 1993.

E. PlasticsEurope, Eco-profiles of the European Plastics Industry, High Density Polyethylene (HDPE), March 2005.

F. Midwest Generation, LLC, 2021; Annual and Quarterly Groundwater Monitoring Report, Joliet #29 Generating Station, January 21, 2021.

G. David E. Nielson, Curriculum Vitae

ATTACHMENT A

Standard Terminology for Geosynthetics
ASTM D4439 - 20

INTERNATIONAL

Designation: D4439 – 20

Standard Terminology for Geosynthetics[1]

This standard is issued under the fixed designation D4439; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Referenced Documents

1.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates
D1987 Test Method for Biological Clogging of Geotextile or Soil/Geotextile Filters
D4354 Practice for Sampling of Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing
D4491/D4491M Test Methods for Water Permeability of Geotextiles by Permittivity
D4533/D4533M Test Method for Trapezoid Tearing Strength of Geotextiles
D4594/D4594M Test Method for Effects of Temperature on Stability of Geotextiles
D4595 Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method
D4632/D4632M Test Method for Grab Breaking Load and Elongation of Geotextiles
D4716/D4716M Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
D4751 Test Methods for Determining Apparent Opening Size of a Geotextile
D4759 Practice for Determining the Specification Conformance of Geosynthetics
D4833/D4833M Test Method for Index Puncture Resistance of Geomembranes and Related Products
D4873/D4873M Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
D4884/D4884M Test Method for Strength of Sewn or Bonded Seams of Geotextiles
D4885 Test Method for Determining Performance Strength of Geomembranes by the Wide Strip Tensile Method
D5101 Test Method for Measuring the Filtration Compatibility of Soil-Geotextile Systems
D5141 Test Method for Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device
D5262 Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics
D5322 Practice for Laboratory Immersion Procedures for Evaluating the Chemical Resistance of Geosynthetics to Liquids
D5323 Practice for Determination of 2 % Secant Modulus for Polyethylene Geomembranes
D5397 Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test
D5494 Test Method for the Determination of Pyramid Puncture Resistance of Unprotected and Protected Geomembranes
D5496 Practice for In Field Immersion Testing of Geosynthetics
D5514/D5514M Test Method for Large-Scale Hydrostatic Puncture Testing of Geosynthetics
D5567 Test Method for Hydraulic Conductivity Ratio (HCR) Testing of Soil/Geotextile Systems
D5594 Test Method for Determination of the Vinyl Acetate Content of Ethylene-Vinyl Acetate (EVA) Copolymers by Fourier Transform Infrared Spectroscopy (FT-IR)
D5617 Test Method for Multi-Axial Tension Test for Geosynthetics
D5641/D5641M Practice for Geomembrane Seam Evaluation by Vacuum Chamber
D5747/D5747M Practice for Tests to Evaluate the Chemical Resistance of Geomembranes to Liquids
D5818 Practice for Exposure and Retrieval of Samples to Evaluate Installation Damage of Geosynthetics
D5820 Practice for Pressurized Air Channel Evaluation of Dual-Seamed Geomembranes
D5994/D5994M Test Method for Measuring Core Thickness of Textured Geomembranes

1.2 *Federal Standard:*[3]

Federal Standard 751a Stitches, Seams, and Stitchings

[1] This terminology is under the jurisdiction of D35 on Geosynthetics and is the direct responsibility of D35.93 on Editorial and Terminology.

Current edition approved Jan. 1, 2020. Published January 2020. Originally approved in 1984. Last previous edition approved in 2018 as D4439 – 18. DOI: 10.1520/D4439-20.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.

2. Terminology

absorption, *n*—the process by which a liquid is drawn into and tends to fill permeable pores in a porous solid body, also, the increase in mass of a porous solid body resulting from penetration of a liquid into its permeable pores. **C125**

aerobic, *n*—a condition in which a measurable volume of air is present in the incubation chamber or system. **D1987**

anaerobic, *n*—a condition in which no measurable volume of air is present in the incubation chamber or system. **D1987**

apparent opening size (AOS), O_{95}, *n—for a geotextile,* a property which indicates the approximate largest particle that would effectively pass through the geotextile. **D4751**

atmosphere for testing geosynthetics, *n*—air maintained at a relative humidity between 50 to 70 % and a temperature of 21 ± 2 °C (70 ± 4 °F). **D4439, D4751, D5494**

back flushing, *n*—a process by which liquid is forced in the reverse direction to the flow direction. **D1987**

basis weight—deprecated term (do not use in the sense of mass per unit area). **D4439**

bend, *vt—in mechanics*, to force an object from its natural or manufactured shape into a curve or into increased curvature. **D4439**

biocide, *n*—a chemical used to kill bacteria and other microorganisms. **D1987**

bituminous geosynthetic barrier (GBR-B), *n*—factory-produced structure of geosynthetic materials in the form of a sheet in which the barrier function is fulfilled by bitumen.

blinding, *n—for geotextiles*, the condition where soil particles block the surface openings of the fabric, thereby reducing the hydraulic conductivity of the system. **D4439**

breaking force, *(F), J, n*—the force at failure. **D4885**

breaking load, *n*—the maximum force applied to a specimen in a tensile test carried to rupture. **D4632/D4632M**

breaking toughness, *T*, (FL^{-1}), Jm^{-2}, *n—for geotextiles*, the actual work-to-break per unit surface area of material. **D4595, D4885**

chemical resistance, *n*—the ability to resist chemical attack. **D5322**

clogging, *n—for geotextiles,* the condition where soil particles move into and are retained in the openings of the fabric, thereby reducing the hydraulic conductivity. **D4439**

clogging potential, *n—in geotextiles*, the tendency for a given geotextile to decrease permeability due to soil particles that have either lodged in the geotextile openings or have built up a restrictive layer on the surface of the geotextile. **D5101**

compressed thickness (t, (L), mm), *n*—thickness under a specified stress applied normal to the material. **D4439**

constant-rate-of-load tensile testing machine (CRL), *n*—a testing machine in which the rate of increase of the load being applied to the specimen is uniform with time after the first 3 s. **D4439**

corresponding force, *n*—synonym for force at specified elongation. **D4885**

coupon, *n*—a portion of a material or laboratory sample from which multiple specimens can be taken for testing. **D5747/D5747M**

creep, *n*—the time-dependent increase in accumulative strain in a material resulting from an applied constant force. **D5262**

critical height *(ch)*, *n*—the maximum exposed height of a cone or pyramid that will not cause a puncture failure of a geosynthetic at a specified hydrostatic pressure for a given period of time. **D5514/D5514M**

cross-machine direction, *n*—the direction in the plane of the fabric perpendicular to the direction of manufacture. **D4632/D4632M**

density (ρ, (ML^{-3}), kg/m^3), *n*—mass per unit volume. **D4439**

design load—the load at which the geosynthetic is required to operate in order to perform its intended function. **D5262**

elastic limit, *n—in mechanics*, the stress intensity at which stress and deformation of a material subjected to an increasing force cease to be proportional; the limit of stress within which a material will return to its original size and shape when the force is removed, and hence, not a permanent set. **D4885**

elongation at break, *n*—the elongation corresponding to the breaking load, that is, the maximum load. **D4632/D4632M**

failure, *n*—an arbitrary point beyond which a material ceases to be functionally capable of its intended use. **D4885, D5262**

failure, *n—in testing geosynthetics*, water or air pressure in the test vessel at failure of the geosynthetic. **D5514/D5514M**

field testing, *n*—testing performed in the field under actual conditions of temperature and exposure to the fluids for which the immersion testing is being performed. **D5496**

fill—deprecated term, see **filling**.

filling, *n*—yarn running from selvage to selvage at right angles to the warp in a woven fabric. **D4439**

flexible polypropylene, *n*—a material having a 2 % secant modulus of less than 300 MPa (40 000 psi) as determined by Practice D5323, produced by polymerization of propylene with or without other alpha olefin monomers.

force at specific elongation, FASE, *n*—the force associated with a specific elongation on the force-elongation curve. **D4439**

force-elongation curve, *n—in a tensile test,* a graphical representation of the relationship between the magnitude of an externally applied force and the change in length of the specimen in the direction of the applied force. (*Synonym* for stress-strain curve.) D4885

geocomposite, *n*—a product composed of two or more materials, at least one of which is a geosynthetic.

geofoam, *n*—block or planar rigid cellular foamed polymeric material used in geotechnical engineering applications.

geogrid, *n*—a geosynthetic formed by a regular network of integrally connected elements with apertures greater than 6.35 mm (¼ in.) to allow interlocking with surrounding soil, rock, earth, and other surrounding materials to function primarily as reinforcement. D5262

geomembrane, *n*—an essentially impermeable geosynthetic composed of one or more synthetic sheets. D4439, D4873/D4873M, D4885, D5994/D5994M, D5820

geonet, *n*—a geosynthetic consisting of integrally connected parallel sets of ribs overlying similar sets at various angles for planar drainage of liquids or gases. D4439

geostrip—polymeric material in the form of a strip of width not more than 200 mm (7.87 in.), used in contact with soil or other materials in geotechnical and civil engineering applications, or both.

geosynthetic, *n*—a planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure, or system. D4354, D4759, D4873/D4873M, D5617, D5818

geosynthetic barrier—low-permeability geosynthetic material, used in geotechnical and civil engineering applications with the purpose of reducing or preventing the flow of fluid through the construction.

geosynthetic barrier clay (GBR-C), *n*—factory-produced structure of geosynthetic materials in the form of a sheet, in which the barrier function is fulfilled by clay.

geosynthetic barrier polymeric (GBR-P), *n*—factory-produced structure of geosynthetic materials in the form of a sheet, in which the barrier function is fulfilled by polymers.

geosynthetic cementitious composite mat (GCCM), *n*—a factory-assembled geosynthetic composite consisting of a cementitious material contained within layer or layers of geosynthetic materials that becomes hardened when hydrated.

geosynthetic clay liner, *n*—a manufactured hydraulic barrier consisting of clay bonded to a layer or layers of geosynthetic materials.

geotechnical engineering, *n*—the engineering application of geotechnics. D4439, D4595

geotechnics, *n*—the application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust to the solution of engineering problems. D4439, D4491/D4491M, D4595, D4716/D4716M, D4751

geotextile, *n*—a permeable geosynthetic comprised solely of textiles.

DISCUSSION—Geotextiles perform several functions in geotechnical engineering applications, including: separation, filtration, drainage, reinforcement, and protection. D1987, D4439, D5594

grab test, *n*—*in fabric testing*, a tension test in which only a part of the width of the specimen is gripped in the clamps. D4632/D4632M

gradient ratio, *n*—*in geotextiles*, the ratio of the hydraulic gradient through a soil-geotextile system to the hydraulic gradient through the soil alone. D5101

gravity flow, *n*—flow in a direction parallel to the plane of a geotextile or related product driven predominately by a difference in elevation between the inlet and outflow points of a specimen. D4716/D4716M

head, *n*—pressure at a point in a liquid, expressed in terms of the vertical distance of the point below the surface of the liquid. D4716/D4716M

hydraulic conductivity *(k)*, *n*—the rate of discharge of water under laminar flow conditions through a unit cross-sectional area of a porous medium under a unit hydraulic gradient and standard temperature conditions (20 °C). D5567

hydraulic conductivity ratio (HCR), *n*—the ratio of the hydraulic conductivty of the soil/geotextile system, k_{sg}, at any time during the test, to the initial hydraulic conductivity, k_{sgo}, measured at the beginning of the test (NEW).

hydraulic gradient, *i, s (D)*—the loss of hydraulic head per unit distance of flow, dH/dL. D5101

hydraulic transmissivity, θ ($L^2\ T^{-1}$), *n*—*for a geotextile or related product*, the volumetric flow rate of water per unit width of specimen per unit gradient in a direction parallel to the plane of the specimen. D4716/D4716M

hydrostatic pressure, *n*—a state of stress in which all the principal stresses are equal (and there is no shear stress), as in a liquid at rest; induced artificially by means of a gaged pressure system; the product of the unit weight of the liquid and the difference in elevation between the given point and the free water elevation. D5514/D5514M

index test, *n*—a test procedure which may contain a known bias but which may be used to establish an order for a set of specimens with respect to the property of interest. D4833/D4833M, D4885

inflection point, *n*—the first point of the force-elongation curve at which the second derivative equals zero. D4885

initial tensile modulus, $J_p\ (FL^{-1}), Nm^{-1}$, *n*—*for geosynthetics*, the ratio of the change in force per unit width to the change in elongation of the initial portion of a force-elongation curve. D4885

in-plane flow, *n*—fluid flow confined to a direction parallel to the plane of a geotextile or related product. D4716/D4716M

integral, *adj—in geosynthetics*, forming a necessary part of the whole; constituent. **D4439**

laboratory sample, *n*—a portion of material taken to represent the lot sample, or the original material, and used in the laboratory as a source of test specimens. **D4354**

laminar flow, *n*—flow in which the head loss is proportional to the first power of the velocity. **D4716/D4716M**

linear density, *n*—mass per unit length; the quotient obtained by dividing the mass of a fiber or yarn by its length.

lot, *n*—a unit of production, or a group of other units or packages, taken for sampling or statistical examination, having one or more common properties and being readily separable from other similar units. **D4354**

lot sample, *n*—one or more shipping units taken at random to represent an acceptance sampling lot and used as a source of laboratory samples. **D4354**

machine direction, *n*—the direction in the plane of the fabric parallel to the direction of manufacture. **D4632/D4632M**

minimum average roll value (MARV), *n*—for geosynthetics, a manufacturing quality control tool used to allow manufacturers to establish published values such that the user/purchaser will have a 97.7 % confidence that the property in question will meet published values. For normally distributed data, "MARV" is calculated as the typical value minus two (2) standard deviations from documented quality control test results for a defined population from one specific test method associated with one specific property.

DISCUSSION—MARV is applicable to a geosynthetic's intrinsic physical properties such as weight, thickness, and strength. MARV may not be appropriate for some hydraulic, performance, or durability properties.

minimum test value, *n—for geosynthetics*, the lowest sample value from documented manufacturing quality control test results for a defined population from one test method associated with one specific property.

modulus of elasticity, *MPa* (FL^{-2}), *n*—the ratio of stress (nominal) to corresponding strain below the proportional limit of a material, expressed in force per unit area, such as megapascals (pounds-force per square inch). **D5323**

multi-axial tension, *n*—stress in more than one direction. **D5617**

multi-linear drainage geocomposite, *n*—a manufactured product composed of a series of parallel single drainage conduits regularly spaced across its width sandwiched between two or more geosynthetics.

nominal, *n*—representative value of a measurable property determined under a set of conditions, by which a product may be described.

nominal value, *n*—representative value of a measurable property by which a product may be described **D4439**

normal direction, *n—for geotextiles*, the direction perpendicular to the plane of a geotextile. **D4439**

normal stress, (FL^{-2}), *n*—the component of applied stress that is perpendicular to the surface on which the force acts. **D4439**

offset modulus, J_o, (FL^{-1}), Nm^{-1}, *n—for geosynthetics*, the ratio of the change in force per unit width to the change in elongation below an arbitrary offset point at which there is a proportional relationship between force and elongation, and above the inflection point on the force-elongation curve. **D4885**

performance property, *n*—a result obtained by conducting a performance test. **D5141**

performance test, *n*—a test which simulates in the laboratory as closely as practicable selected conditions experienced in the field and which can be used in design. (Synonym for **design test**.) **D4885**

performance test, *n—in geosynthetics*, a laboratory procedure which simulates selected field conditions which can be used in design. **D5141**

permeability, *n*—the rate of flow of a liquid under a differential pressure through a material. **D1987, D4491/D4491M**

permeability, *n—of geotextiles,* hydraulic conductivity. **D4491/D4491M**

permeation, *n*—the transmissioin of a fluid through a porous medium (NEW).

permittivity, (Ψ), (T^{-1}), *n—of geotextiles*, the volumetric flow rate of water per unit cross-sectional area per unit head under laminar flow conditions, in the normal direction through a geotextile. **D1987, D4491/D4491M**

pore volume of flow (V_{pq}), *n*—the cumulative volume of flow through a test specimen divided by the volume of voids within the specimen. **D5567**

pre-fabricated vertical drain (PVD), *n*—a geocomposite consisting of geotextile cover and drainage core installed vertically into soil to provide drainage for accelerating consolidation of soils.

DISCUSSION—Also known as band or wick drain.

pressure flow, *n*—flow in a direction parallel to the plane of a geotextile or related product driven predominately by a differential fluid pressure. **D4716/D4716M**

primary sampling unit, *n*—the sampling unit containing all the sources of variability which should be considered in acceptance testing; the sampling unit taken in first stage of selection in any procedure for sampling a lot or shipment. **D4354**

production unit—*as referred to in this practice*, is a quantity of geotextile agreed upon by the purchaser and seller for the purpose of sampling. **D4354**

proportional limit, *n*—the greatest stress which a material is capable of sustaining without any deviation from proportionality of stress to strain (Hooke's law). **D4595**

puncture resistance, (F), *n*—the inherent resisting mechanism of the test specimen to the failure by a penetrating or puncturing object. **D4833/D4833M**

quality assurance, *n*—all those planned or systematic actions necessary to provide adequate confidence that a material, product, system, or service will satisfy given needs. **D4354**

quality control, *n*—the operational techniques and the activities which sustain a quality of material, product, system, or service that will satisfy given needs; also the use of such techniques and activities. **D4354**

rate of creep, *n*—the slope of the creep-time curve at a given time. **D5262**

residual shear strength, *n*—value of shear stress at sufficiently large displacement where the stress remains constant with continued shearing

rib, *n*—for geogrids, the continuous elements of a geogrid which are interconnected to a node or junction.

sample, *n*—(*1*) a portion of material which is taken for testing or for record purposes. (*2*) a group of specimens used, or of observations made, which provide information that can be used for making statistical inferences about the population(s) from which the specimens are drawn. (See also **laboratory sample, lot sample,** and **specimen.**) **D4354, D5818**

sample, laboratory—See **laboratory sample**.

sample, lot—See **lot sample**.

sampling unit, *n*—an identifiable, discrete unit or subunit of material that could be taken as part of a sample. (See also **primary sampling unit, laboratory sample,** and **specimen.**) **D4354**

sampling unit, primary—See **primary sampling unit**.

seam, *n*—a permanent joining of two or more materials. **D5820**

seam, *n*—the connection of two or more pieces of material by mechanical, chemical, or fusion methods to provide the integrity of a single piece of the material. **D5641/D5641M**

seam allowance, *n*—the width of fabric used in making a seam assembly, bounded by the edge of the fabric and the furthest stitch line. **D4884/D4884M**

seam assembly, *n*—the unit obtained by joining fabrics with a seam, including details such as fabric direction(s), seam allowance, sewing threads used, and number of stitches per unit length; and sometimes additional details of fabrication such as sewing-machine type and speed, needle type and size, etc. **D4884/D4884M**

seam design engineering, *n*—the procedures used to select a specific thread, a specific stitch type, and a specific seam type to achieve the required seam strength. **D4884/D4884M**

seam efficiency, sewn, *n*—*in sewn fabrics*, the ratio expressed as a percentage of seam strength to fabric strength.

seam interaction, *n*—the result of combining a specific textile, a specific stitch type, and a specific seam type. **D4884/D4884M**

seam type, *n*—*in sewn fabrics,* an alphanumeric designation relating to the essential characteristics of fabric positioning and rows of stitching in a specific sewn fabric seam (see Federal Standard 751). **D4884/D4884M**

secant modulus, *n*—the ratio of stress (nominal) to corresponding strain at any specified point on the stress-strain curve. **D5323**

secant modulus, J_{sec}, (FL^{-1}), Nm^{-1}, *n*—*for geosynthetics*, the ratio of change in force per unit width to the change in elongation between two points on a force-elongation curve. **D4885**

selvage, *n*—the woven edge portion of a fabric parallel to the warp. **D4884/D4884M**

sewing thread, *n*—a flexible, small-diameter yarn or strand, usually treated with a surface coating, lubricant, or both, intended to be used to stitch one or more pieces of material or an object to a material. **D4884/D4884M**

sewn seam, *n*—*in sewn fabrics*, a series of stitches joining two or more separate plies of a material or materials of planar structure such as textile fabric. **D4884/D4884M**

sewn seam strength, *n*—*for geotextiles*, the maximum resistance, measured in kilonewtons per metre, of the junction formed by stitching together two or more planar structures. **D4884/D4884M**

specification, *n*—a precise statement of a set of requirements to be satisfied by a material, product, system or service that indicates the procedures for determining whether each of the requirements is satisfied. **D4759**

specific gravity, *n*—the ratio of the density of the substance in question to the density of a reference substance at specified conditions of temperature and pressure. **D4439**

specimen, *n*—a specific portion of a material or laboratory sample upon which a test is performed or which is taken for that purpose. (*Syn.* test specimen) **D4354**

standard geosynthetic laboratory environment—a general purposes geosynthetic laboratory should control, monitor, and record the temperature range to 22 ± 3 °C and the relative humidity to 45 to 75 %. In cases of dispute, one should use the "atmosphere for testing" suggested in the appropriate standard test method.

stiffness, *n*—resistance to bending. **D4439**

stitch, *n*—the repeated unit formed by the sewing thread in the production of seams in a sewn fabric (see Federal Standard 751a). **D4884/D4884M**

strain, *n*—the change in length per unit of length in a given direction. **D4439**

stress crack, *n*—an external or internal crack in a plastic caused by tensile stresses less than its short-time mechanical strength. **D5397**

tangent point, *n*—*for geotextiles*, the first point of the force-elongation curve at which a major decrease in slope occurs. **D4595**

tearing strength, (F, (F), kN), *n*—the force required either (*1*) to start or (*2*) to continue or propagate a tear in a fabric under specified conditions. **D4439, D4533/D4533M**

temperature stability, *n—for a geotextile*, the percent change in tensile strength or in percent elongation as measured at a specified temperature and compared to values obtained at the standard conditions for testing geotextiles. **D4594/D4594M**

tensile creep rupture strength, [FL^{-1}], *n—for geosynthetics*, the force per unit width that will produce failure by rupture in a creep test in a given time, at a specified constant environment **D5262**

tensile creep strain, *n*—the total strain at any given time. **D5262**

tensile modulus, *J*, *(FL^{-1}), Nm^{-1}*, *n—for geotextiles*, the ratio of the change in tensile force per unit width to a corresponding change in strain (slope). **D4595**

tensile strength, *n—for geotextiles*, the maximum resistance to deformation developed for a specific material when subjected to tension by an external force. **D4595**

tensile test, *n—in textiles*, a test in which a textile material is stretched in one direction to determine the force-elongation characteristics, the breaking force, or the breaking elongation. **D4595**

test result, *n*—a value obtained by applying a given test method, expressed either as a single observation or a specified combination of a number of observations. **D4354**

test section, *n*—a distinct area of construction. **D5818**

thickness, compressed—See **compressed thickness**.

turbulent flow, *n*—that type of flow in which any water particle may move in any direction with respect to any other particle, and in which the head loss is approximately proportional to the second power of the velocity. **D4716/D4716M**

turf reinforcement mat (TRM), *n—in erosion control*, a non-degradable geosynthetic or geocomposite processed into a matrix sufficient to increase the stability threshold of otherwise unreinforced established vegetation.

DISCUSSION—Products in this category may incorporate ancillary degradable components to enhance the germination and establishment of vegetation.

typical value, *n—for geosynthetics*, the mean value calculated from documented manufacturing quality control test results for a defined population obtained from one test method associated with on specific property. **D4439**

vacuum chamber, *n*—a device that allows a vacuum to be applied to a surface. **D5641/D5641M**

vertical strip drain, *n*—a geocomposite consisting of a geotextile cover and drainage core installed vertically into soil to provide drainage for accelerating consolidation of soils.

DISCUSSION—Also known as band drain, wick drain, or prefabricated vertical drain (PVD).

void ratio (e, (D)), *n*—the ratio of the volume of void space to the volume of solids. **D4439**

warp, *n*—the yarn running lengthwise in a woven fabric. **D4884/D4884M**

weft, *n*—see **filling**.

wide strip tensile test, *n—for geosynthetics*, a tensile test in which the entire width of a 200 mm (8.0 in.) wide specimen is gripped in the clamps and the gage length is 100 mm (4.0 in.). **D4885**

wide-width strip tensile test, *n—for geotextiles*, a uniaxial tensile test in which the entire width of a 200-mm (8.0-in.) wide specimen is gripped in the clamps and the gage length is 100 mm (4.0 in.). **D4595**

work-to-break (W, (LF)), *n—in tensile testing*, the total energy required to rupture a specimen. **D4439, D4595, D4885**

yield point, *n—in geosynthetics*, the point on the force-elongation curve at which the first derivative equals zero (the first maximum). **D4885**

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

ATTACHMENT B

Standard Practice for Collection of Settled Dust Samples
Using Wipe Sampling Methods for Subsequent Determination of Metals
ASTM D6966-18

INTERNATIONAL

Designation: D6966 – 18

Standard Practice for Collection of Settled Dust Samples Using Wipe Sampling Methods for Subsequent Determination of Metals[1]

This standard is issued under the fixed designation D6966; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the collection of settled dust on surfaces using the wipe sampling method. These samples are collected in a manner that will permit subsequent extraction and determination of target metals in the wipes using laboratory analysis techniques such as atomic spectrometry.

1.2 This practice does not address the sampling design criteria (that is, sampling plan which includes the number and location of samples) that are used for clearance, hazard evaluation, risk assessment, and other purposes. To provide for valid conclusions, sufficient numbers of samples should be obtained as directed by a sampling plan, for example, in accordance with Guide D7659.

1.3 This practice contains notes that are explanatory and are not part of the mandatory requirements of this practice.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres
D4840 Guide for Sample Chain-of-Custody Procedures
D7144 Practice for Collection of Surface Dust by Micro-vacuum Sampling for Subsequent Metals Determination
D7659 Guide for Strategies for Surface Sampling of Metals and Metalloids for Worker Protection
D7707 Specification for Wipe Sampling Materials for Beryllium in Surface Dust
E1792 Specification for Wipe Sampling Materials for Lead in Surface Dust

3. Terminology

3.1 For definitions of terms not listed here, see Terminology D1356.

3.2 *Definitions:*

3.2.1 *batch, n*—a group of field or quality control (QC) samples that are collected or processed together at the same time using the same reagents and equipment.

3.2.2 *wipe, n*—a disposable towellette that is moistened with a wetting agent. **E1792**

3.2.2.1 *Discussion*—These towellettes are used to collect samples of settled dust on surfaces for subsequent determination of metals content in the collected dust.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *field blank, n*—a wipe (see 3.2.2) that is exposed to the same handling as field samples except that no sample is collected (no surface is actually wiped).

3.3.1.1 *Discussion*—Analysis results from field blanks provide information on the analyte background level in the wipe, combined with the potential contamination experienced by samples collected within the batch (see 3.2.1) resulting from handling.

4. Summary of Practice

4.1 Wipe samples of settled dust are collected on surfaces from areas of known dimensions with wipes satisfying certain requirements, using a specified pattern of wiping.

4.2 The collected wipes are then ready for subsequent sample preparation and analysis for the measurement of metals of interest.

[1] This practice is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.04 on Workplace Air Quality.

Current edition approved Nov. 1, 2018. Published November 2018. Originally approved in 2003. Last previous edition approved in 2013 as D6966 – 13. DOI: 10.1520/D6966-18.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

5. Significance and Use

5.1 This practice is intended for the collection of settled dust samples for the subsequent measurement of target metals. The practice is meant for use in the collection of settled dust samples that are of interest in clearance, hazard evaluation, risk assessment, and other purposes.

5.2 This practice is recommended for the collection of settled dust samples from hard, relatively smooth nonporous surfaces. This practice is less effective for collecting settled dust samples from surfaces with substantial texture such as rough concrete, brickwork, textured ceilings, and soft fibrous surfaces such as upholstery and carpeting. Micro-vacuum sampling using Practice D7144 may be more suitable for these surfaces. Collection efficiency for metals such as lead from smooth, hard surfaces has been found to exceed 75 % (Specification E1792).

6. Apparatus and Materials

6.1 *Sampling Templates*—One or more of the following: 10 cm by 10 cm (minimum dimensions) reusable or disposable aluminum or plastic template(s), or disposable cardboard templates, (full-square, rectangular, square "U-shaped," rectangular "U-shaped," or "L-shaped," or both); or templates of alternative areas having accurately known dimensions (see Note 1). Templates shall be capable of lying flat on a surface.

NOTE 1—For most surfaces, it is recommended to collect settled dust from a minimum surface area of 100 cm^2 to provide sufficient material for subsequent laboratory analysis. However, larger areas (for example, 30 cm by 30 cm) may be appropriate for surfaces having little or no visible settled dust, while a smaller sampling area (for example, 10 cm by 10 cm) may be appropriate for surfaces with high levels of visible settled dust. It is recommended to have a suite of templates with various sampling dimensions.

6.2 *Wipes,* for collection of settled dust samples from surfaces. Wipes shall be individually wrapped and fully wetted. The background metal(s) content of the wipes should be as low as possible. At a maximum, the background level of target metal(s) shall be no more than one-tenth the target concentration the metal(s) to be measured.

NOTE 2—Wipes meeting the requirements of Specifications E1792 or D7707, or both, may be suitable.

NOTE 3—Wipes made of cellulosic materials may produce fewer analysis problems than wipes made of synthetic polymeric materials.

6.3 *Sample containers,* sealable, rigid-walled, 30-mL minimum volume.

NOTE 4—Screw-top plastic centrifuge tubes are an example of a suitable rigid-walled sample container.

NOTE 5—Use of a sealable plastic bag for holding and transporting the settled dust wipe sample is not recommended due to the potential loss of collected dust within the plastic bag during transportation and laboratory handling. Quantitative removal and processing of the settled dust wipe sample by the laboratory is significantly improved through the use of sealable rigid-walled containers.

6.4 *Measuring tool,* tape or ruler, capable of measuring to the nearest ±0.1 cm.

6.5 *Plastic gloves,* powderless.

6.6 *Cleaning cloths,* for cleaning of templates and other equipment.

NOTE 6—Wipes used for dust sampling (6.2) can be used for cleaning templates and other sampling equipment, but other cleaning cloths or wipes not meeting the requirements described in (6.2) may be suitable for this purpose.

6.7 *Adhesive tape,* suitable for securing the template(s) to the surface(s) to be sampled, and for demarcating sampling areas if templates are not used.

NOTE 7—Masking tape, for example, functions well for these purposes.

6.8 *Disposable shoe covers,* optional.

7. Procedure

7.1 Use one of the following two options when collecting settled dust samples from each sampling location. For wide, flat locations, it is recommended to use the template-assisted sampling procedure (see 7.1.1.2 (*1*)). For small locations (for example, window sill, section of a piece of equipment, or portion of a vehicle interior), it will ordinarily be necessary to use the confined-area sampling procedure (see 7.1.1.2 (*2*)).

NOTE 8—Metal contamination problems during field sampling can be severe and may affect subsequent wipe sample analysis results. Contamination can be minimized through frequent changing of gloves, use of shoe covers (see 6.8), and regular cleaning of sampling equipment with cleaning cloths (see 6.6). Use of disposable shoe covers between different locations, and removal of them prior to leaving the sampling site or entering vehicles, can be helpful in minimizing inadvertent transfer of contaminated dust from one location to another.

7.1.1 *Sampling Procedure:*

7.1.1.1 Don a pair of clean, powderless, plastic gloves (see 6.5 and Note 8).

7.1.1.2 Use either a template-assisted sampling procedure (*1*) or tape-defined sampling procedure (*2*):

(*1*) Carefully place a clean template on the surface to be sampled in a manner that minimizes disturbance of settled dust at the sampling location. Tape the outside edge of the template to prevent the template from moving during sample collection.

(*2*) Alternatively, mark the defined area to be sampled with adhesive tape (6.7) being careful not to disturb the settled dust, and measure the area to be sampled using the measuring tool (6.4).

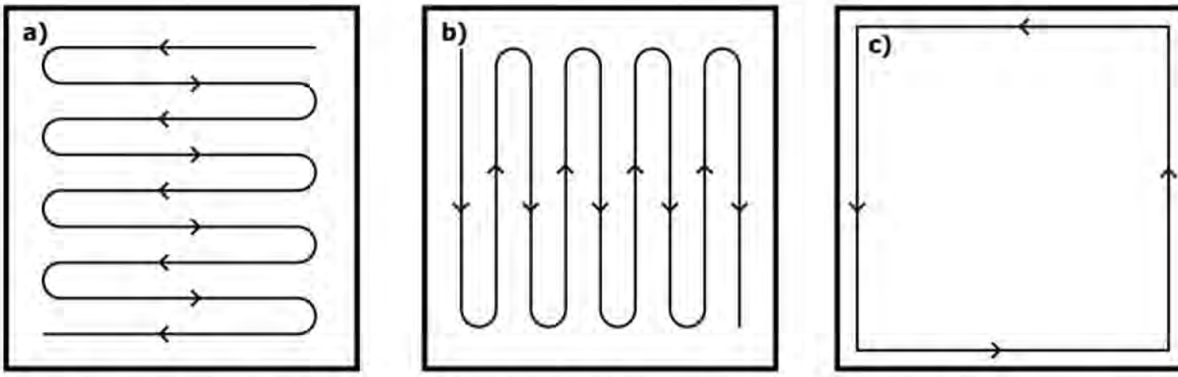
7.1.1.3 Obtain a wipe (6.2) and, if there is a possibility for the package containing the wipe to be contaminated with dust, clean the outside of the package with a cleaning cloth (6.6).

7.1.1.4 Remove the wipe from its package, and inspect the wipe to ensure that it is fully wetted and not contaminated with dust or other material. Discard the wipe if it is found to be too dry or contaminated, or both.

7.1.1.5 Using an open flat hand with the fingers together, place the wipe on the surface to be sampled. Wipe the selected surface area, side to side, in an overlapping "S" or "Z" pattern while applying pressure to the fingertips (refer to Figs. 1 and 2). Wipe the surface so that the entire selected surface area is covered. Perform the wiping procedure using the fingers and not the palm of the hand.

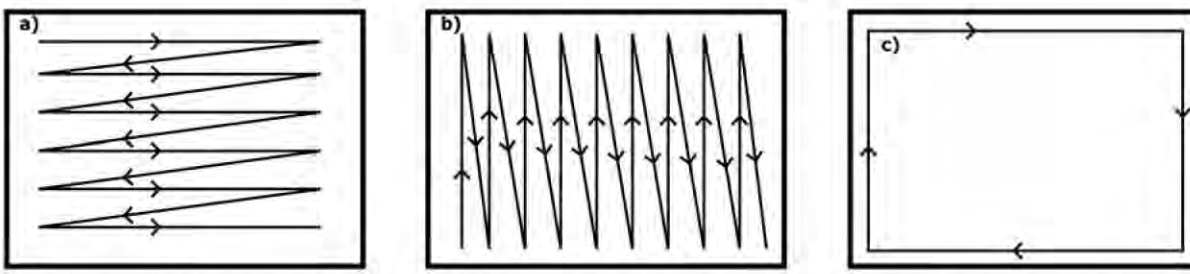
7.1.1.6 Repeat 7.1.1.5 using a different brand of wipe (after selecting a different sampling location) if the wipe originally used significantly changes shape (for example, rolls up by curling) or tears during the wiping process.

NOTE 9—Some surfaces (for example, rough surfaces) may cause certain wipes to curl up or otherwise significantly change shape during the wiping process. A type of wipe that maintains its integrity should be selected for each surface sampled.



NOTE 1—Only the center of the wiping path is shown, not the entire wiping width. Fig. 1a) shows the first "S" wiping pattern over the surface area to be sampled; Fig. 1b) demonstrates the second "S" wiping course over the surface; and Fig. 1c) shows the final wiping which is targeted toward edges and corners.

FIG. 1 Schematic of a Side-to-Side Overlapping "S" Wiping Pattern



NOTE 1—Only the center of the wiping path is shown, not the entire wiping width. Fig. 2a) shows the first "Z" wiping pattern over the surface area to be sampled; Fig. 2b) demonstrates the second "Z" wiping course over the surface; and Fig. 2c) shows the final wiping which is targeted toward edges and corners.

FIG. 2 Schematic of a Side-to-Side Overlapping "Z" Wiping Pattern

7.1.1.7 Fold the wipe in half with the collected dust side folded inward and repeat the preceding wiping procedure (7.1.1.5) within the selected sampling area using an up and down overlapping "S" or "Z" pattern at right angles to the first wiping (see Fig. 1, Fig. 2, and Note 10).

NOTE 10—Wipes are folded to envelop the collected dust within the wipe, to avoid loss of the collected dust, and to expose a clean wipe surface for further dust collection from the sampling location. For sample areas containing large amounts of settled dust, carefully wipe the area to ensure as much dust as possible within the wipe is captured.

7.1.1.8 Fold the wipe in half again with the collected dust side folded inward and repeat the wiping procedure one more time, concentrating on collecting settled dust from edges and corners within the selected surface area (see Fig. 1, Fig. 2, and Note 10).

7.1.1.9 Fold the wipe again with the collected dust side folded inward and insert the wipe into a sample container (6.3).

7.1.1.10 Label the sample container with sufficient information to uniquely and indelibly identify the sample.

7.1.1.11 Record the dimensions (in square centimetres) of the selected sampling area (that is, the internal dimensions defined by the template or the taped area) or that the sample is a blank.

7.1.1.12 Discard the gloves.

7.2 Collect field blanks at a minimum frequency of 5 % (at least one field blank for every 20 wipe samples collected). The minimum number of field blanks to collect for each batch of wipe samples used should be three. Place field blanks in sample containers and label these samples in the same fashion as the collected surface dust samples (see 7.1.1.10).

7.3 Follow sampling chain of custody procedures to ensure sample traceability. Ensure that the documentation which accompanies the samples is suitable for a chain of custody to be established in accordance with Guide D4840.

8. Records

8.1 Field data related to sample collection shall be documented in a sample log form or field notebook (see Note 11). If field notebooks are used, then they shall be bound with pre-numbered pages. All entries on sample data forms and field notebooks shall be made using ink, with the signature and date of entry. Any entry errors shall be corrected by using only a single line through the incorrect entry (no scratch outs), accompanied by the initials of the person making the correction, and the date of the correction (see Note 12).

8.1.1 *Electronic Laboratory Notebooks*—If electronic laboratory notebooks, or ELNs, are used in lieu of a field notebook or sample log, procedures shall be implemented to assure the integrity of the data recorded, including prevention of falsification or other unauthorized changes, and regular backup of data.

NOTE 11—Field notebooks are useful for recording field data even when preprinted sample data forms are used.

NOTE 12—These procedures are important to properly document and trace field data.

8.2 At a minimum, the following information shall be documented:

8.2.1 Project or client name, address, and city/state/country location.

8.2.2 General sampling site description.

8.2.3 Information as to the specific collection protocol used (for example, template-assisted; "Z"-wiping pattern, etc.).

8.2.4 Information as to the specific type or brand of wipes used, including manufacturer and lot number.

8.2.5 Information on quality control (QC) samples: which samples are associated with what group of field blanks.

8.2.6 For each sample collected (including field blanks): an individual and unique sample identifier and date of collection. This information shall be recorded on the sample container in addition to the field documentation.

8.2.7 For field samples (not including field blanks), record in field documentation (field notebook or sample log form) the dimensions of each area sampled (in square centimetres).

8.2.8 For each sample collected: name of person collecting the sample, and specific sampling location information from which the sample was removed.

9. Keywords

9.1 metals measurement; sample collection; settled dust; surfaces; wipe

ATTACHMENT C

A Leachate Pond Geomembrane After 25 years of Service

Categories

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A leachate pond geomembrane after 25 years of service

February 1st, 2019 / By: Richard Thiel / Feature

FIGURE 1 Aerial view of operational leachate and rainwater ponds built 25 years ago

This article reports on the evaluation of an exposed geomembrane liner in a landfill leachate pond after being in service for 25 years. The evaluation was performed in two campaigns: in August 2014 and in May 2018. The purpose of the evaluation was to determine the condition of the geomembrane and to provide a recommendation to the owner on whether or not it was in need of imminent replacement. The results of the evaluation indicate that the geomembrane appears to be in decent condition and is expected to last some number of additional years, but the definitive number is not possible to estimate. Based on the work performed in 2014, it seems that the material is still readily repairable, if need be. Recommendations for future periodic inspection and testing are provided herein.

The leachate pond is a 5-million-gallon (19-million-L) double-lined leachate storage pond that was constructed

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for the Headquarters Landfill in Cowlitz County, Wash., in 1993. The pond is designed with a dividing berm that partitions the pond into two equal, symmetric halves. The dividing berm is lined over its top so that the liner system is continuous between the two pond halves. The southern half of the pond has historically contained various levels of clean rainwater, with only occasional containment of leachate toward the end of a few wet winters. The northern half of the pond has historically been the primary management basin for leachate storage, and its sump is used for leachate transfer via an outlet pipe. **Figure 1** shows an aerial view of the ponds.

The pond was operated for 21 years by Weyerhaeuser for its forest products landfill, the leachate of which derived from pulp and paper industrial waste, ash, and related industrial and construction waste. In 2014 the county purchased the landfill, and since that time the landfill has been operated as a mixed municipal solid waste (MSW)/industrial waste landfill.

TABLE 1 Summary of test results for headquarters landfill facility leachate pond primary geomembrane

The 80-mil (2-mm) primary exposed geomembrane that was installed in 1993 was manufactured by GSE Environmental (then Gundle) as a custom order with three co-extruded layers. The top layer is textured high-density polyethylene (HDPE) with a white pigment. The middle layer is very low density polyethylene (VLDPE). The bottom layer is smooth HDPE containing extra carbon black to make it electrically conductive for spark testing. The original project specifications and conformance testing results for the primary pond geomembrane are included in **Table 1**.

Sampling strategy and field observations

In 2014 two above-water samples were taken and tested. Sample #1 was taken from the anchor trench. Sample #2 was taken from the middle of the berm slope on the southern pond (which is south facing) near the crest of the slope. The sample was 12-inches wide × 48-inches long (30-cm × 122-cm) (parallel to the slope crest). The hole was easily repaired with HDPE geomembrane that was on-site for construction of a new landfill cell.

In May 2018 two "below-water" samples were taken from rub sheets in the bottoms of both the southern and northern halves of the pond that had been largely submerged for the past 25 years. Sample #3 was taken from the southern pond that typically contained clean rainwater, and Sample #4 was taken from the northern pond that had continuously contained landfill leachate. Due to sediment and sludge buildup around the outlet in the sump of the northern pond, that pond was cleaned in April 2018. The southern pond also had to be completely emptied and cleaned at this time, because it had been used temporarily for leachate management in the past winter and needed to be prepared to store clean water again. The cleaning activities in both ponds at this time allowed access to the pond bottoms where samples could be cut from existing loose rub sheets. It should be noted that the conditions of the rub sheets would be conservative in the sense that both sides of the rub sheets had been exposed to the contained fluids, whereas for the primary geomembrane, only the upper side would have been exposed to the contained fluids.

FIGURE 2 Patching a hole in pond liner where a sample was taken for testing in May 2014. The photograph shows trial weld being performed

Visual inspection of the exposed and cleaned geomembrane in both halves of the pond indicated the geomembrane to be in good condition with no signs of degradation or cracks. While *where new HDPE is being welded to old pond liner.*

no repair welds were required in 2018, the repair welds performed in 2014 appeared to be successful with excellent trial-weld field test observations. **Figure 2** shows a patch being installed on the sampling location, **Figure 3** shows the beginning of removing sludge from the northern half of the pond in 2018, and **Figure 4** shows the empty northern pond after cleaning.

Results

The samples that were taken in 2014 and 2018 were tested for a suite of index and performance parameters. A summary of the results for both the 2014 and 2018 testing campaigns is presented in **Table 1**. The anchor trench sample appears to meet or exceed the original project specifications. Where there are actual test results from 1993 (thickness, density, carbon black content, carbon black dispersion, tensile break strength and tensile break elongation), there appear to be no degradation in the anchor trench sample. We note there are still substantial oxidative induction time (OIT) and high-pressure oxidative induction time (HP-OIT) values in the anchor trench sample that would exceed current GRI-GM13 standards for new geomembranes. The stress crack results from the single point-notched constant tensile load test (SP-NCTL) are exceptional, which is undoubtedly due to the VLDPE core. Having this stress crack-resistant core was the original purpose of coextruding with VLDPE.

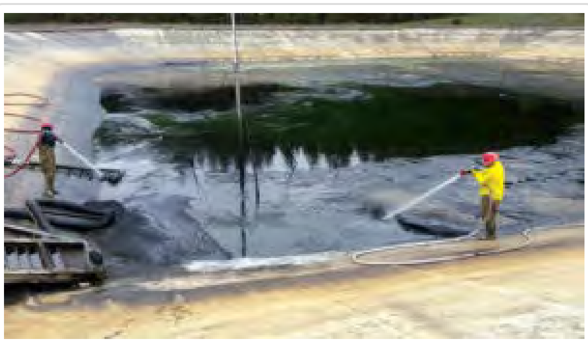

FIGURE 3 April 2018 cleaning sludge from northern half of pond

Comparing the test results between the 2014 above-water exposed sample, the 2018 below-water sample from the northern (leachate) side of the pond, and the 2018 below-water sample from the southern (rainwater) side of the pond indicates very interesting patterns of degradation. With the exception of HP-OIT, the least amount of degradation (as indicated by the test results) occurred in the below-water sample from the leachate (northern) side of the pond. This result was the opposite of what was expected. For HP-OIT, the least amount of degradation occurred in the above-water sample.

The greatest amount of degradation, across the board, occurred in the below-water sample from the rainwater (southern) side of the pond.

Degradation in the exposed above-water sample from 2014 was generally midway between the other two samples, with the exceptions of melt flow index (MFI) and HP-OIT, where it had the least amount of degradation. The small amounts of apparent degradation in tensile yield strength, puncture and tear (all < 10%) in the below-water samples is probably not substantial.

FIGURE 4 April 2018 northern half of pond after cleaning

The increase in MFI of 14% in both of the below-water samples is not excessive but is relatively substantial evidence that some level of polymer-chain breakdown is occurring in the primary geomembrane as a result of submergence. However, it is not known in which of the three coextruded layers of the primary geomembrane this might be occurring. That could be determined through more sophisticated testing.

The most significant test parameters of concern that indicate substantive degradation are the OIT test results that reveal a substantial amount of depletion of the antioxidant package. These results indicate that even though there was some significant degradation, especially in the rainwater side of the pond, there are still ample stabilizers present in the material to protect it for some time, but exactly how much time is not predictable.

The key performance test result is the SP-NCTL stress crack test data, in which all samples continue to perform well.

Discussion

Why was the below-water leachate sample the least degraded? Perhaps the leachate contains a soup of dissolved solids and compounds that was not aggressive in using up or dissolving the antioxidant package and also provided a low diffusion gradient potential for leaching and blooming of antioxidants from the interior of the geomembrane to its surface, and thus preserved the antioxidants within the geomembrane.

Conversely, the clean rainwater may create a high diffusion-gradient differential to pull antioxidants to the surface of the geomembrane. The "very clean" and aggressive pure rainwater may also react with the antioxidants or cause them to move out of the geomembrane and go into solution with the water. In the same manner, the aggressive and very clean water may have also attacked the polyethylene resin at a higher rate than either the leachate or the atmosphere, resulting in apparent degradation in tensile properties.

One interesting conclusion that could be derived from the testing is that if the geomembrane is going to experience failure, it will likely occur on the clean rainwater side of the pond before the leachate side of the pond. This is good news for the pond operator who is wondering when the liner should be replaced. If a failure would occur significantly in advance in the rainwater side of the pond compared to the leachate side, then that may allow adequate response time and not be of great consequence because the water is clean. The clean (southern) side of the pond could be immediately emptied and relined, followed by a transfer of leachate to the relined southern side, and a subsequent relining of the northern side, hopefully before the northern side fails.

While this study was very fortunate in being able to evaluate four samples from a range of exposure conditions (anchor trench, above-water exposed, below-water leachate and below-water rainwater), there could exist elevation zones in both halves of the pond, such as at the waterline, or various UV exposure locations that created a higher level of degradation than any of the samples that were retrieved.

FIGURE 5 Photograph from 2014 of original razor-blade slit that extended through the white surface into the VLDPE core. During the NCTL stress-crack test, the sharp notch eventually blunted and did not propagate, which is a testimony to the functionality of the VLDPE core to resist stress cracking. No photographs were taken in 2018, but the NCTL results indicated continued very strong performance for this test.

In 2014 the testing laboratory took some close-up photographs (e.g., **Figure 5**) of the razor-blade slit in the test specimen during the SP-NCTL test. It was clear, even in such photographs, that blunting of the sharp razor cut had occurred during the test due to the performance of the VLDPE core and that cracks will not easily expand through the VLDPE layer. This provides further confidence that a sudden failure may not be catastrophic, especially considering the presence of a complete secondary geomembrane and leakage collection layer between the primary and secondary geomembranes.

Conclusions, recommendations, qualifiers and other considerations

Field observations indicated that the exposed geomembrane is in decent shape after 25 years of service and shows no visible signs of degradation. There does not appear to be any leakage of leachate into the leakage detection layer in these double-lined ponds, which is again indicative of positive primary liner performance.

Laboratory test results of geomembrane samples taken from the northern and southern halves of the pond support the field observations and indicate that there are still ample stabilizers present to protect this material for some years to come, perhaps even on the order of five to ten years. We must add a caveat that these conclusions with the fact that a limited number of samples were taken, and there could be more critical areas that were not detected.

Based on these results, the team concluded that the leachate pond can continue in operation in the same manner it has been since put into service 26 years ago. The owner was advised to obtain additional samples from the southern pond in three years' time and that it be tested for the same parameters that were tested in this study. This will allow for a better estimate to be made of remaining lifetime. The sample would be of highest value if it could be taken in the summer when the water level is low and a trial weld be performed to continue to assess liner repairability. In addition, the leakage detection sumps should continue to be monitored. Some leakage can be allowed to the extent that it would not exceed 12 inches (30 cm) of head on the secondary liner system outside the sumps. Since there is a dual-basin system in the pond, one side of the pond could be taken out of service, if need be, while the pond was operated from the other side.

Richard Thiel, P.E., is the president of Thiel Engineering in Oregon House, Calif.

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September 1993

Technical Guidance Document:

QUALITY ASSURANCE AND QUALITY CONTROL FOR WASTE CONTAINMENT FACILITIES

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This document contains numerous references to various procedures for performing tests as part of the process of quality control and quality assurance. Standards published by the American Society for Testing and Materials (ASTM) are referenced wherever possible because ASTM procedures represent consensus standards. Other testing procedures referenced in this document were generally developed by an individual or a small group of individuals and, therefore, do not represent consensus standards. The mention of non-consensus standards does not constitute their endorsement.

The reader is cautioned against using this document for the direct preparation of site specific quality assurance plans or related documents without giving proper consideration to the site- and project-specific requirements. To do so would ignore the educational context of the accompanying text, innovations made since the publication of the document, and the prevailing unique and site-specific aspects of all waste containment facilities.

FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The United States Environmental Protection Agency (U.S. EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the U.S. EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the U.S. EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This document provides information needed to develop comprehensive quality assurance plans and to carry out quality control procedures at waste containment sites. It discusses quality assurance and quality control issues for compacted soil liners, soil drainage systems, geosynthetic drainage systems, vertical cutoff walls, ancillary materials, and appurtenances.

E. Timothy Oppelt
Director
Risk Reduction Engineering Laboratory

ABSTRACT

This Technical Guidance Document provides comprehensive guidance on procedures for quality assurance and quality control for waste containment facilities. The document includes a discussion of principles and concepts, compacted soil liners, soil drainage systems, geosynthetic drainage systems, vertical cutoff walls, ancillary materials, appurtenances, and other details. The guidance document outlines critical quality assurance (QA) and quality control (QC) issues for each major segment and recommends specific procedures, observations, tests, corrective actions, and record keeping requirements. For geosynthetics, QA and QC practices for both manufacturing and construction are suggested.

The main body of the text details recommended procedures for quality assurance and control. Appendices include a list of acronyms, glossary, and index. A companion document was under development by the American Society for Testing and Materials (ASTM) at the time of this writing that will contain all of the ASTM standards referenced in this guidance document as well as most, if not all, of the other test procedures that are referenced in this guidance document.

This report was submitted in fulfillment of CR-815546 by the University of Texas, Austin, under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from June 1991 to July 1993, and work was completed as of August 1993.

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Acknowledgments

The authors gratefully acknowledge the following individuals and organizations who provided many of the photographs included in this report: Stephen T. Butchko of Tensar Environmental Systems, Inc., Richard W. Carriker of James Clem Corporation, Steven R. Day of Geo-Con, Inc., Anthony E. Eith of RUST Environmental and Infrastructure, Inc., Vito Galante of Waste Management of North America, Inc., Gary Kolbasuk of National Seal Co., David C. Lauwers of Occidental Chemical Corp., David L. Snyder of Webtec, Edward Staff, Jr., of Staff Industries, Inc., Fred Struve of Gundle Lining Systems, Inc., Michael T. Taylor of JPS Elastomerics Corp., and Dennis B. Wedding of Hoechst Celanese Corp.

The authors wish to express their sincere appreciation to the following individuals, who reviewed and critiqued an earlier version of this manuscript: Craig H. Benson, Gordon P. Boutwell, Mark Cadwallader, Craig R. Calabria, James G. Collin, Jose D. Constantino, Steven R. Day, Robert Denis, Richard H. Dickinson, Thomas N. Dobras, Lee Embrey, Jeffrey C. Evans, Richard A. Goodrum, Dave Guram, Janice Hall, Bill Hawkins, Georg Heerten, William A. Hoffman III, Ted Koerner, David C. Lauwers, Larry D. Lydick, Lance Mabry, Stephen F. Maher, William C. Neal, Leo Overmann, Ian Peggs, Gregory N. Richardson, Charles Rivette, Mark D. Sieracke, Edward C. Staff, James Stenborg, Frank Taylor, Stephen J. Trautwein, James F. Urek, Luke van't Hoog, Mark H. Wayne, Felon R. Wilson, and John P. Workman. The authors also thank Joseph A. Dieltz who, through the Industrial Fabrics Association International, provided assistance in obtaining reviews of an earlier draft of this document.

The authors also gratefully acknowledge the many individuals, too numerous to name here, who over the years have shared their experiences and recommendations concerning quality assurance and quality control with the authors. The member organizations of the Geosynthetic Research Institute are thanked for support of this effort. Finally, the assistance of and input by Mr. Robert E. Landreth with the U.S. EPA is gratefully acknowledged.

Chapter 1

Manufacturing Quality Assurance (MQA) and Construction Quality Assurance (CQA) Concepts and Overview

1.1 Introduction

As a prelude to description of the detailed components of a waste containment facility, some introductory comments are felt to be necessary. These comments are meant to clearly define the role of the various parties associated with the manufacture, installation and inspection of all components of a total liner and/or closure system for landfills, surface impoundments and waste piles.

1.1.1 Scope

Construction quality assurance (CQA) and construction quality control (CQC) are widely recognized as critically important factors in overall quality management for waste containment facilities. The best of designs and regulatory requirements will not necessarily translate to waste containment facilities that are protective of human health and the environment unless the waste containment and closure facilities are properly constructed. Additionally, for geosynthetic materials, manufacturing quality assurance (MQA) and manufacturing quality control (MQC) of the manufactured product is equally important. Geosynthetics refer to factory fabricated polymeric materials like geomembranes, geotextiles, geonets, geogrids, geosynthetic clay liners, etc.

The purpose of this document is to provide detailed guidance for proper MQA and CQA procedures for waste containment facilities. (The document also is applicable to MQC and CQC programs on the part of the manufacturer and contractor). Although facility designs are different, MQA and CQA procedures are the same. In this document, no distinction is made concerning the type of waste to be contained (e.g., hazardous or nonhazardous waste) because the MQA and CQA procedures needed to inspect quality lining systems, fluid collection and removal systems, and final cover systems are the same regardless of the waste type. This technical guidance document has been written to apply to all types of waste disposal facilities, including new hazardous waste landfills and impoundments, new municipal solid waste landfills, nonhazardous waste liquid impoundments, and final covers for new facilities and site remediation projects.

This document is intended to aid those who are preparing MQA/CQA plans, reviewing MQA/CQA plans, performing MQA/CQA observations and tests, and reviewing field MQC/CQC and MQA/CQA procedures. Permitting agencies may use this document as a technical resource to aid in the review of site-specific MQA/CQA plans and to help in identification of any deficiencies in the MQA/CQA plan. Owner/operators and their MQA/CQA consultants may consult this document for guidance on the plan, the process, and the final certification report. Field inspectors may use this document and the references herein as a guide to field MQA/CQA procedures. Geosynthetic manufacturers may use the document to help in establishing appropriate MQC procedures and as a technical resource to explain the reasoning behind MQA procedures. Construction personnel may use this document to help in establishing appropriate CQC procedures and as a technical resource to explain the reasoning behind CQA procedures.

This technical guidance document is intended to update and expand EPA's Technical Guidance Document, "Construction Quality Assurance for Hazardous Waste Land Disposal

Facilities," (EPA, 1986). The scope of this document includes all natural and geosynthetic components that might normally be used in waste containment facilities, e.g., in liner systems, fluid collection and removal systems, and cover systems.

This document draws heavily upon information presented in three EPA Technical Guidance Documents: "Design, Construction, and Evaluation of Clay Liners for Waste Management Facilities" (EPA, 1988a), "Lining of Waste Containment and Other Impoundment Facilities" (1988b), and "Inspection Techniques for the Fabrication of Geomembrane Field Seams" (EPA, 1991a). In addition, general technical backup information concerning many of the principles involved in construction of liner and cover systems for waste containment facilities is provided in two additional EPA documents: "Requirements for Hazardous Waste Landfill Design, Construction, and Closure" (EPA, 1989) and "Design and Construction of RCRA/CERCLA Final Covers" (EPA, 1991b). Additionally, there are numerous books and technical papers in the open literature which form a large data base from which information and reference will be drawn in the appropriate sections.

1.1.2 Definitions

It is critical to define and understand the differences between MQC and MQA and between CQC and CQA and to counterpoint where the different activities contrast and/or complement one another. The following definitions are made.

- *Manufacturing Quality Control (MQC):* A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract plans.

- *Manufacturing Quality Assurance (MQA):* A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract plans. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract plans for a project.

- *Construction Quality Control (CQC)*: A planned system of inspections that is used to directly monitor and control the quality of a construction project (EPA, 1986). Construction quality control is normally performed by the geosynthetics installer, or for natural soil materials by the earthwork contractor, and is necessary to achieve quality in the constructed or installed system. Construction quality control (CQC) refers to measures taken by the installer or contractor to determine compliance with the requirements for materials and workmanship as stated in the plans and specifications for the project.

- *Construction Quality Assurance (CQA)*: A planned system of activities that provides the owner and permitting agency assurance that the facility was constructed as specified in the design (EPA, 1986). Construction quality assurance includes inspections, verifications, audits, and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. Construction quality assurance (CQA) refers to measures taken by the CQA organization to assess if the installer or contractor is in compliance with the plans and specifications for a project.

MQA and CQA are performed independently from MQC and CQC. Although MQA/CQA and MQC/CQC are separate activities, they have similar objectives and, in a smoothly running construction project, the processes will complement one another. Conversely, an effective MQA/CQA program can lead to identification of deficiencies in the MQC/CQC process, but a MQA/CQA program by itself (in complete absence of a MQC/CQC program) is unlikely to lead to acceptable quality management. Quality is best ensured with effective MQC/CQC and MQA/CQA programs. See Fig. 1.1 for the usual interaction of the various elements in a total inspection program.

1.2 Responsibility and Authority

Many individuals are involved directly or indirectly in MQC/CQC and MQA/CQA activities. The individuals, their affiliation, and their responsibilities and authority are discussed below.

The principal organizations and individuals involved in designing, permitting, constructing, and inspecting a waste containment facility are:

- *Permitting Agency*. The permitting agency is often a state regulatory agency but may include local or regional agencies and/or the federal U. S. Environmental Protection Agency (EPA). Other federal agencies, such as the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, the U.S. Bureau of Mines, etc., or their regional or state affiliates are sometimes also involved. It is the responsibility of the permitting agency to review the owner/operator's permit application, including the site-specific MQA/CQA plan, for compliance with the agency's regulations and to make a decision to issue or deny a permit based on this review. The permitting agency also has the responsibility to review all MQA/CQA documentation during or after construction of a facility, possibly including visits to the manufacturing facility and construction site to observe the MQC/CQC and MQA/CQA practices, to confirm that the approved MQA/CQA plan was followed and that the facility was constructed as specified in the design.

- *Owner/Operator*. This is the organization that will own and operate the disposal unit. The owner/operator is responsible for the design, construction, and operation of the waste disposal unit. This responsibility includes complying with the requirements of the permitting agency, the submission of MQA/CQA documentation, and assuring the permitting agency that the facility was constructed as specified in the construction plans and specifications and as approved by the permitting agency. The owner/operator has the authority to select and dismiss organizations charged with design, construction, and MQA/CQA. If the owner and operator of a facility are different organizations, the owner is ultimately responsible for these activities. Often the owner/operator, or owner, will be a municipality rather than a private corporation. The interaction of a state office regulating another state or local organization should have absolutely no impact on procedures, intensity of effort and ultimate decisions of the MQA/CQA or MQC/CQC process as described herein.

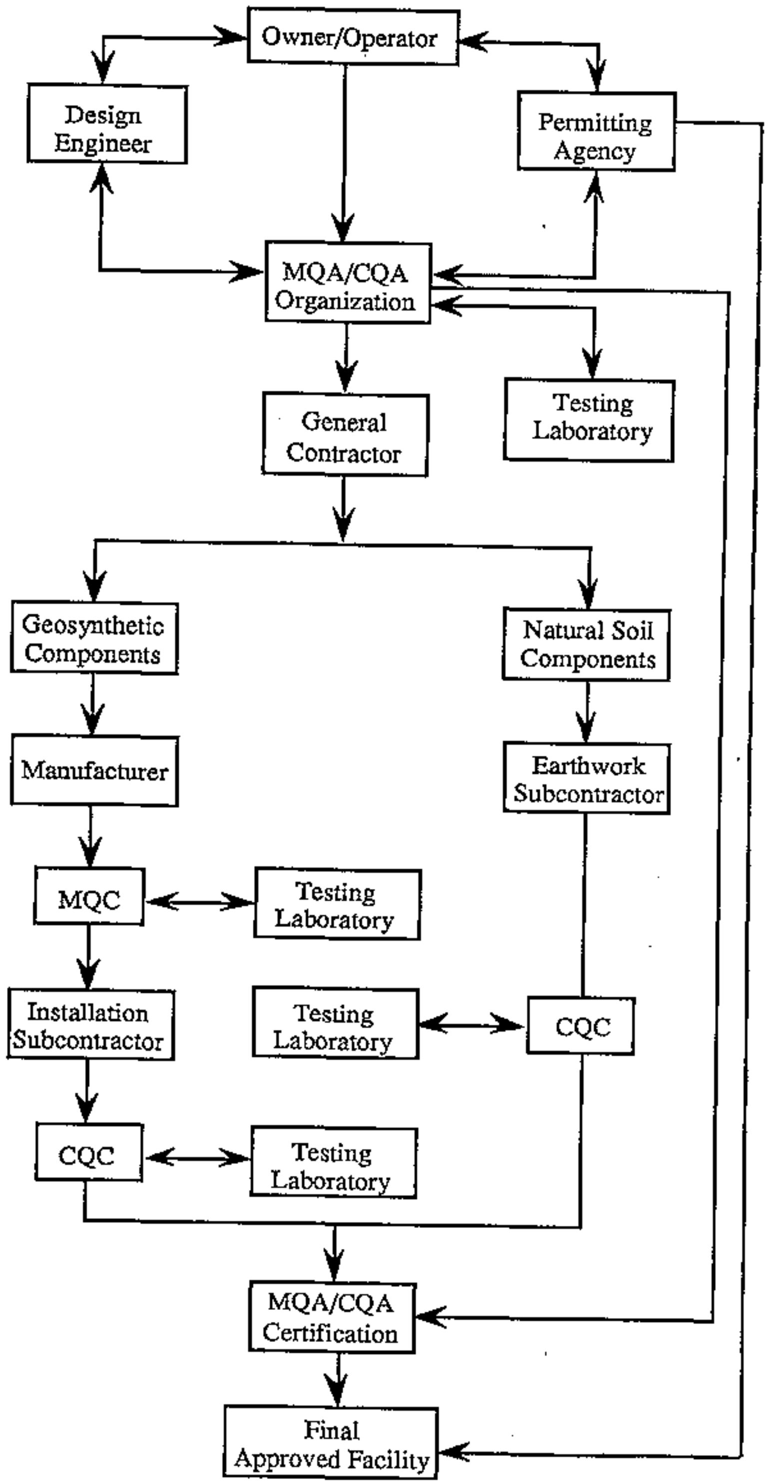

Figure 1.1 - Organizational Structure of MQA/CQA Inspection Activities

- *Owner's Representative*. The owner/operator usually has an official representative who is responsible for coordinating schedules, meetings, and field activities. This responsibility includes communications to other members in the owner/operator's organization, owner's representative, permitting agency, material suppliers, general contractor, specialty subcontractors or installers, and MQA/CQA engineer.

- *Design Engineer*. The design engineer's primary responsibility is to design a waste containment facility that fulfills the operational requirements of the owner/operator, complies with accepted design practices for waste containment facilities, and meets or exceeds the minimum requirements of the permitting agency. The design engineer may be an employee of the owner/operator or a design consultant hired by the owner/operator. The design engineer may be requested to change some aspects of the design if unexpected conditions are encountered during construction (e.g., a change in site conditions, unanticipated logistical problems during construction, or lack of availability of certain materials). Because design changes during construction are not uncommon, the design engineer is often involved in the MQA/CQA process. The plans and specifications referred to in this manual will generally be the product of the Design Engineer. They are a major and essential part of the permit application process and the subsequently constructed facility.

- *Manufacturer*. Many components, including all geosynthetics, of a waste containment facility are manufactured materials. The manufacturer is responsible for the manufacture of its materials and for quality control during manufacture, i.e., MQC. The minimum or maximum (when appropriate) characteristics of acceptable materials should be specified in the permit application. The manufacturer is responsible for certifying that its materials conform to those specifications and any more stringent requirements or specifications included in the contract of sale to the owner/operator or its agent. The quality control steps taken by a manufacturer are critical to overall quality management in construction of waste containment facilities. Such activities often take the form of process quality control, computer-aided quality control and the like. All efforts at producing better quality materials are highly encouraged. If requested, the manufacturer should provide information to the owner/operator, permitting agency, design engineer, fabricator, installer, or MQA engineer that describes the quality control (MQC) steps that are taken during the manufacturing of the product. In addition, the manufacturer should be willing to allow the owner/operator, permitting agency, design engineer, fabricator, installer, and MQA engineer to observe the manufacturing process and quality control procedures if they so desire. Such visits should be able to be made on an announced or unannounced basis. However, such visits might be coordinated with the manufacturer to assure that the appropriate people are present to conduct the tour and that the proper geosynthetic is scheduled for that date so as to obtain the most information from the visit. The manufacturer should have a designated individual who is in charge of the MQC program and to whom questions can be directed and/or through whom visits can be arranged. Random samples of materials should be able to be taken for subsequent analysis and/or archiving. However, the manufacturer should retain the right to insist that any proprietary information concerning the manufacturing of a product be held confidential. Signed agreements of confidentiality are at the option of the manufacturer. The owner/operator, permitting agency, design engineer, fabricator, installer, or MQA engineer may request that they be allowed to observe the manufacture and quality control of some or all of the raw materials and final product to be utilized on a particular job; the manufacturer should be willing to accommodate such requests. Note that these same comments apply to marketing organizations which represent a manufactured product made by others, as well as the manufacturing organization itself.

- *Fabricator.* Some materials are fabricated from manufactured components. For example, certain geomembranes are fabricated by seaming together smaller, manufactured geomembrane sheets at the fabricator's facility. The minimum characteristics of acceptable fabricated materials are specified in the permit application. The fabricator is responsible for certifying that its materials conform to those specifications and any more stringent requirements or specifications included in the fabrication contract with the owner/operator or its agent. The quality control steps taken by a fabricator are critical to overall quality in construction of waste containment facilities. If requested, the fabricator should provide information to the owner/operator, permitting agency, design engineer, installer, or MQA engineer that describes the quality control steps that are taken during the fabrication of the product. In addition, the fabricator should be willing to allow the owner/operator, permitting agency, design engineer, installer, or MQA engineer to observe the fabrication process and quality control procedures if they so desire. Such visits may be made on an announced or unannounced basis. However, such visits might be coordinated with the fabricator to assure that the appropriate people are present to conduct the tour and that the proper geosynthetic is scheduled for that date so as to obtain the most information from the visit. Random samples of materials should be able to be taken for subsequent analysis and/or archiving. However, the fabricator should retain the right to insist that any proprietary information concerning the fabrication of a product be held confidential. Signed agreements of confidentiality are at the option of the fabricator. The owner/operator, permitting agency, design engineer, or MQA engineer may request that they be allowed to observe the fabrication process and quality control of some or all fabricated materials to be utilized on a particular job; the fabricator should be willing to accommodate such a requests.

- *General Contractor.* The general contractor has overall responsibility for construction of a waste containment facility and for CQC during construction. The general contractor arranges for purchase of materials that meet specifications, enters into a contract with one or more fabricators (if fabricated materials are needed) to supply those materials, contracts with an installer (if separate from the general contractor's organization), and has overall control over the construction operations, including scheduling and CQC. The general contractor has the primary responsibility for ensuring that a facility is constructed in accord with the plans and specifications that have been developed by the design engineer and approved by the permitting agency. The general contractor is also responsible for informing the owner/operator and the MQA/CQA engineer of the scheduling and occurrence of all construction activities. Occasionally, a waste containment facility may be constructed without a general contractor. For example, an owner/operator may arrange for all the necessary material, fabrication, and installation contracts. In such cases, the owner/operator's representative will serve the same function as the general contractor.

- *Installation Contractor.* Manufactured products (such as geosynthetics) are placed and installed in the field by an installation contractor who is the general contractor, a subcontractor to the general contractor, or is a specialty contractor hired directly by the owner/operator. The installer's personnel may be employees of the owner/operator, manufacturer, or fabricator, or they may work for an independent installation company hired by the general contractor or by the owner/operator directly. The installer is responsible for handling, storage, placement, and installation of manufactured and/or fabricated materials. The installer should have a CQC plan to detail the proper manner that materials are handled, stored, placed, and installed. The installer is also responsible for informing the owner/operator and the MQA/CQA engineer of the scheduling and occurrence of all geosynthetic construction activities.

- *Earthwork Contractor.* The earthwork contractor is responsible for grading the site to elevations and grades shown on the plans and for constructing earthen components of the waste containment facility, e.g., compacted clay liners and granular drainage layers according to the specifications. The earthwork contractor may be hired by the general contractor or if the owner/operator serves as the general contractor, by the owner/operator directly. In some cases, the general contractor's personnel may serve as the earthwork contractor. The earthwork contractor is responsible not only for grading the site to proper elevations but also for obtaining suitable earthen materials, transport and storage of those materials, preprocessing of materials (if necessary), placement and compaction of materials, and protection of materials during and (in some cases) after placement. If a test pad is required, the earthwork contractor is usually responsible for construction of the test pad. It is highly suggested that the same earthwork contractor that constructs the test fill also construct the waste containment facility compacted clay liner so that the experience gained from the test fill process will not be lost. Earthwork functions must be carried out in accord with plans and specifications approved by the permitting agency. The earthwork contractor should have a CQC plan (or agree to one written by others) and is responsible for CQC operations aimed at controlling materials and placement of those materials to conform with project specifications. The earthwork contractor is also responsible for informing the owner/operator and the CQA engineer of the scheduling and occurrence of all earthwork construction activities.

- *CQC Personnel.* Construction quality control personnel are individuals who work for the general contractor, installation contractor, or earthwork contractor and whose job it is to ensure that construction is taking place in accord with the plans and specifications approved by the permitting agency. In some cases, CQC personnel, perhaps even a separate company, may also be part of the installation or construction crews. In other cases, supervisory personnel provide CQC or, for large projects, separate CQC personnel, perhaps even a separate company, may be utilized. It is recommended that a certain portion of the CQC staff should be certified* as per the implementation schedule of Table 1.1. The examinations have been available as of October, 1992.

- *MQA/CQA Engineer.* The MQA/CQA engineer has overall responsibility for manufacturing quality assurance and construction quality assurance. The engineer is usually an individual experienced in a variety of activities although particular specialists in soil placement, polymeric materials and geosynthetic placement will invariably be involved in a project. The MQA/CQA engineer is responsible for reviewing the MQA/CQA plan as well as general plans and specifications for the project so that the MQA/CQA plan can be implemented with no contradictions or unresolved discrepancies. Other responsibilities of the MQA/CQA engineer include education of inspection personnel on MQA/CQA requirements and procedures and special steps that are needed on a particular project, scheduling and coordinating of MQA/CQA inspection activities, ensuring that proper procedures are followed, ensuring that testing laboratories are conforming to MQA/CQA requirements and procedures, ensuring that sample custody procedures are followed, confirming that test data are accurately reported and that test data are maintained for later reporting, and preparation of periodic reports. The most important duty of the MQA/CQA engineer is overall responsibility for confirming that the facility was constructed in accord with plans and specifications approved by the

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* A certification program is available from the National Institute for Certification of Engineering Technologies (NICET); 1420 King Street; Alexandria, Virginia 22314 (phone: 703-684-2835)

permitting agency. In the event of nonconformance with the project specifications or CQA Plan, the MQA/CQA engineer should notify the owner/operator as to the details and, if appropriate, recommend work stoppage and possibly remedial actions. The MQA/CQA engineer is normally hired by the owner/operator and functions separately of the contractors and owner/operator. The MQA/CQA engineer must be a registered professional engineer who has shown competency and experience in similar projects and is considered qualified by the permitting agency. It is recommended that the person's resume and record on like facilities must be submitted in writing and accordingly accepted by the permitting agency before activities commence. The permitting agency may request additional information from the prospective MQA/CQA engineer and his/her associated organization including experience record, education, registry and ownership details. The permitting agency may accept or deny the MQA/CQA engineer's qualifications based on such data and revelations. If the permitting agency requests additional information or denies the MQA/CQA engineer's qualifications it should be done prior to construction, so that alternatives can be made which do not negatively impact on the progress of the work. The MQA/CQA engineer is usually required to be at the construction site during all major construction operations to oversee MQA/CQA personnel. The MQA/CQA engineer is usually the MQA/CQA certification engineer who certifies the completed project.

Table 1.1 - Recommended Impentation Program for Construction Quality Control (CQC) for Geosynthetics* (Beginning January 1, 1993)

No. of Field Crews** At Each Site	End of 18 Months (i.e., June 30, 1994)	End of 36 Months (i.e., January 1, 1996)
1-4	1 - Level II	1 - Level III***
≥ 5	1 - Level II	1 - Level III***
	2 - Level I	1 - Level I

*Certification for natural materials is under development as of this writing
**Performing a Critical Operation; Typically 4 to 6 People/Crew
***Or PE with applicable experience

- *MQA/CQA Personnel.* Manufacturing quality assurance and construction quality assurance personnel are responsible for making observations and performing field tests to ensure that a facility is constructed in accord with the plans and specifications approved by the permitting agency. MQA/CQA personnel normally are employed by the same firm as the MQA/CQA engineer, or by a firm hired by the firm employing the MQA/CQA engineer. Construction MQA/CQA personnel report to the MQA/CQA engineer. A relatively large proportion (if not the entire group) of the MQA/CQA staff should be certified. Table 1.2 gives the currently recommended implementation schedule. As mentioned previously, certification examinations have been available as of October, 1992, from the National Institute for Certification of Engineering Technologies in Alexandria, Virginia.

- *Testing Laboratory.* Many MQC/CQC and MQA/CQA tests are performed by commercial laboratories. The testing laboratory should have its own internal QC plan to ensure that laboratory procedures conform to the appropriate American Society for Testing and Materials (ASTM) standards or other applicable testing standards. The testing laboratory is responsible for ensuring that tests are performed in accordance with applicable methods and standards, for following internal QC procedures, for maintaining sample chain-of-custody records, and for reporting data. The testing laboratory must be willing to allow the owner/operator, permitting agency, design engineer, installer, or MQA/CQA engineer to observe the sample preparation and testing procedures, or record-keeping procedures, if they so desire. The owner/operator, permitting agency, design engineer, or MQA/CQA engineer may request that they be allowed to observe some or all tests on a particular job at any time, either announced or unannounced. The testing laboratory personnel must be willing to accommodate such a request, but the observer should not interfere with the testing or slow the testing process.

Table 1.2 - Recommended Implementation Program for Construction Quality Assurance (CQA) for Geosynthetics* (Beginning January 1, 1993)

No. of Field Crews** At Each Site	End of 18 Months (i.e., June 30, 1994)	End of 36 Months (i.e., January 1, 1996)
1-2	1 - Level II	1 - Level III***
3-4	1 - Level II 1 - Level I	1 - Level III*** 1 - Level I
≥ 5	1 - Level II 2 - Level I	1 - Level III*** 1 - Level II 1 - Level I

*Certification for natural materials is under development as of this writing
**Performing a Critical Operation; Typically 4 to 6 People/Crew
***Or PE with applicable experience

- *MQA/CQA Certifying Engineer.* The MQA/CQA certifying engineer is responsible for certifying to the owner/operator and permitting agency that, in his or her opinion, the facility has been constructed in accord with plans and specifications and MQA/CQA document approved by the permitting agency. The certification statement is normally accompanied by a final MQA/CQA report that contains all the appropriate documentation, including daily observation reports, sampling locations, test results, drawings of record or sketches, and other relevant data. The MQA/CQA certifying engineer may be the MQA/CQA engineer or someone else in the MQA/CQA engineer's organization who is a registered professional engineer with experience and competency in certifying like installations.

1.3 Personnel Qualifications

The key individuals involved in MQA/CQA and their minimum recommended qualifications are listed in Table 1.3.

Table 1.3 - Recommended Personnel Qualifications

Individual	Minimum Recommended Qualifications
Design Engineer	Registered Professional Engineer
Owner's Representative	The specific individual designated by the owner with knowledge of the project, its plans, specifications and QC/QA documents.
Manufacturer/Fabricator	Experience in manufacturing, or fabricating, at least 1,000,000 m^2 (10,000,000 ft^2) of similar geosynthetic materials.
MQC Personnel	Manufacturer, or fabricator, trained personnel in charge of quality control of the geosynthetic materials to be used in the specific waste containment facility.
MQC Officer	The individual specifically designated by a manufacturer or fabricator, in charge of geosynthetic material quality control.
Geosynthetic Installer's Representative	Experience installing at least 1,000,000 m^2 (10,000,000 ft^2) of similar geosynthetic materials.
CQC Personnel	Employed by the general contractor, installation contractor or earthwork contractor involved in waste containment facilities; certified to the extent shown in Table 1.1.
CQA Personnel	Employed by an organization that operates separately from the contractor and the owner/operator; certified to the extent shown in Table 1.2.
MQA/CQA Engineer	Employed by an organization that operates separately from the contractor and owner/operator; registered Professional Engineer and approved by permitting agency.
MQA/CQA Certifying Engineer	Employed by an organization that operates separately from the contractor and owner/operator; registered Professional Engineer in the state in which the waste containment facility is constructed and approved by the appropriate permitting agency.

1.4 Written MQA/CQA Plan

Quality assurance begins with a quality assurance plan. This includes both MQA and CQA. These activities are never ad hoc processes that are developed while they are being implemented. A written MQA/CQA plan must precede any field construction activities.

The MQA/CQA plan is the owner/operator's written plan for MQA/CQA activities. The MQA/CQA plan should include a detailed description of all MQA/CQA activities that will be used during materials manufacturing and construction to manage the installed quality of the facility. The MQA/CQA plan should be tailored to the specific facility to be constructed and be completely integrated into the project plans and specifications. Differences should be settled before any construction work commences.

Most state and federal regulatory agencies require that a MQA/CQA plan be submitted by the owner/operator and be approved by that agency prior to construction. The MQA/CQA plan is usually part of the permit application.

A copy of the site-specific plans and specifications, MQA/CQA plan, and MQA/CQA documentation reports should be retained at the facility by the owner/operator or the MQA/CQA engineer. The plans, specifications, and MQA/CQA documents may be reviewed during a site inspection by the permitting agency and will be the chief means for the facility owner/operator to demonstrate to the permitting agency that MQA/CQA objectives for a project are being met.

Written MQA/CQA plans vary greatly from project to project. No general outline or suggested list of topics is applicable to all projects or all regulatory agencies. The elements covered in this document provides guidance on topics that should be addressed in the written MQA/CQA plan.

1.5 Documentation

A major purpose of the MQA/CQA process is to provide documentation for those individuals who were unable to observe the entire construction process (e.g., representatives of the permitting agency) so that those individuals can make informed judgments about the quality of construction for a project. MQA/CQA procedures and results must be thoroughly documented.

1.5.1 Daily Inspection Reports

Routine daily reporting and documentation procedures should be required. Inspectors should prepare daily written inspection reports that may ultimately be included in the final MQA/CQA document. Copies of these reports should be available from the MQA/CQA engineer. The daily reports should include information about work that was accomplished, tests and observations that were made, and descriptions of the adequacy of the work that was performed.

1.5.2 Daily Summary Reports

A daily written summary report should be prepared by the MQA/CQA engineer. This report provides a chronological framework for identifying and recording all other reports and aids in tracking what was done and by whom. As a minimum, the daily summary reports should contain the following (modified from Spigolon and Kelly, 1984, and EPA, 1986):

- Date, project name, location, waste containment unit under construction, personnel involved in major activities and other relevant identification information;
- Description of weather conditions, including temperature, cloud cover, and precipitation;
- Summaries of any meetings held and actions recommended or taken;
- Specific work units and locations of construction underway during that particular day;
- Equipment and personnel being utilized in each work task, including subcontractors;
- Identification of areas or units of work being inspected;
- Unique identifying sheet number of geomembranes for cross referencing and document control;
- Description of off-site materials received, including any quality control data provided by the supplier;
- Calibrations or recalibrations of test equipment, including actions taken as a result of recalibration;
- Decisions made regarding approval of units of material or of work, and/or corrective actions to be taken in instances of substandard or suspect quality;
- Unique identifying sheet numbers of inspection data sheets and/or problem reporting and corrective measures used to substantiate any MQA/CQA decisions described in the previous item;
- Signature of the MQA/CQA engineer.

1.5.3 Inspection and Testing Reports

All observations, results of field tests, and results of laboratory tests performed on site or off site should be recorded on a suitable data sheet. Recorded observations may take the form of notes, charts, sketches, photographs, or any combination of these. Where possible, a checklist may be useful to ensure that pertinent factors are not overlooked.

As a minimum, the inspection data sheets should include the following information (modified from Spigolon and Kelly, 1984, and EPA, 1986):

- Description or title of the inspection activity;
- Location of the inspection activity or location from which the sample was obtained;
- Type of inspection activity and procedure used (reference to standard method when appropriate or specific method described in MQA/CQA plan);
- Unique identifying geomembrane sheet number for cross referencing and document control;

- Recorded observation or test data;
- Results of the inspection activity (e.g., pass/fail); comparison with specification requirements;
- Personnel involved in the inspection besides the individual preparing the data sheet;
- Signature of the MQA/CQA inspector and review signature by the MQA/CQA engineer.

1.5.4 Problem Identification and Corrective Measures Reports

A problem is defined as material or workmanship that does not meet the requirements of the plans, specifications or MQA/CQA plan for a project or any obvious defect in material or workmanship, even if there is conformance with plans, specifications and the MQA/CQA plan. As a minimum, problem identification and corrective measures reports should contain the following information (modified from EPA, 1986):

- Location of the problem;
- Description of the problem (in sufficient detail and with supporting sketches or photographic information where appropriate) to adequately describe the problem;
- Unique identifying geomembrane sheet number for cross referencing and document control;
- Probable cause;
- How and when the problem was located (reference to inspection data sheet or daily summary report by inspector);
- Where relevant, estimation of how long the problem has existed;
- Any disagreement noted by the inspector between the inspector and contractor about whether or not a problem exists or the cause of the problem;
- Suggested corrective measure(s);
- Documentation of correction if corrective action was taken and completed prior to finalization of the problem and corrective measures report (reference to inspection data sheet, where applicable);
- Where applicable, suggested methods to prevent similar problems;
- Signature of the MQA/CQA inspector and review signature of MQA/CQA engineer.

1.5.5 Drawings of Record

Drawings of record (also called "as-built" drawings) should be prepared to document the actual lines and grades and conditions of each component of the disposal unit. For soil components, the record drawings shall include survey data that show bottom and top elevations of a particular component, the plan dimensions of the component, and locations of all destructive test samples. For geosynthetic components, the record drawings often show the dimensions of all geomembrane field panels, the location of each panel, identification of all seams and panels with appropriate identification numbering or lettering, location of all patches and repairs, and location of all destructive test samples. Separate drawings are often needed to show record cross sections and special features such as sump areas.

1.5.6 Final Documentation and Certification

At the completion of a project, or a component of a large project, the owner/operator should submit a final report to the permitting agency. This report may include all of the daily inspection reports, the daily MQA/CQA engineer's summary reports, inspection data sheets, problem identification and corrective measures reports, and other documentation such as quality control data provided by manufacturers or fabricators, laboratory test results, photographs, as-built drawings, internal MQA/CQA memoranda or reports with data interpretation or analyses, and design changes made by the design engineer during construction. The document should be certified correct by the MQA/CQA certifying engineer.

The final documentation should emphasize that areas of responsibility and lines of authority were clearly defined, understood, and accepted by all parties involved in the project (assuming that this was the case). Signatures of the owner/operator's representative, design engineer, MQA/CQA engineer, general contractor's representative, specialty subcontractor's representative, and MQA/CQA certifying engineer may be included as confirmation that each party understood and accepted the areas of responsibility and lines of authority outlined in the MQA/CQA plan.

1.5.7 Document Control

The MQA/CQA documents which have been agreed upon should be maintained under a document control procedure. Any portion of the document(s) which are modified must be communicated to and agreed upon by all parties involved. An indexing procedure should be developed for convenient replacement of pages in the MQA/CQA plan, should modifications become necessary, with revision status indicated on appropriate pages.

A control scheme should be implemented to organize and index all MQA/CQA documents. This scheme should be designed to allow easy access to all MQA/CQA documents and should enable a reviewer to identify and retrieve original inspection reports or data sheets for any completed work element.

1.5.8 Storage of Records

During construction, the MQA/CQA engineer should be responsible for all MQA/CQA documents. This includes a copy of the design criteria, plans, specifications, MQA/CQA plan, and originals of all data sheets and reports. Duplicate records should be kept at another location to avoid loss of this valuable information if the originals are destroyed.

Once construction is complete, the document originals should be stored by the owner/operator in a manner that will allow for easy access while still protecting them from damage. An additional copy should be kept at the facility if this is in a different location from the owner/operator's main files. A final copy should be kept by the permitting agency. All documentation should be maintained through the operating and post-closure monitoring periods of the facility by the owner/operator and the permitting agency in an agreed upon format (paper hard copy, microfiche, electronic medium, etc.).

1.6 Meetings

Communication is extremely important to quality management. Quality construction is easiest to achieve when all parties involved understand clearly their responsibility and authority. Meetings can be very helpful to make sure that responsibility and authority of each organization is clearly understood. During construction, meetings can help to resolve problems or misunderstandings and to find solutions to unanticipated problems that have developed.

1.6.1 Pre-Bid Meeting

The first meeting is held to discuss the MQA/CQA plan and to resolve differences of opinion before the project is let for bidding. The pre-bid meeting is held after the permitting agency has issued a permit for a waste containment facility and before a construction contract has been awarded. The pre-bid meeting is held before construction bids are prepared so that the companies bidding on the construction will better understand the level of MQA/CQA to be employed on the project. Also, if the bidders identify problems with the MQA/CQA plan, this affords the owner/operator an opportunity to rectify those problems early in the process.

1.6.2 Resolution Meeting

The objectives of the resolution meeting are to establish lines of communication, review construction plans and specifications, emphasize the critical aspects of a project necessary to ensure proper quality, begin planning and coordination of tasks, and anticipate any problems that might cause difficulties or delays in construction. The meeting should be attended by the owner/operator's representative, design engineer, representatives of the general contractor and/or major subcontractors, the MQA/CQA engineer, and the MQA/CQA certifying engineer.

The resolution meeting normally involves the following activities:

- An individual is assigned to take minutes (usually a representative of the owner/operator or of the MQA/CQA engineer's organization);
- Individuals are introduced to one another and their responsibilities (or potential responsibilities) are identified;
- Copies of the project plans and specifications are made available for discussion;
- The MQA/CQA plan is distributed;
- Copies of any special permit restrictions that are relevant to construction or MQA/CQA are distributed;
- The plans and specifications are described, any unique design features are discussed (so the contractors will understand the rationale behind the general design), any potential construction problems are identified and discussed, and questions from any of the parties concerning the construction are discussed;
- The MQA/CQA plan is reviewed and discussed, with the MQA/CQA engineer and MQA/CQA certifying engineer identifying their expectations and identifying the most critical components;

- Procedures for MQC/CQC proposed by installers and contractors are reviewed and discussed;
- Corrective actions to resolve potential construction problems are discussed;
- Procedures for documentation and distribution of documents are discussed;
- Each organization's responsibility, authority, and lines of communication are discussed;
- Suggested modifications to the MQA/CQA plan that would improve quality management on the project are solicited; and
- Construction variables (e.g., precipitation, wind, temperature) and schedule are discussed.

It is very important that the procedures for inspection and testing be known to all, that the criteria for pass/fail decisions be clearly defined (including the resolution of test data outliers), that all parties understand the key problems that the MQA/CQA personnel will be particularly careful to identify, that each individual's responsibilities and authority be understood, and that procedures regarding resolution of problems be understood. The resolution meeting may be held in conjunction with either the pre-bid meeting (rarely) or the pre-construction meeting (often).

1.6.3 Pre-construction Meeting

The pre-construction meeting is held after a general construction contract has been awarded and the major subcontractors and material suppliers are established. It is usually held concurrent with the initiation of construction. The purpose of this meeting is to review the details of the MQA/CQA plan, to make sure that the responsibility and authority of each individual is clearly understood, to agree on procedures to resolve construction problems, and to establish a foundation of cooperation in quality management. The pre-construction meeting should be attended by the owner/operator's representative, design engineer, representatives of the general contractor and major subcontractors, the MQA/CQA engineer, the MQA/CQA certifying engineer, and a representative from the permitting agency, if that agency expects to visit the site during construction or independently observe MQA/CQA procedures.

The pre-construction meeting should include the following activities:

- Assign an individual (usually representative of MQA/CQA engineer) to take minutes;
- Introduce parties and identify their responsibility and authority;
- Distribute the MQA/CQA plan, identify any revisions made after the resolution meeting, and answer any questions about the MQA/CQA plan, procedures, or documentation;
- Discuss responsibilities and lines of communication;
- Discuss reporting procedures, distribution of documents, schedule for any regular meetings, and resolution of construction problems;
- Review site requirements and logistics, including safety procedures;

- Review the design, discuss the most critical aspects of the construction, and discuss scheduling and sequencing issues;
- Discuss MQC procedures that the geosynthetics manufacturer(s) will employ;
- Discuss CQC procedures that the installer or contractor will employ, for example, establish and agree on geomembrane repair procedures;
- Make a list of action items that require resolution and assign responsibilities for these items.

1.6.4 Progress Meetings

Weekly progress meetings should be held. Weekly meetings can be helpful in maintaining lines of communication, resolving problems, identifying action items, and improving overall quality management. When numerous critical work elements are being performed, the frequency of these meetings can be increased to biweekly, or even daily. Persons who should attend this meeting are those involved in the specific issues being discussed. At all times the MQA/CQA engineer, or designated representative, should be present.

1.7 Sample Custody

All samples shall be identified as described in the MQA/CQA plan. Whenever a sample is taken, a chain of custody record should be made for that sample. If the sample is transferred to another individual or laboratory, records shall be kept of the transfer so that chain of custody can be traced. The purpose of keeping a record of sample custody is to assist in tracing the cause of anomalous test results or other testing problem, and to help prevent accidental loss of test samples.

Soil samples are usually discarded after testing. Destructive testing samples of geosynthetic materials are often taken in triplicate, with one sample tested by CQC personnel, one tested by CQA personnel, and the third retained in storage as prescribed in the CQA plan.

1.8 Weather

Weather can play a critical role in the construction of waste containment facilities. Installation of all geosynthetic materials (including geosynthetic clay liners) and natural clay liners is particularly sensitive to weather conditions, including temperature, wind, humidity, and precipitation. The contractor or installer is responsible for complying with the contract plans and specifications (along with the MQC/CQC plans for the various components of the system). Included in this information should be details which restrict the weather conditions in which certain activities can take place. It is the responsibility of the contractor or installer to make sure that these weather restrictions are observed during construction.

1.9 Work Stoppages

Unexpected work stoppages can occur due to a variety of causes, including labor strikes, contractual disputes, weather, QC/QA problems, etc. The MQA/CQA engineer should be particularly careful during such stoppages to determine (1) whether in-place materials are covered and protected from damage (e.g., lifting of a geomembrane by wind or premature hydration of geosynthetic clay liners); (2) whether partially covered materials are protected from damage (e.g., desiccation of a compacted clay liners); and (3) whether manufactured materials are properly stored and properly or adequately protected (e.g., whether geotextiles are protected from ultraviolet exposure). The cessation of construction should not mean the cessation of MQA/CQA inspection and documentation.

1.10 References

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Chapter 2

Compacted Soil Liners

2.1 Introduction and Background

2.1.1 Types of Compacted Soil Liners

Compacted soil liners have been used for many years as engineered hydraulic barriers for waste containment facilities. Some liner and cover systems contain a single compacted soil liner, but others may contain two or more compacted soil liners. Compacted soil liners are frequently used in conjunction with geomembranes to form a *composite liner,* which usually consists of a geomembrane placed directly on the surface of a compacted soil liner. Examples of soil liners used in liner and cover systems are shown in Fig. 2.1.

Compacted soil liners are composed of clayey materials that are placed and compacted in layers called *lifts*. The materials used to construct soil liners include natural mineral materials (natural soils), bentonite-soil blends, and other material

2.1.1.1 Natural Mineral Materials

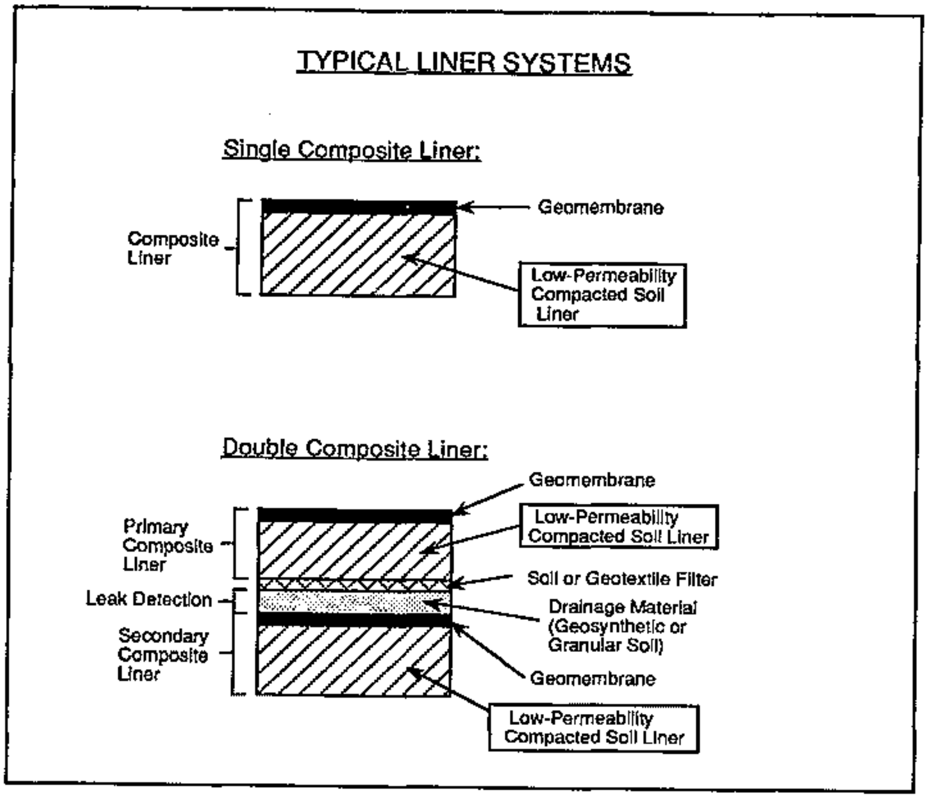
The most common type of compacted soil liner is one that is constructed from naturally occurring soils that contain a significant quantity of clay. Soils are usually classified as CL, CH, or SC soils in the Unified Soil Classification System (USCS) and ASTM D-2487. Soil liner materials are excavated from locations called *borrow pits*. These borrow areas are located either on the site or offsite. The soil in the borrow pit may be used directly without processing or may be processed to alter the water content, break down large pieces of material, or remove oversized particles. Sources of natural soil liner materials include lacustrine deposits, glacial tills, aeolian materials, deltaic deposits, residual soils, and other types of soil deposits. Weakly cemented or highly weathered rocks, e.g., mudstones and shales, can also be used for soil liner materials, provided they are processed properly.

2.1.1.2 Bentonite-Soil Blends

If the soils found in the vicinity of a waste disposal facility are not sufficiently clayey to be suitable for direct use as a soil liner material, a common practice is to blend natural soils available on or near a site with bentonite. The term *bentonite* is used in different ways by different people. For purposes of this discussion, bentonite is any commercially processed material that is composed primarily of the mineral smectite. Bentonite may be supplied in granular or pulverized form. The dominant adsorbed cation of commercial bentonite is usually sodium or calcium, although the sodium form is much more commonly used for soil sealing applications. Bentonite is mixed with native soils either in thin layers or in a pugmill.

2.1.1.3 Other

Other materials have occasionally been used for compacted soil liners. For example, bentonite may be blended with flyash to form a liner under certain circumstances. Modified soil minerals and commercial additives, e.g., polymers, have sometimes been used.



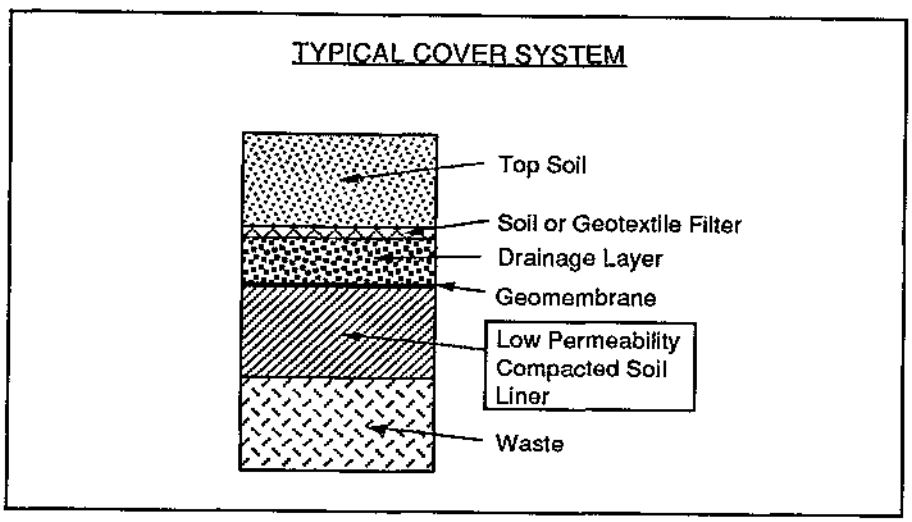


Figure 2.1 - Examples of Compacted Soil Liners in Liner and Cover Systems

2.1.2 Critical CQC and CQA Issues

The CQC and CQA processes for soil liners are intended to accomplish three objectives:

1. Ensure that soil liner materials are suitable.
2. Ensure that soil liner materials are properly placed a. ⌄ compacted.
3. Ensure that the completed liner is properly protected.

Some of these issues, such as protection of the liner from desiccation after completion, simply require application of common-sense procedures. Other issues, such preprocessing of materials, are potentially much more complicated because, depending on the material, many construction steps may be involved. Furthermore, tests alone will not adequately address many of the critical CQC and CQA issues -- visual observations by qualified personnel, supplemented by intelligently selected tests, provide the best approach to ensure quality in the constructed soil liner.

As discussed in Chapter 1, the objective of CQA is to ensure that the final product meets specifications. A detailed program of tests and observations is necessary to accomplish this objective. The objective of CQC is to control the manufacturing or construction process to meet project specifications. With geosynthetics, the distinction between CQC and CQA is obvious: the geosynthetics installer performs CQC while an independent organization conducts CQA. However, CQC and CQA activities for soils are more closely linked than in geosynthetics installation. For example, on many earthwork projects the CQA inspector will typically determine the water content of the soil and report the value to the contractor; in effect, the CQA inspector is also providing CQC input to the contractor. On some projects, the contractor is required to perform extensive tests as part of the CQC process, and the CQA inspector performs tests to check or confirm the results of CQC tests.

The lack of clearly separate roles for CQC and CQA inspectors in the earthwork industry is a result of historic practices and procedures. This chapter is focused on CQA procedures for soil liners, but the reader should understand that CQA and CQC practices are often closely linked in earthwork. In any event, the QA plan should clearly establish QA procedures and should consider whether there will be QC tests and observations to complement the QA process.

2.1.3 Liner Requirements

The construction of soil liners is a challenging task that requires many careful steps. A blunder concerning any one detail of construction can have disastrous impacts upon the hydraulic conductivity of a soil liner. For example, if a liner is allowed to desiccate, cracks might develop that could increase the hydraulic conductivity of the liner to above the specified requirement.

As stated in Section 2.1.2, the CQC and CQA processes for soil liners essentially consist of using suitable materials, placing and compacting the materials properly, and protecting the completed liner. The steps required to fulfill these requirements may be summarized as follows:

1. The subgrade on which the soil liner will be placed should be properly prepared.
2. The materials employed in constructing the soil liner should be suitable and should conform to the plans and specifications for the project.

3. The soil liner material should be preprocessed, if necessary, to adjust the water content, to remove oversized particles, to break down clods of soil, or to add amendments such as bentonite.

4. The soil should be placed in lifts of appropriate thickness and then be properly remolded and compacted.

5. The completed soil liner should be protected from damage caused by desiccation or freezing temperatures.

6. The final surface of the soil liner should be properly prepared to support the next layer that will be placed on top of the soil liner.

The six steps mentioned above are described in more detail in the succeeding subsections to provide the reader with a general introduction to the nature of CQC and CQA for soil liners. Detailed requirements are discussed later.

2.1.3.1 Subgrade Preparation

The subgrade on which a soil liner is placed should be properly prepared, i.e., provide adequate support for compaction and be free from mass movements. The compacted soil liner may be placed on a natural or geosynthetic material, depending on the particular design and the individual component in the liner or cover system. If the soil liner is the lowest component of the liner system, native soil or rock forms the subgrade. In such cases the subgrade should be compacted to eliminate soft spots. Water should be added or removed as necessary to produce a suitably firm subgrade per specification requirements. In other instances the soil liner may be placed on top of geosynthetic components of the liner system, e.g., a geotextile. In such cases, the main concern is the smoothness of the geosynthetic on which soil is placed and conformity of the geosynthetic to the underlying material (e.g., no bridging over ruts left by vehicle traffic).

Sometimes it is necessary to "tie in" a new section of soil liner to an old one, e.g., when a landfill is being expanded laterally. It is recommended that a lateral excavation be made about 3 to 6 m (10 to 20 ft) into the existing soil liner, and that the existing liner be stair-stepped as shown in Fig. 2.2 to tie the new liner into the old one. The surface of each of the steps in the old liner should be scarified to maximize bonding between the new and old sections.

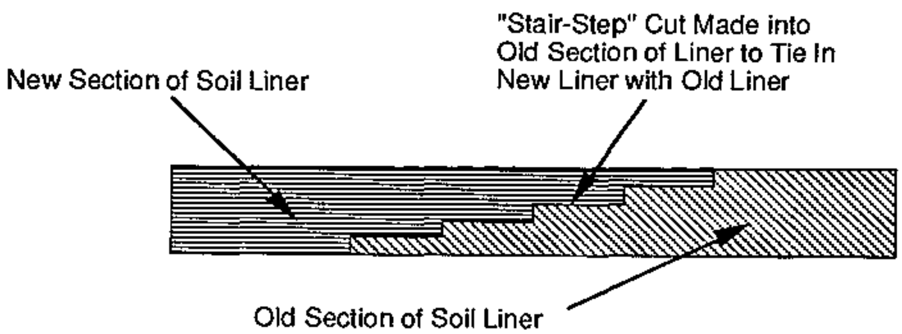


Figure 2.2 - Tie-In of New Soil Liner to Existing Soil Liner

2.1.3.2 Material Selection

Soil liner materials are selected so that a low hydraulic conductivity will be produced after the soil is remolded and compacted. Although the performance specification is usually hydraulic conductivity, CQA considerations dictate that restrictions be placed on certain properties of the soil used to build a liner. For example, limitations may be placed on the liquid limit, plastic limit, plasticity index, percent fines, and percent gravel allowed in the soil liner material.

The process of selecting construction materials and verifying the suitability of the materials varies from project to project. In general, the process is as follows:

1. A potential borrow source is located and explored to determine the vertical and lateral extent of the source and to obtain representative samples, which are tested for properties such as liquid limit, plastic limit, percent fines, etc.

2. Once construction begins, additional CQC and CQA observations and tests may be performed in the borrow pit to confirm the suitability of materials being removed.

3. After a lift of soil has been placed, additional CQA tests should be performed for final verification of the suitability of the soil liner materials.

On some projects, the process may be somewhat different. For example, a materials company may offer to sell soil liner materials from a commercial pit, in which case the first step listed above (location of borrow source) is not relevant.

A variety of tests is performed at various stages of the construction process to ensure that the soil liner material conforms with specifications. However, tests alone will not necessarily ensure an adequate material -- observations by qualified CQA inspectors are essential to confirm that deleterious materials (such as stones or large pieces of organic or other deleterious matter) are not present in the soil liner material.

2.1.3.3 Preprocessing

Some soil liner materials must be processed prior to use. The principal preprocessing steps that may be required include the following:

1. Drying of soil that is too wet.

2. Wetting of soil that is too dry.

3. Removal of oversized particles.

4. Pulverization of clods of soil.

5. Homogenization of nonuniform soil.

6. Addition of bentonite.

Tests are performed by CQA personnel to confirm proper preprocessing, but visual observations by CQC and CQA personnel are needed to confirm that proper procedures have been followed and that the soil liner material has been properly preprocessed.

2.1.3.4 Placement, Remolding, and Compaction

Soil liners are placed and compacted in lifts. The soil liner material must first be placed in a loose lift of appropriate thickness. If a loose lift is too thick, adequate compactive energy may not be delivered to the bottom of a lift.

The type and weight of compaction equipment can have an important influence upon the hydraulic conductivity of the constructed liner. The CQC/CQA program should be designed to ensure that the soil liner material will be properly placed, remolded, and compacted as described in the plans and specifications for the project.

2.1.3.5 Protection

The completed soil liner must be protected from damage caused by desiccation or freezing temperatures. Each completed lift of the soil liner, as well as the completed liner, must be protected.

2.1.3.6 Final Surface Preparation

The surface of the liner must be properly compacted and smoothed to serve as a foundation for an overlying geomembrane liner or other component of a liner or cover system. Verification of final surface preparation is an important part of the CQA process.

2.1.4 Compaction Requirements

One of the most important aspects of constructing soil liners that have low hydraulic conductivity is the proper remolding and compaction of the soil. Background information on soil compaction is presented in this subsection.

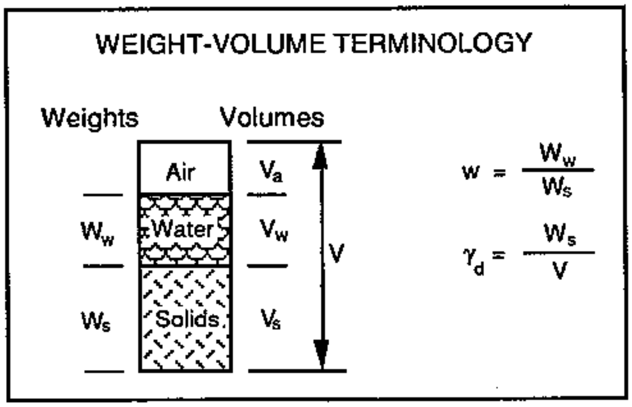
2.1.4.1 Compaction Curve

A compaction curve is developed by preparing several samples of soil at different water contents and then sequentially compacting each of the samples into a mold of known volume with a specified compaction procedure. The total unit weight (γ), which is also called the wet density, of each specimen is determined by weighing the compacted specimen and dividing the total weight by the total volume. The water content (w) of each compacted specimen is determined by oven drying the specimen. The dry unit weight (γ_d), which is sometimes called the dry density, is calculated as follows:

$$\gamma_d = \gamma/(1 + w) \qquad (2.1)$$

The (w, γ_d) points are plotted and a smooth curve is drawn between the points to define the compaction curve (Fig. 2.3). Judgment rather than an analytic algorithm is usually employed to draw the compaction curve through the measured points.

The *maximum dry unit weight* ($\gamma_{d,max}$) occurs at a water content that is called the *optimum water content*, w_{opt} (Fig. 2.3). The main reason for developing a compaction curve is to determine the optimum water content and maximum dry unit weight for a given soil and compaction procedure.



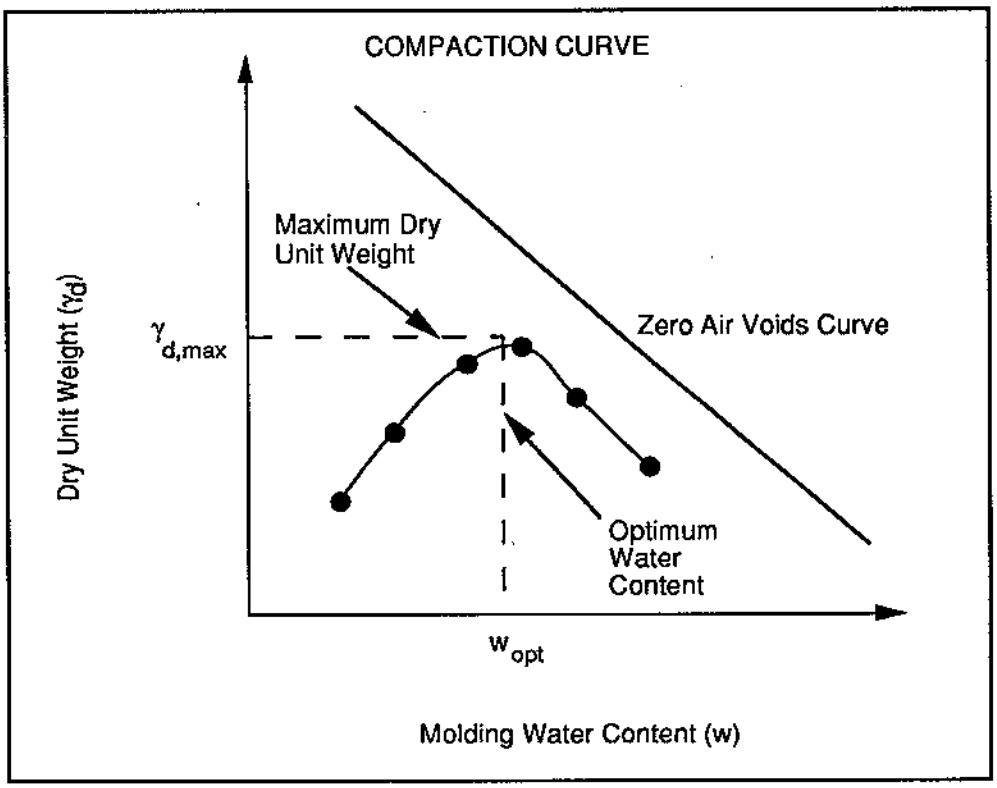


Figure 2.3 - Compaction Curve

The *zero air voids curve* (Fig. 2.3), also known as the *100% saturation curve,* is a curve that relates dry unit weight to water content for a saturated soil that contains no air. The equation for the zero air voids curve is:

$$\gamma_d = \gamma_w/[w + (1/G_s)] \tag{2.2}$$

where G_s is the specific gravity of solids (typically 2.6 to 2.8) and γ_w is the unit weight of water. If the soil's specific gravity of solids changes, the zero air voids curve will also change. Theoretically, no points on a plot of dry unit weight versus water content should lie above the zero air voids curve, but in practice some points usually lie slightly above the zero air voids curve as a result of soil variability and inherent limitations in the accuracy of water content and unit weight measurements (Schmertmann, 1989).

Benson and Boutwell (1992) summarize the maximum dry unit weights and optimum water content measured on soil liner materials from 26 soil liner projects and found that the degree of saturation at the point of (w_{opt}, $\gamma_{d,max}$) ranged from 71% to 98%, based on an assumed G_s value of 2.75. The average degree of saturation at the optimum point was 85%.

2.1.4.2 Compaction Tests

Several methods of laboratory compaction are commonly employed. The two procedures that are most commonly used are standard and modified compaction. Both techniques usually involve compacting the soil into a mold having a volume of 0.00094 m^3 (1/30 ft^3). The number of lifts, weight of hammer, and height of fall are listed in Table 2.1. The compaction tests are sometimes called *Proctor* tests after Proctor, who developed the tests and wrote about the procedures in several 1933 issues of Engineering News Record. Thus, the compaction curves are sometimes called Proctor curves, and the maximum dry unit weight may be termed the *Proctor density.*

Table 2.1 - Compaction Test Details

Compaction Procedure	Number of Lifts	Weight of Hammer	Height of Fall	Compactive Energy
Standard	3	24.5N (5.5 lbs)	305 mm (12 in.)	594 $kN\text{-}m/m^3$ (12,375 $ft\text{-}lb/ft^3$)
Modified	5	44.5N (10 lbs)	457 mm (18 in.)	2,693 $kN\text{-}m/m^3$ (56,250 $ft\text{-}lb/ft^3$)

Proctor's original test, now frequently called the *standard Proctor compaction test*, was developed to control compaction of soil bases for highways and airfields. The maximum dry unit weights attained from the standard Proctor compaction test were approximately equal to unit weights observed in the field on well-built fills using compaction equipment available in the 1920s and 1930s. During World War II, much heavier compaction equipment was developed and the unit weights attained from field compaction sometimes exceeded the laboratory values. Proctor's original procedure was modified by increasing compactive energy. By today's standards:

- Standard Compaction (ASTM D-698) produces maximum dry unit weights approximately equal to field dry unit weights for soils that are well compacted using modest-sized compaction equipment.
- Modified Compaction (ASTM D-1557) produces maximum dry unit weights approximately equal to field dry unit weights for soils that are well compacted using the heaviest compaction equipment available.

2.1.4.3 Percent Compaction

The compaction test is used to help CQA personnel to determine: 1) whether the soil is at the proper water content for compaction, and 2) whether the soil has received adequate compactive effort. Field CQA personnel will typically measure the water content of the field-compacted soil (w) and compare that value with the optimum water content (w_{opt}) from a laboratory compaction test. The construction specifications may limit the value of w relative to w_{opt}, e.g., specifications may require w to be between 0 and +4 percentage points of w_{opt}. Field CQC personnel should measure the water content of the soil prior to remolding and compaction to ensure that the material is at the proper water content before the soil is compacted. However, experienced earthwork personnel can often tell if the soil is at the proper water content from the look and feel of the soil. Field CQA personnel should measure the water content and unit weight after compaction to verify that the water content and dry unit weight meet specifications. Field CQA personnel often compute the percent compaction, P, which is defined as follows:

$$P = \gamma_d / \gamma_{d,max} \times 100\% \qquad (2.3)$$

where γ_d is the dry unit weight of the field-compacted soil. Construction specifications often stipulate a minimum acceptable value of P.

In summary, the purpose of the laboratory compaction test as applied to CQC and CQA is to provide water content (w_{opt}) and dry unit weight ($\gamma_{d,max}$) reference points. The actual water content of the field-compacted soil liner may be compared to the optimum value determined from a specified laboratory compaction test. If the water content is not in the proper range, the engineering properties of the soil are not likely to be in the range desired. For example, if the soil is too wet, the shear strength of the soil may be too low. Similarly, the dry unit weight of the field-compacted soil may be compared to the maximum dry unit weight determined from a specified laboratory compaction test. If the percent compaction is too low, the soil has probably not been adequately compacted in the field. Compaction criteria may also be established in ways that do not involve percent compaction, as discussed later, but one way or another, the laboratory compaction test provides a reference point.

2.1.4.4 Estimating Optimum Water Content and Maximum Dry Unit Weight

Many CQA plans require that the water content and dry unit weight of the field-compacted soil be compared to values determined from laboratory compaction tests. Compaction tests are a routine part of nearly all CQA programs. However, from a practical standpoint, performing compaction tests introduces two problems:

1. A compaction test often takes 2 to 4 days to complete -- field personnel cannot wait for the completion of a laboratory compaction test to make "pass-fail" decisions.

2. The soil will inevitably be somewhat variable -- the optimum water content and maximum dry unit weight will vary. The values of w_{opt} and $\gamma_{d,max}$ appropriate for one location may not be appropriate for another location. This has been termed a "mismatch" problem (Noorany, 1990).

Because dozens (sometimes hundreds) of field water content and density tests are performed, it is impractical to perform a laboratory compaction test each and every time a field measurement of water content and density is obtained. Alternatively, simpler techniques for estimating the maximum dry unit weight are almost always employed for rapid field CQA assessments. These techniques are subjective assessment, one-point compaction test, and three-point compaction test.

2.1.4.4.1 Subjective Assessment

Relatively homogeneous fill materials produce similar results when repeated compaction tests are performed on the soil. A common approach is to estimate optimum water content and maximum dry unit weight based on the results of previous compaction tests. The results of at least 2 to 3 laboratory compaction tests should be available from tests on borrow soils prior to actual compaction of any soil liner material for a project. With subjective assessment, CQA personnel estimate the optimum water content and maximum dry unit weight based upon the results of the previously-completed compaction tests and their evaluation of the soil at a particular location in the field. Slight variations in the composition of fill materials will cause only slight variations in w_{opt} and $\gamma_{d,max}$. As an approximate guide, a relatively homogeneous borrow soil would be considered a material in which w_{opt} does not vary by more than $\pm$ 3 percentage points and $\gamma_{d,max}$ does not vary by more than $\pm$ 0.8 kN/ft^3 (5 pcf). The optimum water content and maximum dry unit weight should not be estimated in this manner if the soil is heterogeneous -- too much guess work and opportunity for error would exist.

2.1.4.4.2 One-Point Compaction Test

The results of several complete compaction tests should always be available for a particular borrow source prior to construction, and the data base should expand as a project progresses and additional compaction tests are performed. The idea behind a one-point compaction test is shown in Fig. 2.4. A sample of soil is taken from the field and dried to a water content that appears to be just dry of optimum. An experienced field technician can usually tell without much difficulty when the water content is just dry of optimum. The sample of soil is compacted into a mold of known volume according to the compaction procedure relevant to a particular project, e.g., ASTM D-698 or D-1557. The weight of the compacted specimen is measured and the total unit weight is computed. The sample is dried using one of the rapid methods of measurement discussed later to determine water content. Dry unit weight is computed from Eq. 2.2. The water content-dry unit weight point from the one-point compaction test is plotted as shown in Fig. 2.4 and used in conjunction with available compaction curves to estimate w_{opt} and $\gamma_{d,max}$. One assumes that the shape of the compaction is similar to the previously-developed compaction curves and passes through the one point that has been determined.

The dashed curve in Fig. 2.4 is the estimated compaction curve. The one-point compaction test is commonly used for variable soils. In extreme cases, a one-point compaction test may be required for nearly all field water content and density measurements for purposes of computing percent compaction. However, if the material is so variable to require a one-point compaction test for nearly all field density measurements, the material is probably too variable to be suitable for use in a soil liner. The best use of the one-point compaction test is to assist with estimation of the optimum water content and maximum dry unit weight for questionable materials and to fill in data gaps when results of complete compaction tests are not available quickly enough.

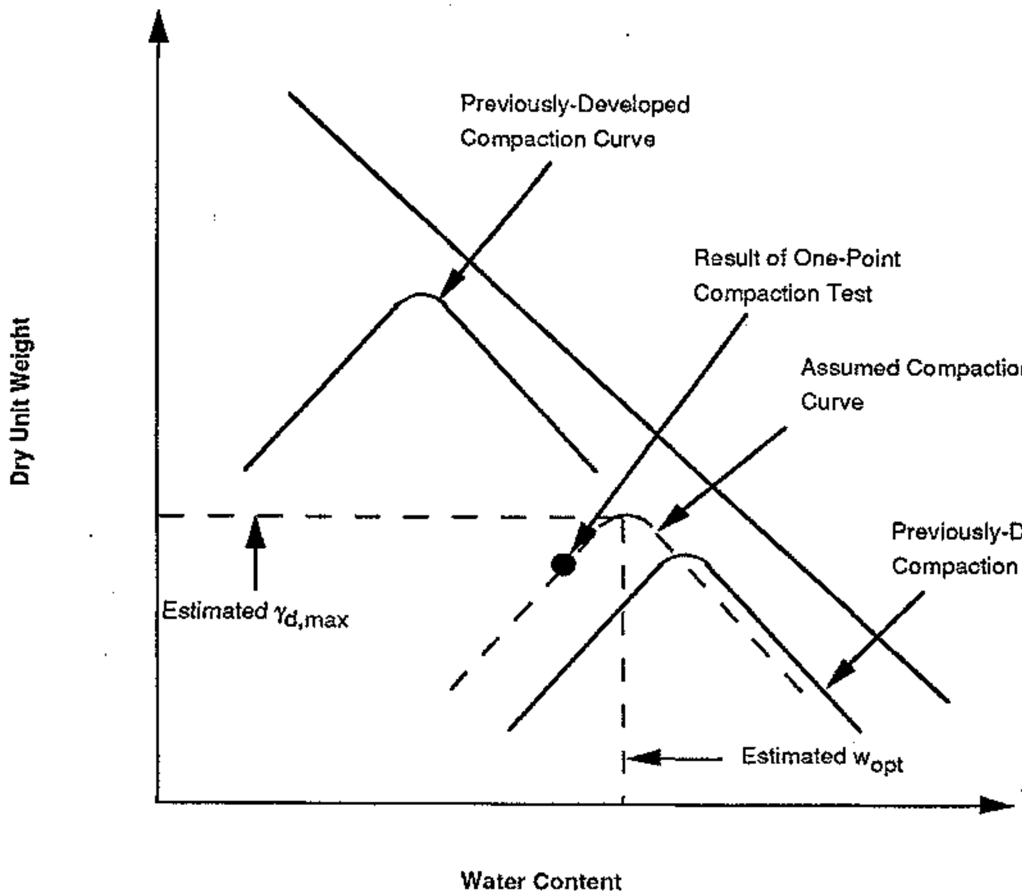


Figure 2.4 - One-Point Compaction Test

2.1.4.4.3 <u>Three-Point Compaction Test (ASTM D-5080)</u>

A more reliable technique than the one-point compaction test for estimating the optimum water content and maximum dry unit weight is to use a minimum of three compaction points to define a curve rather than relying on a single compaction point. A representative sample of soil is obtained from the field at the same location where the in-place water content and dry unit weight have been measured. The first sample of soil is compacted at the field water content. A second sample is prepared at a water content two percentage points wetter than the first sample and is compacted. However, for extremely wet soils that are more than 2% wet of optimum (which is often the case for soil liner materials), the second sample should be dried 2% below natural water content. Depending on the outcome of this compaction test, a third sample is prepared at a water content either two percentage points dry of the first sample or two percentage points wet of the second sample (or, for wet soil liners, 2 percentage points dry of the second sample). A parabola is fitted to the three compaction data points and the optimum water content and maximum dry unit weight are determined from the equation of the best-fit parabola. This technique is significantly more time consuming than the one-point compaction test but offers 1) a standard ASTM procedure and 2) greater reliability and repeatability in estimated w_{opt} and $\gamma_{d,max}$.

2.1.4.5 Recommended Procedure for Developing Water Content-Density Specification

One of the most important aspects of CQC and CQA for soil liners is documentation of the water content and dry unit weight of the soil immediately after compaction. Historically, the method used to specify water content and dry unit weight has been based upon experience with structural fill. Design engineers often require that soil liners be compacted within a specified range of water content and to a minimum dry unit weight. The "Acceptable Zone" shown in Fig. 2.5 represents the zone of acceptable water content/dry unit weight combinations that is often prescribed. The shape of the Acceptable Zone shown in Fig. 2.5 evolved empirically from construction practices applied to roadway bases, structural fills, embankments, and earthen dams. The specification is based primarily upon the need to achieve a minimum dry unit weight for adequate strength and limited compressibility. As discussed by Mundell and Bailey (1985), Boutwell and Hedges (1989), and Daniel and Benson (1990), this method of specifying water content and dry unit weight is not necessarily the best method for compacted soil liners.

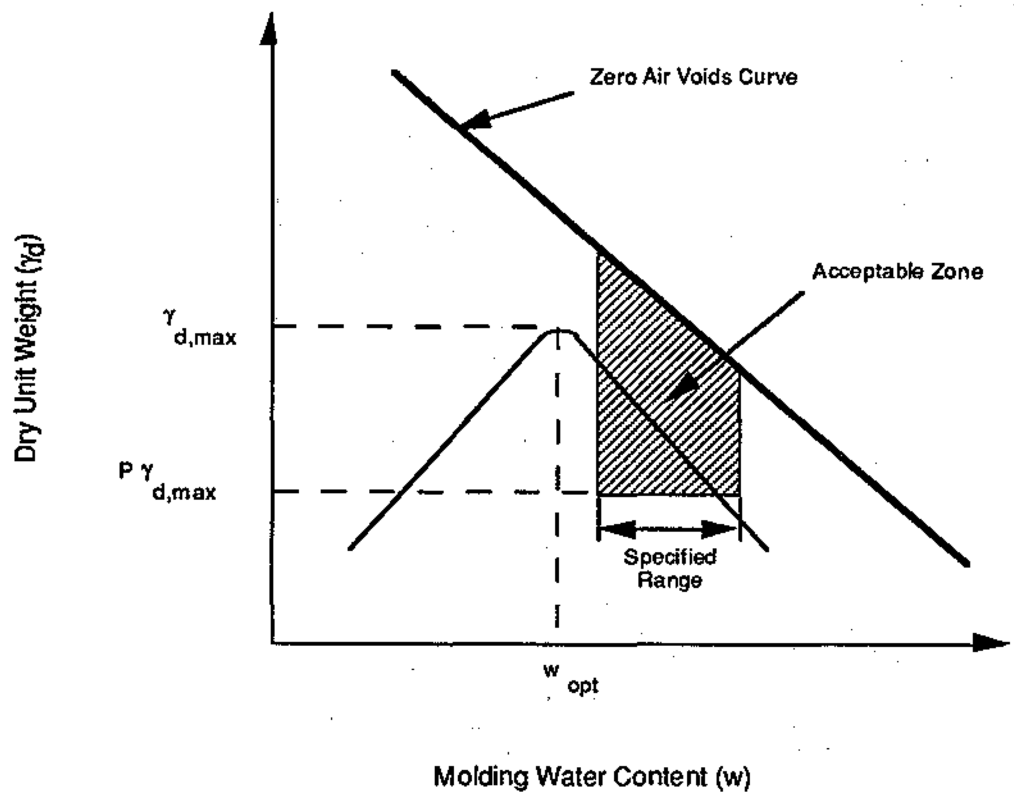


Figure 2.5 - Form of Water Content-Dry Unit Weight Specification Often Used in the Past

The recommended approach is intended to ensure that the soil liner will be compacted to a water content and dry unit weight that will lead to low hydraulic conductivity and adequate engineering performance with respect to other considerations, e.g., shear strength. Rational specification of water content/dry unit weight criteria should be based upon test data developed for each particular soil. Field test data would be better than laboratory data, but the cost of determining compaction criteria in the field through a series of test sections would almost always be prohibitive. Because the compactive effort will vary in the field, a logical approach is to select several compactive efforts in the laboratory that span the range of compactive effort that might be anticipated in the field. If this is done, the water content/dry unit weight criterion that evolves would be expected to apply to any reasonable compactive effort.

For most earthwork projects, modified Proctor effort represents a reasonable upper limit on the compactive effort likely to be delivered to the soil in the field. Standard compaction effort (ASTM D-698) likely represents a medium compactive effort. It is conceivable that soil in some locations will be compacted with an effort less than that of standard Proctor compaction. A reasonable lower limit of compactive energy is the "reduced compaction" procedure in which standard compaction procedures (ASTM D-698) are followed except that only 15 drops of the hammer per lift are used instead of the usual 25 drops. The reduced compaction procedure is the same as the 15 blow compaction test described by the U.S. Army Corps of Engineers (1970). The reduced compactive effort is expected to correspond to a reasonable minimum level of compactive energy for a typical soil liner or cover. Other compaction methods, e.g., kneading compaction, could be used. The key is to span the range of compactive effort expected in the field with laboratory compaction procedures.

One satisfactory approach is as follows:

1. Prepare and compact soil in the laboratory with modified, standard, and reduced compaction procedures to develop compaction curves as shown in Fig. 2.6a. Make sure that the soil preparation procedures are appropriate; factors such as clod size reduction may influence the results (Benson and Daniel, 1990). Other compaction procedures can be used if they better simulate field compaction and span the range of compactive effort expected in the field. Also, as few as two compaction procedures can be used if field construction procedures make either the lowest or highest compactive energy irrelevant.

2. The compacted specimens should be permeated, e.g., per ASTM D-5084. Care should be taken to ensure that permeation procedures are correct, with important details such as degree of saturation and effective confining stress carefully selected. The measured hydraulic conductivity should be plotted as a function of molding water content as shown in Fig. 2.6b.

3. As shown in Fig. 2.6c, the dry unit weight/water content points should be replotted with different symbols used to represent compacted specimens that had hydraulic conductivities greater than the maximum acceptable value and specimens with hydraulic conductivities less than or equal to the maximum acceptable value. An "Acceptable Zone" should be drawn to encompass the data points representing test results meeting or exceeding the design criteria. Some judgment is usually necessary in constructing the Acceptable Zone from the data points. Statistical criteria (e.g., Boutwell and Hedges, 1989) may be introduced at this stage.

4. The Acceptable Zone should be modified (Fig. 2.6d) based on other considerations such as shear strength. Additional tests are usually necessary in order to define the acceptable range of water content and dry unit weight that satisfies both hydraulic conductivity and shear strength criteria. Figure 2.7 illustrates how one might overlap Acceptable Zones defined from hydraulic conductivity and shear strength considerations to define a single Acceptable Zone. The same procedure can be applied to take into consideration other factors such as shrink/swell potential relevant to any particular project.

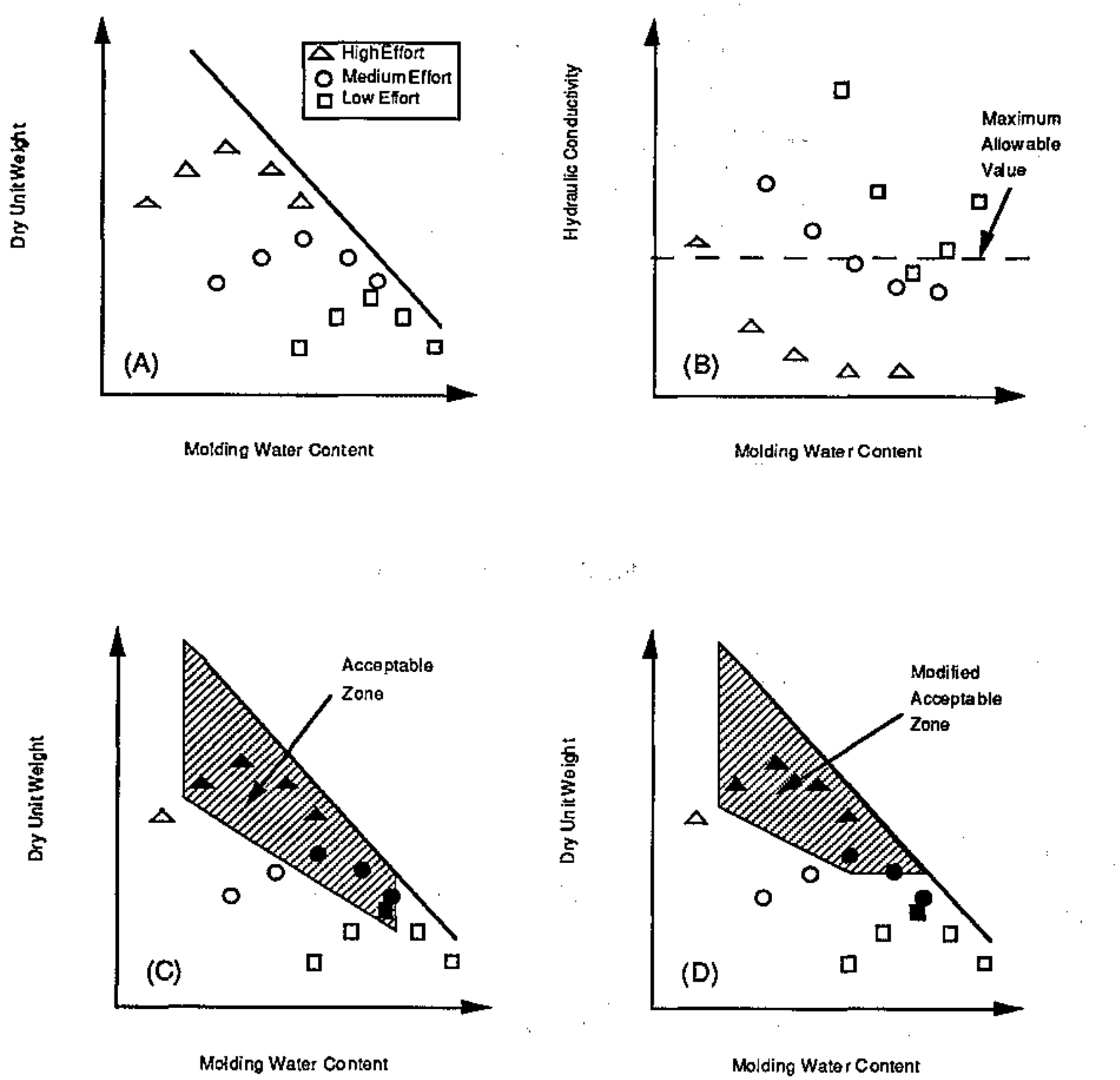


Figure 2.6 - Recommended Procedure to Determine Acceptable Zone of Water Content/Dry Unit Weight Values Based Upon Hydraulic Conductivity Considerations (after Daniel and Benson, 1990).

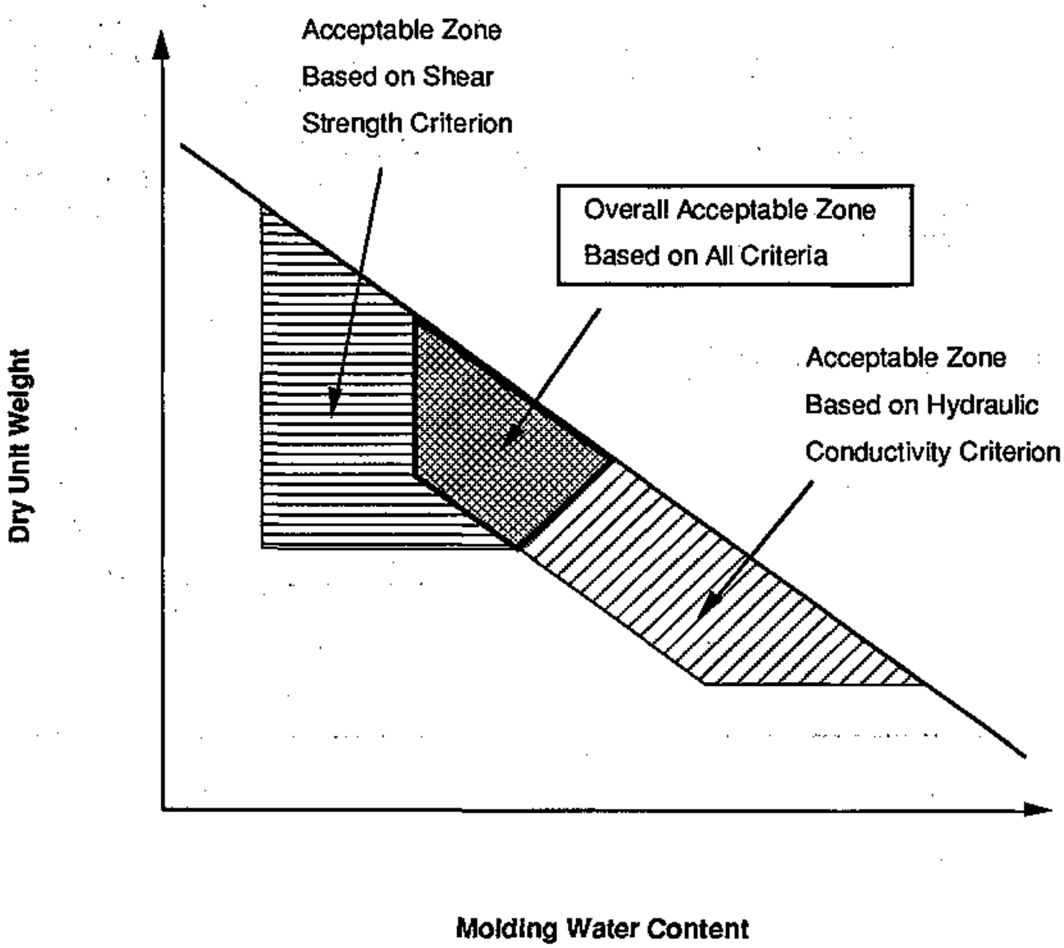


Figure 2.7 - Acceptable Zone of Water Content/Dry Unit Weights Determined by Superposing Hydraulic Conductivity and Shear Strength Data (after Daniel and Benson, 1990).

The same general procedure just outlined may also be used for soil-bentonite mixtures. However, to keep the scope of testing reasonable, the required amount of bentonite should be determined before the main part of the testing program is initiated. The recommended procedure for soil-bentonite mixes may be summarized as follows:

1. The type, grade, and gradation of bentonite that will be used should be determined. This process usually involves estimating costs from several potential suppliers. A sufficient quantity of the bentonite likely to be used for the project should be obtained and tested to characterize the bentonite (characterization tests are discussed later).

2. A representative sample of the soil to which the bentonite will be added should be obtained.

3. Batches of soil-bentonite mixtures should be prepared by blending in bentonite at several percentages, e.g., 2%, 4%, 6%, 8%, and 10% bentonite. Bentonite content is defined as the weight or mass of bentonite divided by the weight or mass of soil mixed with bentonite. For instance, if 5 kg of bentonite are mixed with 100 kg of soil, the bentonite content is 5%. Some people use the gross weight of bentonite rather than oven dry weight. Since air-dry bentonite usually contains 10% to 15% hygroscopic water by weight, the use of oven-dry, air-dry, or damp weight can make a difference in the percentage. Similarly, the weight of soil may be defined as either moist or dry (air- or oven-dry) weight. The contractor would rather work with total (moist) weights since the materials used in forming a soil-bentonite blend do contain some water. However, the engineering characteristics are controlled by the relative amounts of dry materials. A dry-weight basis is generally recommended for definition of bentonite content, but CQC and CQA personnel must recognize that the project specifications may or may not be on a dry-weight basis.

4. Develop compaction curves for each soil-bentonite mixture prepared from Step 3 using the method of compaction appropriate to the project, e.g., ASTM D-698 or ASTM D-1557.

5. Compact samples at 2% wet of optimum for each percentage of bentonite using the same compaction procedure employed in Step 4.

6. Permeate the soils prepared from Step 5 using ASTM D-5084 or some other appropriate test method. Graph hydraulic conductivity versus percentage of bentonite.

7. Decide how much bentonite to use based on the minimum required amount determined from Step 6. The minimum amount of bentonite used in the field should always be greater than the minimum amount suggested by laboratory tests because mixing in the field is usually not as thorough as in the laboratory. Typically, the amount of bentonite used in the field is one to four percentage points greater than the minimum percent bentonite indicated by laboratory tests.

8. A master batch of material should be prepared by mixing bentonite with a representative sample of soil at the average bentonite content expected in the field. The procedures described earlier for determining the Acceptable Zone of water content and dry unit weight are then applied to the master batch.

2.1.5 Test Pads

Test pads are sometimes constructed and tested prior to construction of the full-scale compacted soil liner. The test pad simulates conditions at the time of construction of the soil liner. If conditions change, e.g., as a result of emplacement of waste materials over the liner, the properties of the liner will change in ways that are not normally simulated in a test pad. The objectives of a test pad should be as follows:

1. To verify that the materials and methods of construction will produce a compacted soil liner that meets the hydraulic conductivity objectives defined for a project, hydraulic conductivity should be measured with techniques that will characterize the large-scale hydraulic conductivity and identify any construction defects that cannot be observed with small-scale laboratory hydraulic conductivity tests.

2. To verify that the proposed CQC and CQA procedures will result in a high-quality soil liner that will meet performance objectives.

3. To provide a basis of comparison for full-scale CQA: if the test pad meets the performance objectives for the liner (as verified by appropriate hydraulic conductivity tests) and the full-scale liner is constructed to standards that equal or exceed those used in building the test pad, then assurance is provided that the full-scale liner will also meet performance objectives.

4. If appropriate, a test pad provides an opportunity for the facility owner to demonstrate that unconventional materials or construction techniques will lead to a soil liner that meets performance objectives.

In terms of CQA, the test pad can provide an extremely powerful tool to ensure that performance objectives are met. The authors recommend a test pad for any project in which failure of the soil liner to meet performance objectives would have a potentially important, negative environmental impact.

A test pad need not be constructed if results are already available for a particular soil and construction methodology. By the same token, if the materials or methods of construction change, an additional test pad is recommended to test the new materials or construction procedures. Specific CQA tests and observations that are recommended for the test pad are described later in Section 2.10.

2.2 Critical Construction Variables that Affect Soil Liners

Proper construction of compacted soil liners requires careful attention to construction variables. In this section, basic principles are reviewed to set the stage for discussion of detailed CQC and CQA procedures.

2.2.1 Properties of the Soil Material

The construction specifications place certain restrictions on the materials that can be used in constructing a soil liner. Some of the restrictions are more important than others, and it is important for CQC and CQA personnel to understand how material properties can influence the performance of a soil liner.

2.2.1.1 Plasticity Characteristics

The plasticity of a soil refers to the capability of a material to behave as a plastic, moldable material. Soils are said to be either plastic or non-plastic. Soils that contain clay are usually plastic whereas those that do not contain clay are usually non-plastic. If the soil is non-plastic, the soil is almost always considered unsuitable for a soil liner unless additives such as bentonite are introduced.

The plasticity characteristics of a soil are quantified by three parameters: liquid limit, plastic limit, and plasticity index. These terms are defined as follows:

- Liquid Limit (LL): The water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil.

- Plastic Limit (PL): The water content corresponding to the arbitrary limit between the plastic and solid states of consistency of a soil.

- Plasticity Index (PI): The numerical difference between liquid and plastic limits, i.e., LL - PL.

The liquid limit and plastic limit are measured using ASTM D-4318.

Experience has shown that if the soil has extremely low plasticity, the soil will possess insufficient clay to develop low hydraulic conductivity when the soil is compacted. Also, soils that have very low PI's tend to grade into non-plastic soils in some locations. The question of how low the PI can be before the soil is not sufficiently plastic is impossible to answer universally. Daniel (1990) recommends that the soil have a PI $\geq$ 10% but notes that some soils with PI's as low as 7% have been used successfully to build soil liners with extremely low in situ hydraulic conductivity (Albrecht and Cartwright, 1989). Benson et al. (1992) compiled a data base from CQA documents and related the hydraulic conductivity measured in the laboratory on small, "undisturbed" samples of field-compacted soil to various soil characteristics. The observed relationship between hydraulic conductivity and plasticity index is shown in Fig. 2.8. The data base reflects a broad range of construction conditions, soil materials, and CQA procedures. It is clear from the data base that many soils with PI's as low as approximately 10% can be compacted to achieve a hydraulic conductivity $\leq 1 \times 10^{-7}$ cm/s.

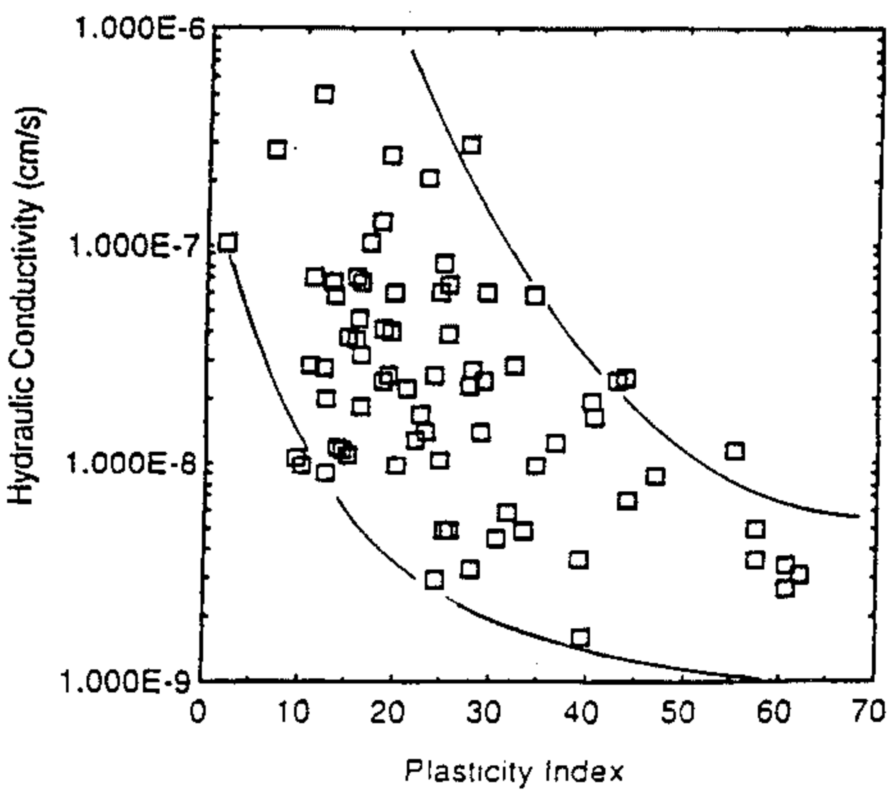


Figure 2.8 - Relationship between Hydraulic Conductivity and Plasticity Index (Benson et al., 1992)

Soils with high plasticity index (>30% to 40%) tend to form hard clods when dried and sticky clods when wet. Highly plastic soils also tend to shrink and swell when wetted or dried. With highly plastic soils, CQC and CQA personnel should be particularly watchful for proper processing of clods, effective remolding of clods during compaction, and protection from desiccation.

2.2.1.2 Percentage Fines

Some earthwork specifications place a minimum requirement on the percentage of fines in the soil liner material. *Fines* are defined as the fraction of soil that passes through the openings of the No. 200 sieve (opening size = 0.075 mm). Soils with inadequate fines typically have too little silt- and clay-sized material to produce suitably low hydraulic conductivity. Daniel (1990) recommends that the soil liner materials contain at least 30% fines. Data from Benson et al. (1992), shown in Fig. 2.9, suggest that a minimum of 50% fines might be an appropriate requirement for many soils. Field inspectors should check the soil to make sure the percentage of fines meets or exceeds the minimum stated in the construction specifications and should be particularly watchful for soils with less than 50% fines.

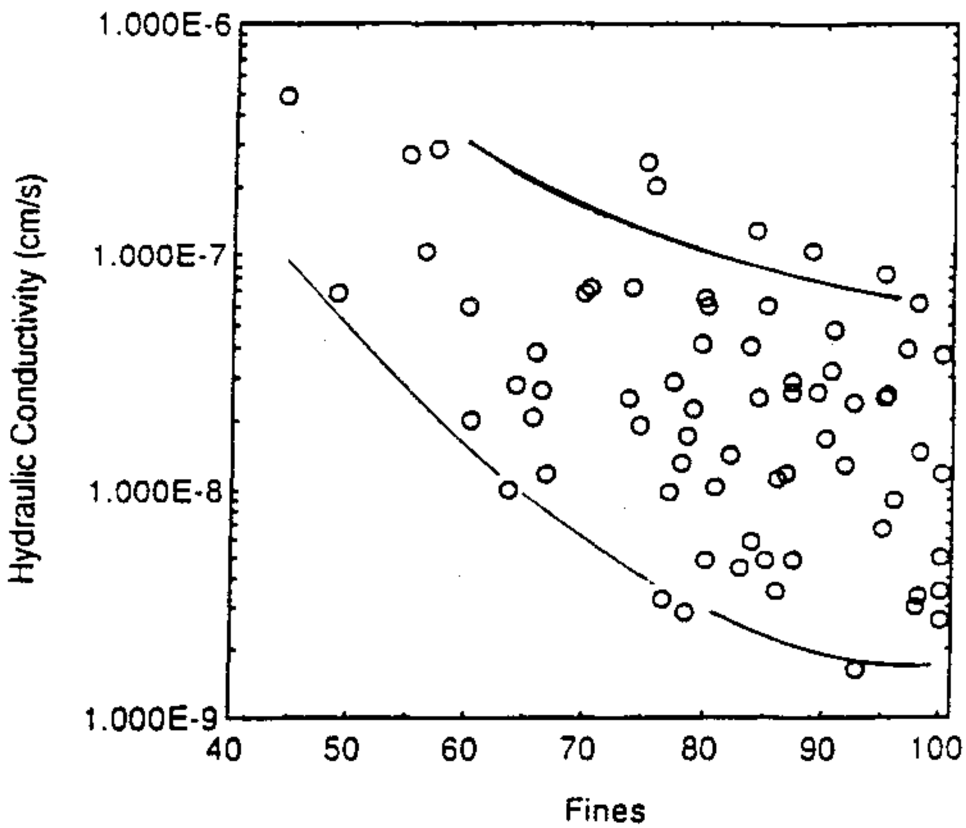


Figure 2.9 - Relationship between Hydraulic Conductivity and Percent Fines (Benson et al., 1992)

2.2.1.3 Percentage Gravel

Gravel is herein defined as particles that will not pass through the openings of a No. 4 sieve (opening size = 4.76 mm). Gravel itself has a high hydraulic conductivity. However, a relatively large percentage (up to about 50%) of gravel can be uniformly mixed with a soil liner material without significantly increasing the hydraulic conductivity of the material (Fig. 2.10). The hydraulic conductivity of mixtures of gravel and clayey soil is low because the clayey soil fills the voids between the gravel particles. The critical observation for CQA inspectors to make is for possible segregation of gravel into pockets that do not contain sufficient soil to plug the voids between the gravel particles. The uniformity with which the gravel is mixed with the soil is more important than the gravel content itself for soils with no more than 50% gravel by weight. Gravel also may possess the capability of puncturing geosynthetic materials -- the maximum size and the angularity of the gravel are very important for the layer of soil that will serve as a foundation layer for a geomembrane.

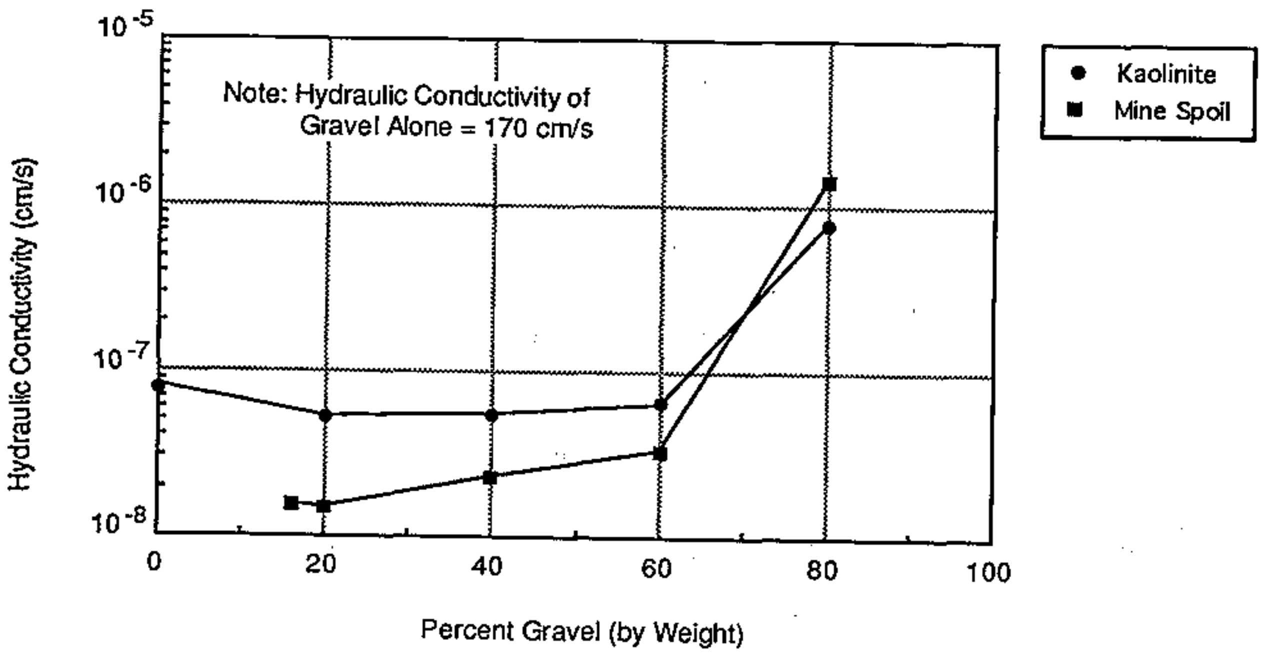


Figure 2.10 - Relationship between Hydraulic Conductivity and Percentage Gravel Added to Two Clayey Soils (after Shelley and Daniel, 1993).

2.2.1.4 Maximum Particle Size

The maximum particle size is important because: (1) cobbles or large stones can interfere with compaction, and (2) if a geomembrane is placed on top of the compacted soil liner, oversized particles can damage the geomembrane. Construction specifications may stipulate the maximum allowable particle size, which is usually between 25 and 50 mm (1 to 2 in.) for compaction considerations but which may be much less for protection against puncture of an adjacent geomembrane. If a geomembrane is to be placed on the soil liner, only the upper lift of the soil liner is relevant in terms of protection against puncture. Construction specifications may place one set of restrictions on all lifts of soil and place more stringent requirements on the upper lift to protect the geomembrane from puncture. Sieve analyses on small samples will not usually lead to detection of an occasional piece of oversized material. Observations by attentive CQC and CQA personnel are the most effective way to ensure that oversized materials have been removed. Oversized materials are particularly critical for the top lift of a soil liner if a geomembrane is to be placed on the soil liner to form a composite geomembrane/soil liner.

2.2.1.5 Clay Content and Activity

The clay content of the soil may be defined in several ways but it is usually considered to be the percentage of soil that has an equivalent particle diameter smaller than 0.005 or 0.002 mm, with 0.002 mm being the much more common definition. The clay content is measured by sedimentation analysis (ASTM D-422). Some construction specifications specify a minimum clay content but many do not.

A parameter that is sometimes useful is the activity, A, of the soil, which is defined as the plasticity index (expressed as a percentage) divided by the percentage of clay (< 0.002 mm) in the soil. A high activity (> 1) indicates that expandable clay minerals such as montmorillonite are present. Lambe and Whitman (1969) report that the activities of kaolinite, illite, and montmorillonite (three common clay minerals) are 0.38, 0.9, and 7.2, respectively. Activities for naturally occurring clay liner materials, which contain a mix of minerals, is frequently in the range of $0.5 \leq A \leq 1$.

Benson et al. (1992) related hydraulic conductivity to clay content (defined as particles < 0.002 mm) and reported the correlation shown in Fig. 2.11. The data suggest that soils must have at least 10% to 20% clay in order to be capable of being compacted to a hydraulic conductivity $\leq 1 \times 10^{-7}$ cm/s. However, Benson et al. (1992) also found that clay content correlated closely with plasticity index (Fig. 2.12). Soils with PI >10% will generally contain at least 10% to 20% clay.

It is recommended that construction specification writers and regulation drafters indirectly account for clay content by requiring the soil to have an adequate percentage of fines and a suitably large plasticity index -- by necessity the soil will have an adequate amount of clay.

2.2.1.6 Clod Size

The term *clod* refers to chunks of cohesive soil. The maximum size of clods may be specified in the construction specifications. Clod size is very important for dry, hard, clay-rich soils (Benson and Daniel, 1990). These materials generally must be broken down into small clods in order to be properly hydrated, remolded, and compacted. Clod size is less important for wet soils -- soft, wet clods can usually be remolded into a homogeneous, low-hydraulic-conductivity mass with a reasonable compactive effort.

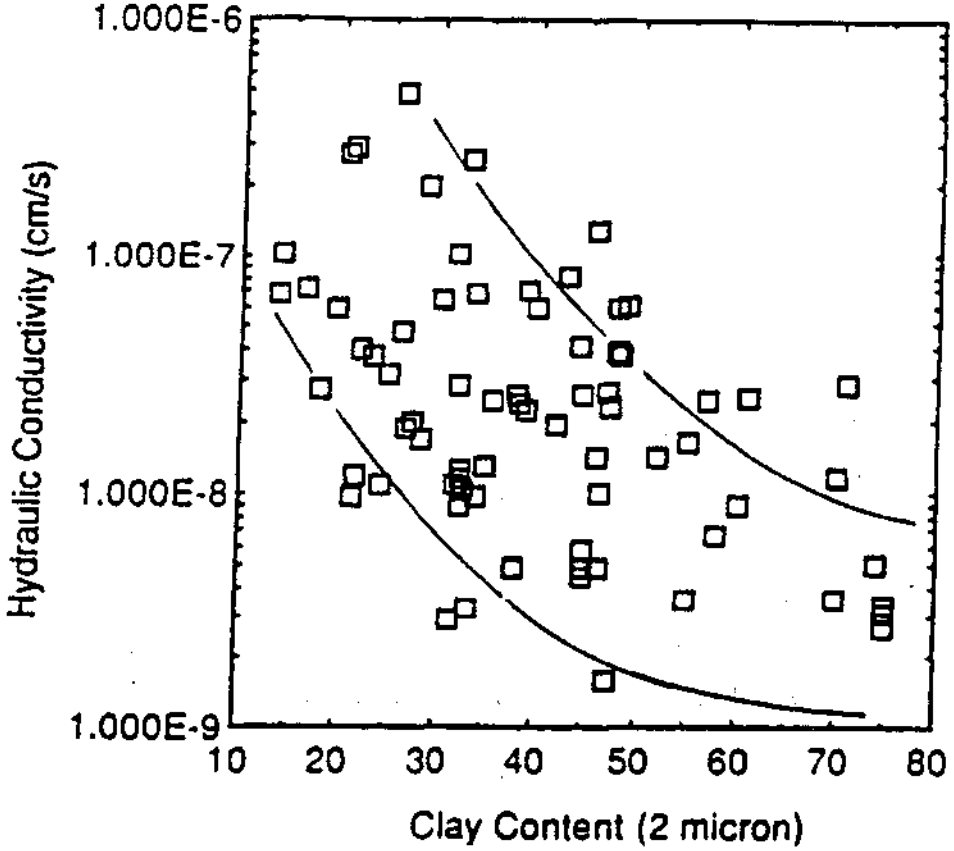


Figure 2.11 - Relationship between Hydraulic Conductivity and Clay Content (Benson et al., 1992)

No standard method is available to determine clod size. Inspectors should observe the soil liner material and occasionally determine the dimensions of clods by direct measurement with a ruler to verify conformance with construction specifications.

2.2.1.7 Bentonite

Bentonite may be added to clay-deficient soils in order to fill the voids between the soil particles with bentonite and to produce a material that, when compacted, has a very low hydraulic conductivity. The effect of the addition of bentonite upon hydraulic conductivity is shown in Fig. 2.13 for one silty sand. For this particular soil, addition of 4% sodium bentonite was sufficient to lower the hydraulic conductivity to less than 1 x 10^{-7} cm/s.

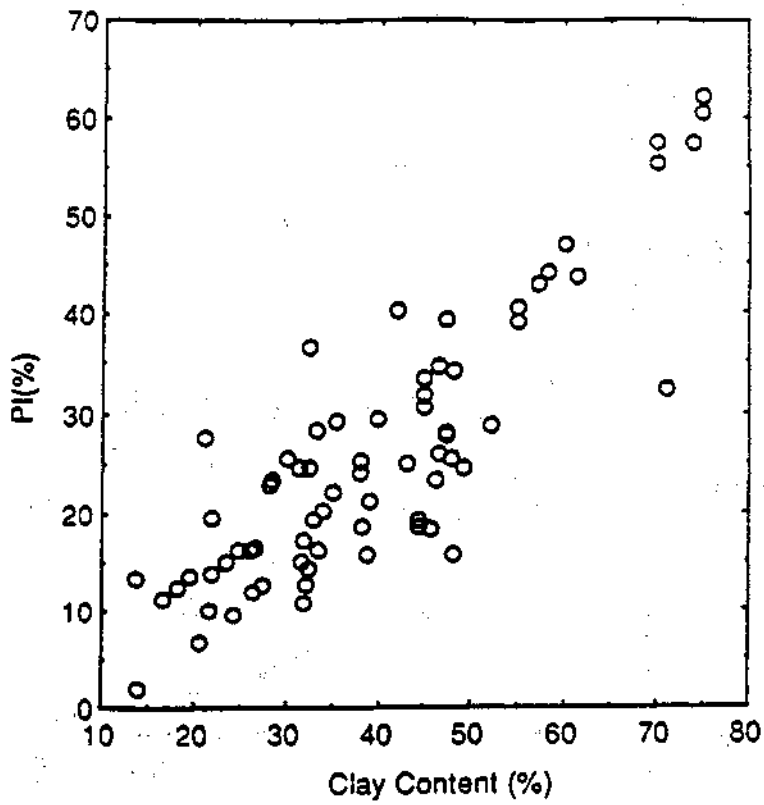


Figure 2.12 - Relationship between Clay Content and Plasticity Index (Benson et al., 1992)

The critical CQC and CQA parameters are the type of bentonite, the grade of bentonite, the grain size distribution of the processed bentonite, the amount of bentonite added to the soil, and the uniformity of mixing of the bentonite with the soil. Two types of bentonite are the primary commercial materials: sodium and calcium bentonite. Sodium bentonite has much greater water absorbency and swelling potential, but calcium bentonite may be more stable when exposed to certain chemicals. Sodium bentonite is used more frequently than calcium bentonite as a soil amendment for lining applications.

Any given type of bentonite may be available in several grades. The grade is a function of impurities in the bentonite, processing procedures, or additives. Some calcium bentonites are processed with sodium solutions to modify the bentonite to a sodium form. Some companies add polymers or other compounds to the bentonite to make the bentonite more absorbent of water or more resistant to alteration by certain chemicals.

Another variable is the gradation of the bentonite. A facet often overlooked by CQC and CQA inspectors is the grain size distribution of the processed bentonite. Bentonite can be ground to different degrees. A fine, powdered bentonite will behave differently from a coarse, granular bentonite -- if the bentonite was supposed to be finely ground but too coarse a grade was delivered, the bentonite may be unsuitable in the mixture amounts specified. Because bentonite is available in variable degrees of pulverization, a sieve analysis (ASTM D422) of the processed dry bentonite is recommended to determine the grain size distribution of the material.

The most difficult parameters to control are sometimes the amount of bentonite added to the soil and the thoroughness of mixing. Field CQC and CQA personnel should observe operational practices carefully.

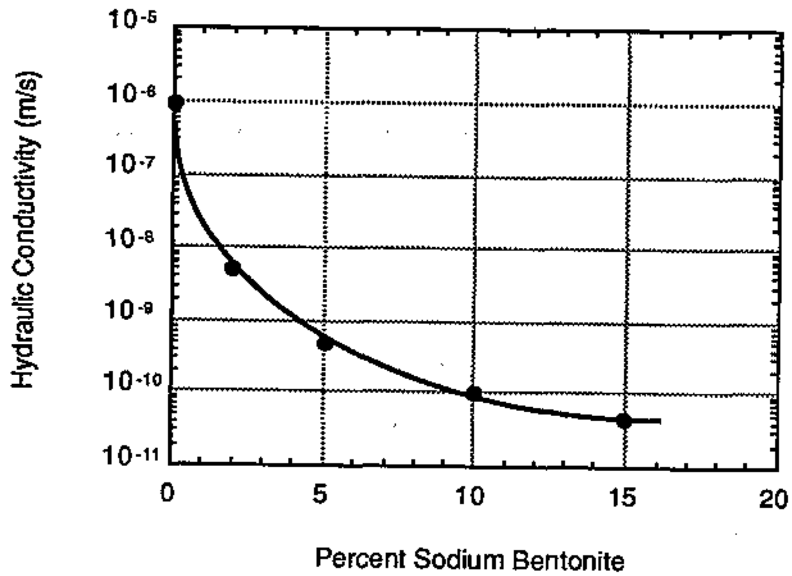


Figure 2.13 - Effect of Addition of Bentonite to Hydraulic Conductivity of Compacted Silty Sand

2.2.2 Molding Water Content

For natural soils, the degree of saturation of the soil liner material at the time of compaction is perhaps the single most important variable that controls the engineering properties of the compacted material. The typical relationship between hydraulic conductivity and molding water content is shown in Fig. 2.14. Soils compacted at water contents less than optimum (*dry of optimum*) tend to have a relatively high hydraulic conductivity; soils compacted at water contents greater than optimum (*wet of optimum*) tend to have a low hydraulic conductivity and low strength. For some soils, the water content relative to the plastic limit (which is the water content of the soil when the soil is at the boundary between being a solid and plastic material) may indicate the degree to which the soil can be compacted to yield low hydraulic conductivity. In general, if the water content is greater than the plastic limit, the soil is in a plastic state and should be capable of being remolded into a low-hydraulic-conductivity material. Soils with water contents dry of the plastic limit will exhibit very little "plasticity" and may be difficult to compact into a low-hydraulic-conductivity mass without delivering enormous compactive energy to the soil. With soil-bentonite mixes, molding water content is usually not as critical as it is for natural soils.

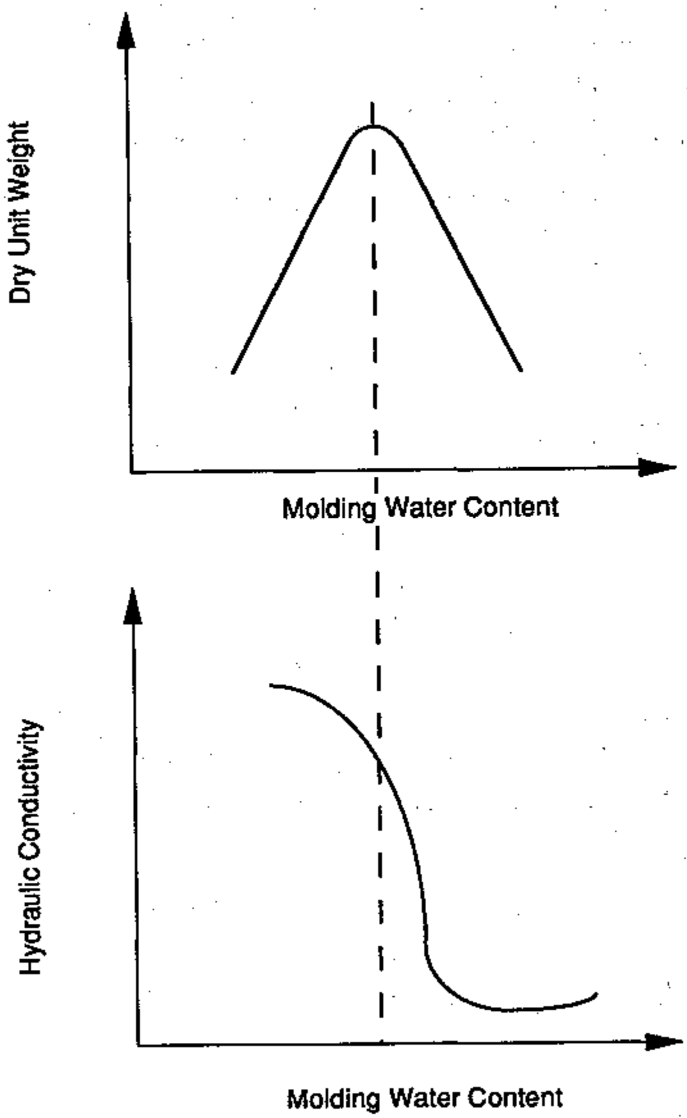


Figure 2.14 - Effect of Molding Water Content on Hydraulic Conductivity

The water content of highly plastic soils is particularly critical. A photograph of a highly plastic soil (PI = 41%) compacted 1% dry of the optimum water content of 17% is shown in Fig. 2.15. Large inter-clod voids are visible; the clods of clay were too dry and hard to be effectively remolded with the compactive effort used. A photograph of a compacted specimen of the same soil moistened to 3% wet of optimum and then compacted is shown in Fig. 2.16. At this water content, the soft soil could be remolded into a homogenous, low-hydraulic-conductivity mass.

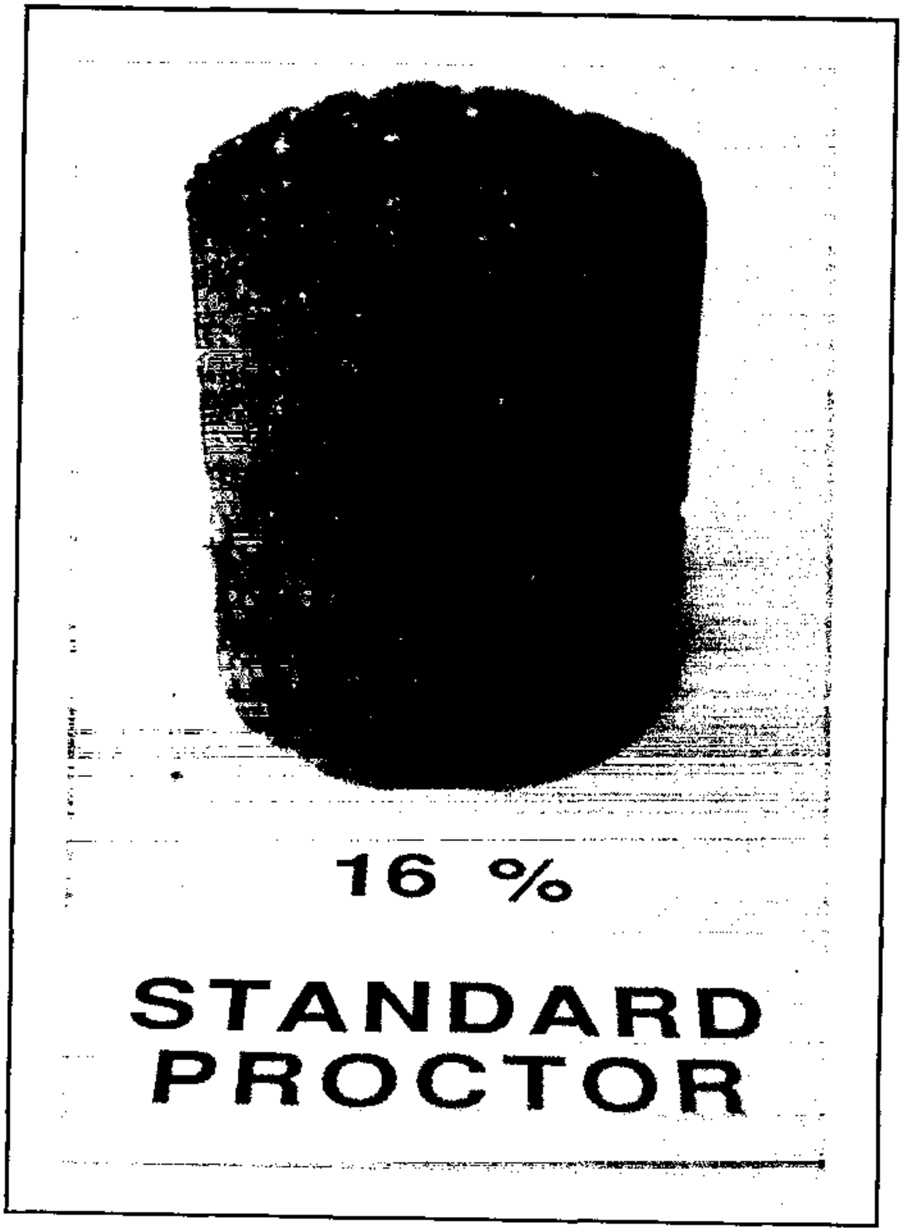


Figure 2.15 - Photograph of Highly Plastic Clay Compacted with Standard Proctor Effort at a Water Content of 16% (1% Dry of Optimum).

Figure 2.16 - Photograph of Highly Plastic Clay Compacted with Standard Proctor Effort at a Water Content of 20% (3% Wet of Optimum).

It is usually preferable to compact the soil wet of optimum to minimize hydraulic conductivity. However, the soil must not be placed at too high a water content. Otherwise, the shear strength may be too low, there may be great risk of desiccation cracks forming if the soil dries, and ruts may form when construction vehicles pass over the liner. It is critically important that CQC and CQA inspectors verify that the water content of the soil is within the range specified in the construction documents.

2.2.3 Type of Compaction

In the laboratory, soil can be compacted in four ways:

1. Impact Compaction: A ram is repeatedly raised and dropped to compact a lift soil into a mold (Fig. 2.17a), e.g., standard and modified Proctor.

2. Static Compaction: A piston compacts a lift of soil with a constant stress (Fig. 2.17b).

3. Kneading Compaction: A "foot" kneads the soil (Fig. 2.17c).

4. Vibratory Compaction: The soil is vibrated to densify the material (Fig. 2.17d).

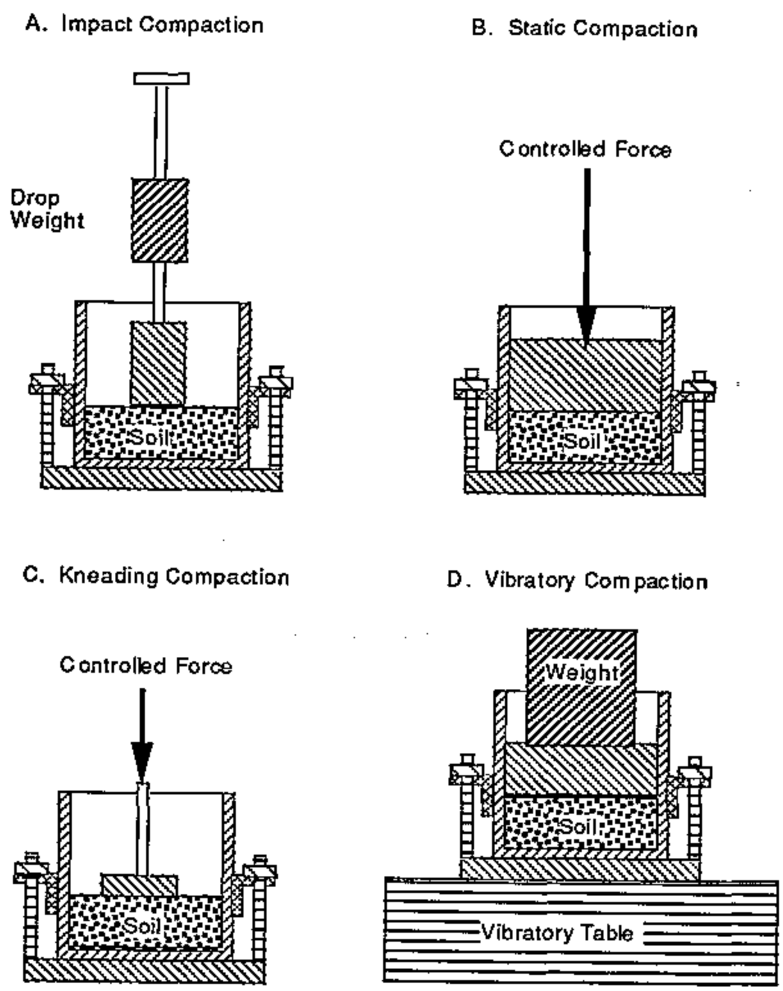


Figure 2.17 - Four Types of Laboratory Compaction Tests

Experience from the laboratory has shown that the type of compaction can affect hydraulic conductivity, e.g., as shown in Fig. 2.18. Kneading the soil helps to break down clods and remold the soil into a homogenous mass that is free of voids or large pores. Kneading of the soil is particularly beneficial for highly plastic soils. For certain bentonite-soil blends that do not form clods, kneading is not necessary. Most soil liners are constructed with "footed" rollers. The "feet" on the roller penetrate into a loose lift of soil and knead the soil with repeated passages of the roller. The dimensions of the feet on rollers vary considerably. Footed rollers with short feet (≈ 75 mm or 3 in.) are called "pad foot" rollers; the feet are said to be "partly penetrating" because the foot is too short to penetrate fully a typical loose lift of soil. Footed rollers with long feet (≈ 200 mm or 8 in.) are often called "sheepsfoot" rollers; the feet fully penetrate a typical loose lift. Figure 2.19 contrasts rollers with partly and fully penetrating feet.

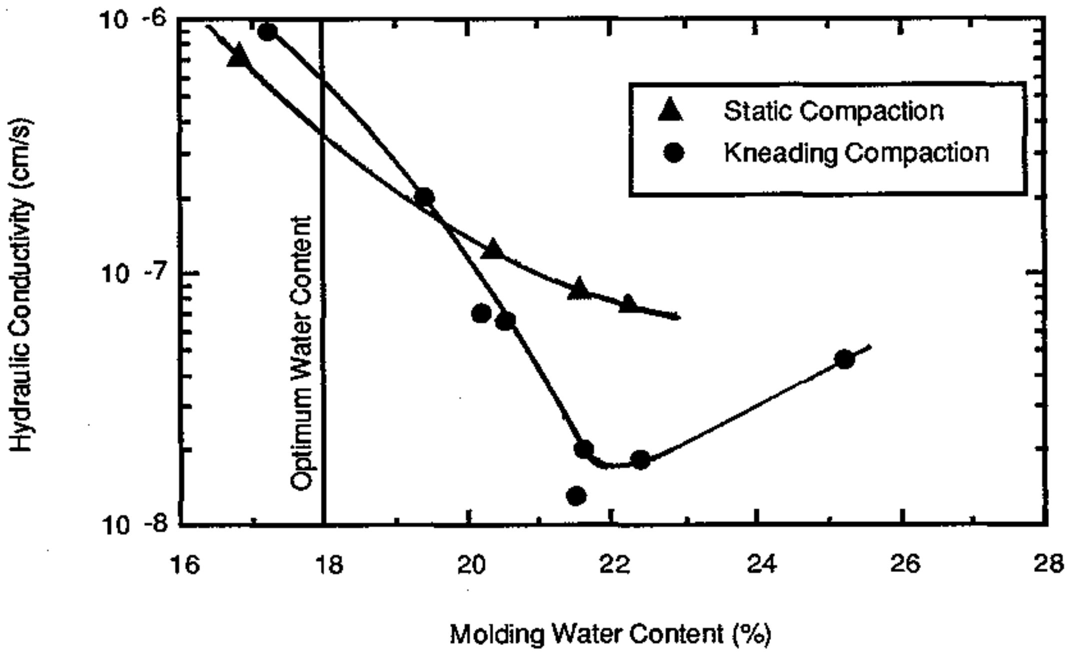


Figure 2.18 - Effect of Type of Compaction on Hydraulic Conductivity (from Mitchell et al., 1965)

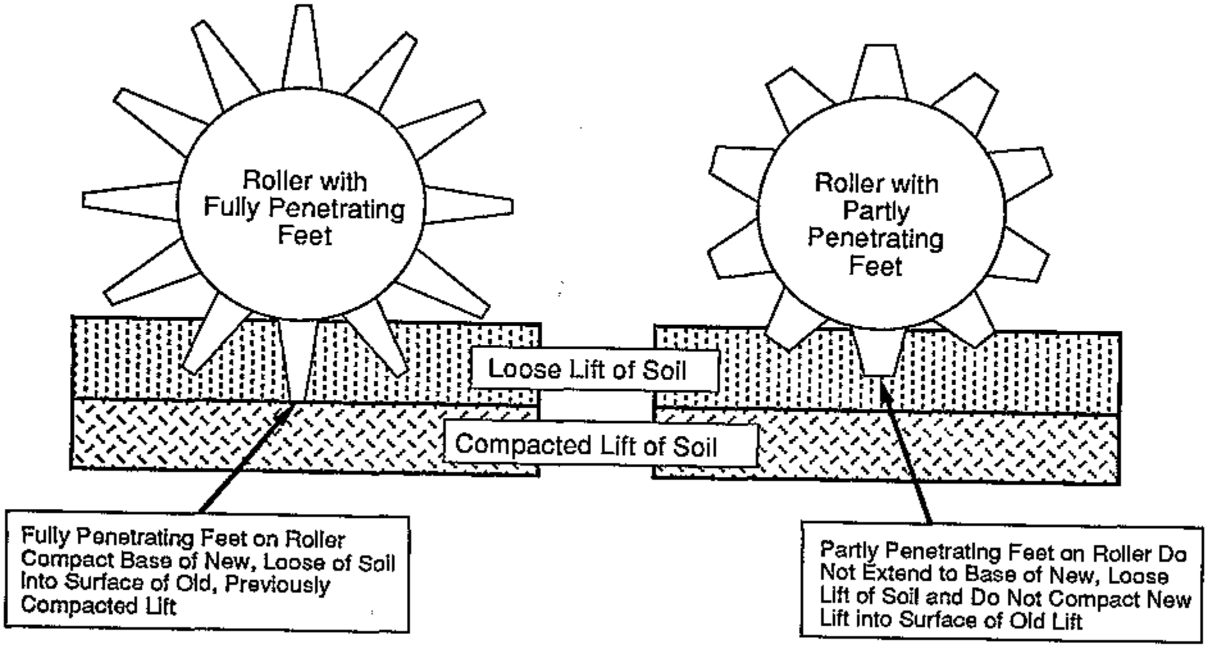


Figure 2.19 - Footed Rollers with Partly and Fully Penetrating Feet

Some construction specifications place limitations on the type of roller that can be used to compact a soil liner. Personnel performing CQC and CQA should be watchful of the type of roller to make sure it conforms to construction specifications. It is particularly important to use a roller with fully penetrating feet if such a roller is required; use of a non-footed roller or pad foot roller would result in less kneading of the soil.

2.2.4 Energy of Compaction

The energy used to compact soil can have an important influence on hydraulic conductivity. The data shown in Fig. 2.20 show that increasing the compactive effort produces soil that has a greater dry unit weight and lower hydraulic conductivity. It is important that the soil be compacted with adequate energy if low hydraulic conductivity is to be achieved.

In the field, compactive energy is controlled by:

1. The weight of the roller and the way the weight is distributed (greater weight produces more compactive energy).

2. The thickness of a loose lift (thicker lifts produce less compactive energy per unit volume of soil).

3. The number of passes of the compactor (more passes produces more compactive energy).

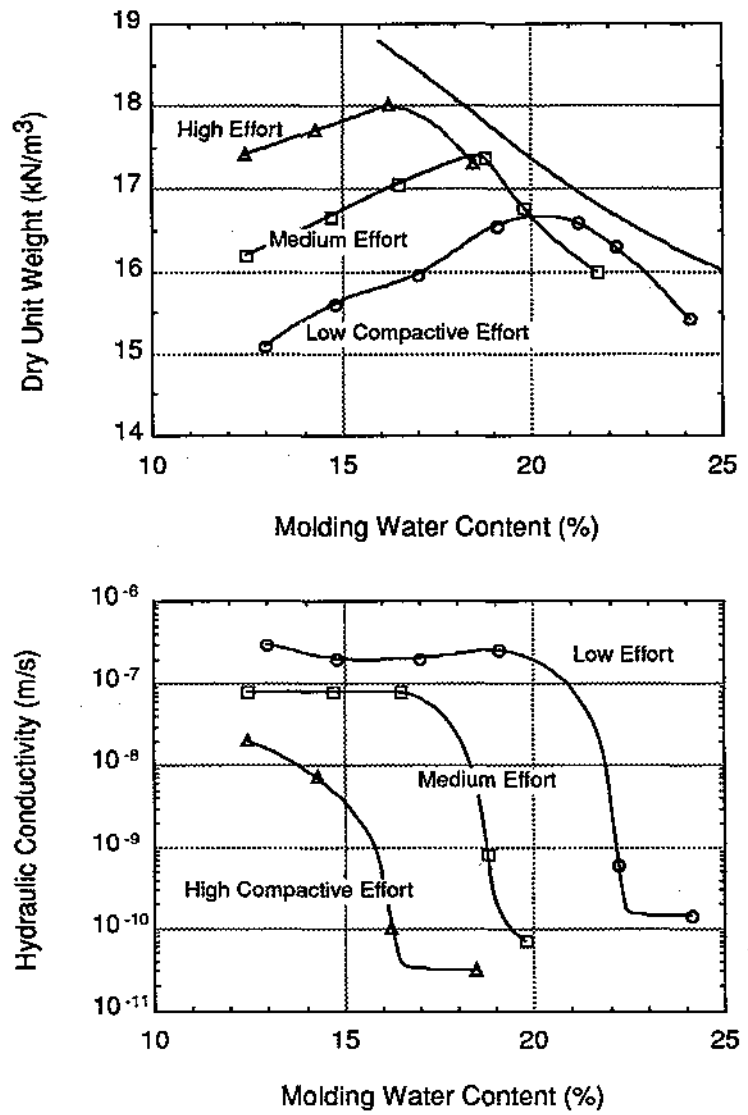


Figure 2.20 - Effect of Compactive Energy on Hydraulic Conductivity (after Mitchell et al., 1965)

Many engineers and technicians assume that percent compaction is a good measure of compactive energy. Indeed, for soils near optimum water content or dry of optimum, percent compaction is a good indicator of compactive energy: if the percent compaction is low, then the compactive energy was almost certainly low. However, for soil compacted wet of optimum, percent compaction is not a particularly good indicator of compactive energy. This is illustrated by the curves in Fig. 2.21. The same soil is compacted with Compactive Energy A and Energy B (Energy B > Energy A) to develop the compaction curves shown in Fig. 2.21. Next, two specimens are compacted to the same water content ($w_A = w_B$). The dry unit weights are practically identical ($\gamma_{d,A} \approx \gamma_{d,B}$) despite the fact that the energies of compaction were different. Further, the hydraulic conductivity (k) of the specimen compacted with the larger energy (Energy B) has a lower hydraulic conductivity than the specimen compacted with Energy A despite the fact that $\gamma_{d,A} \approx \gamma_{d,B}$. The percent compaction for the two compacted specimens is computed as follows:

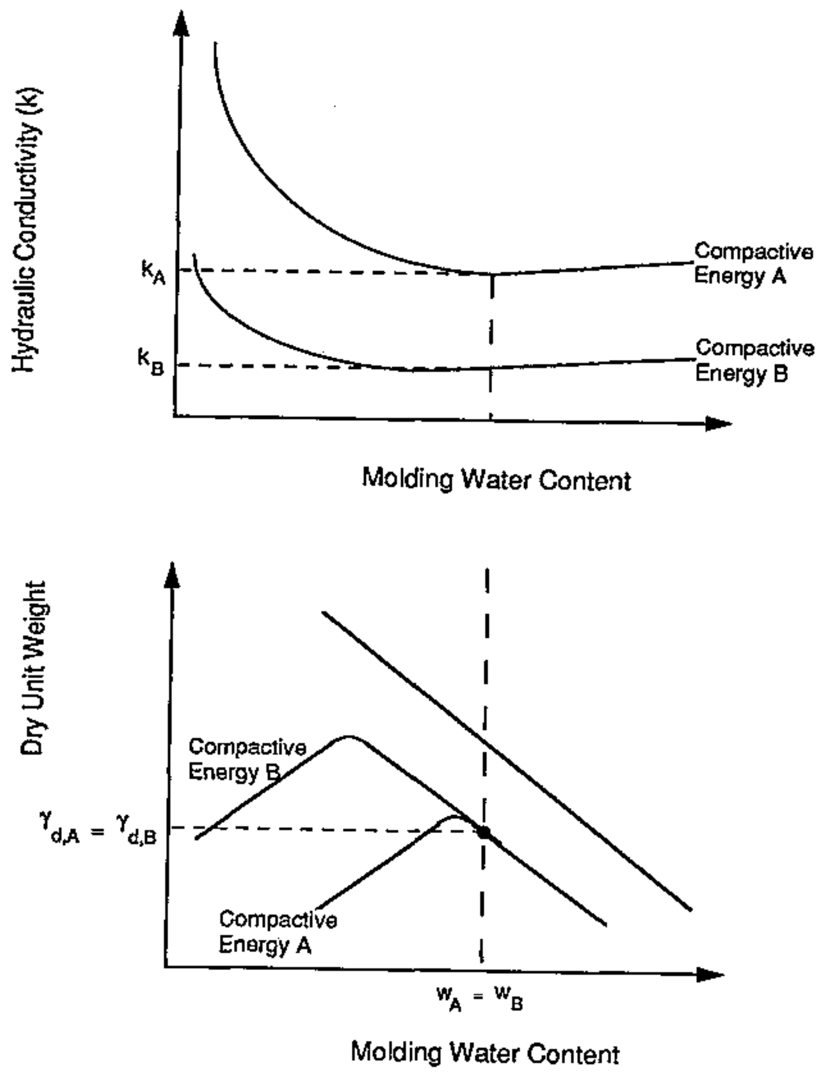


Figure 2.21 - Illustration of Why Dry Unit Weight Is a Poor Indicator of Hydraulic Conductivity for Soil Compacted Wet of Optimum

$$P_A = \gamma_{d,A}/[\gamma_{d,max}]_A \times 100\%$$

$$P_B = \gamma_{d,B}/[\gamma_{d,max}]_B \times 100\%$$

Since $\gamma_{d,A} = \gamma_{d,B}$ but $[\gamma_{d,max}]_B > [\gamma_{d,max}]_A$, then $P_A > P_B$. Thus, based on percent compaction, since $P_A > P_B$, one might assume Soil A was compacted with greater compactive energy than Soil B. In fact, just the opposite is true. CQC and CQA personnel are strongly encouraged to monitor equipment weight, lift thickness, and number of passes (in addition to dry unit weight) to ensure that appropriate compactive energy is delivered to the soil. Some CQC and CQA inspectors have failed to realize that footed rollers towed by a dozer must be filled with liquid to have the intended large weight.

Experience has shown that effective CQC and CQA for soil liners can be accomplished using the line of optimums as a reference. The "line of optimums" is the locus of (w_{opt}, $\gamma_{d,max}$) points for compaction curves developed on the same soil with different compactive energies (Fig. 2.22). The greater the percentage of actual (w,γ_d) points that lie above the line of optimums the better the overall quality of construction (Benson and Boutwell, 1992). Inspectors are encouraged to monitor the percentage of field-measured (w,γ_d) points that lie on or above the line of optimums. If the percentage is less than 80% to 90%, inspectors should carefully consider whether adequate compactive energy is being delivered to the soil (Benson and Boutwell, 1992).

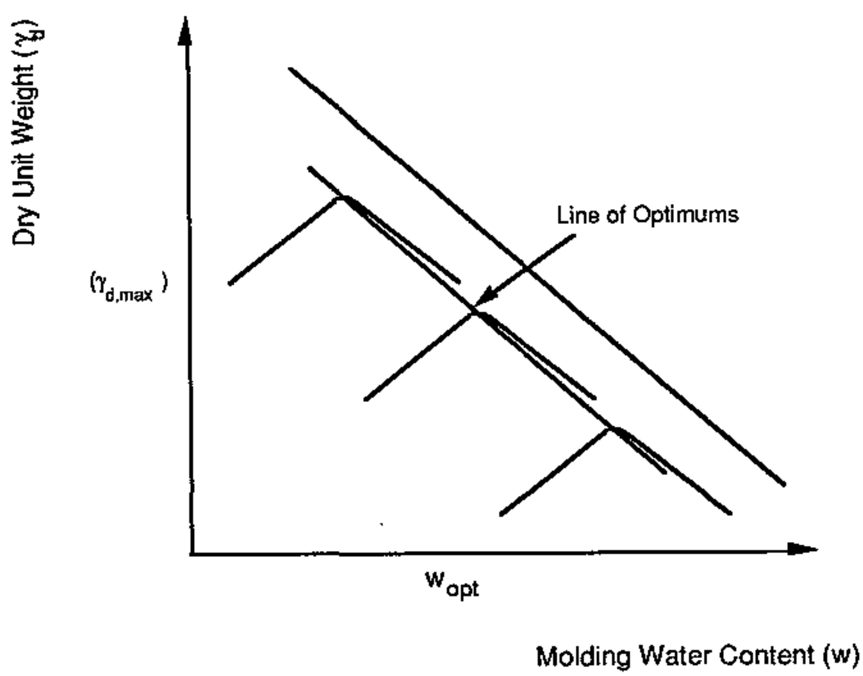


Figure 2.22 - Line of Optimums

2.2.5 Bonding of Lifts

If lifts of soil are poorly bonded, a zone of high hydraulic conductivity will develop at interfaces between lifts. Poorly bonded lift interfaces provide hydraulic connection between more permeable zones in adjacent lifts (Fig. 2.23). It is important to bond lifts together to the greatest extent possible, and to maximize hydraulic tortuosity along lift interfaces, in order to minimize the overall hydraulic conductivity.

Bonding of lifts is enhanced by:

1. Making sure the surface of a previously-compacted lift is rough before placing the new lift of soil (the previously-compacted lift is often scarified with a disc prior to placement of a new lift), which promotes bonding and increased hydraulic tortuosity along the lift interface..

2. Using a fully-penetrating footed roller (the feet pack the base of the new lift into the surface of the previously-compacted lift).

Inspectors should pay particular attention to requirements for scarification and the length of feet on rollers.

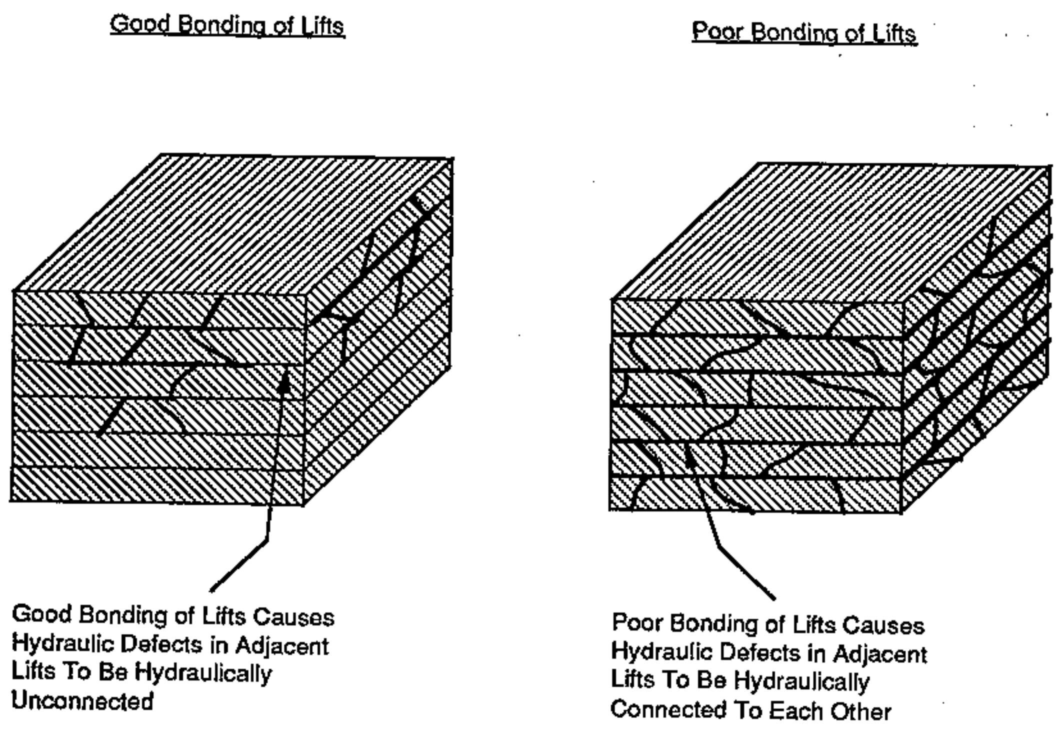


Figure 2.23 - Flow Pathways Created by Poorly Bonded Lifts

2.2.6 Protection Against Desiccation and Freezing

Clay soils shrink when they are dried and, depending on the amount of shrinkage, may crack. Cracks that extend deeper than one lift can be disastrous. Inspectors must be very careful to make sure that no significant desiccation occurs during or after construction. Water content should be measured if there are doubts.

Freezing of a soil liner will cause the hydraulic conductivity to increase. Damage caused by superficial freezing to a shallow depth is easily repaired by rerolling the surface. Deeper freezing is not so easily repaired and requires detailed investigation discussed in Section 2.9.2.3. CQC & CQA personnel should be watchful during periods when freezing temperatures are possible.

2.3 Field Measurement of Water Content and Dry Unit Weight

2.3.1 Water Content Measurement

2.3.1.1 Overnight Oven Drying (ASTM D-2216)

The standard method for determining the water content of a soil is to oven dry the soil overnight in a forced-convention oven at 110°C. This is the most fundemental and most accurate method for determining the water content of a soil. All other methods of measurement are referenced to the value of water content determined with this method.

Were it not for the fact that one has to wait overnight to determine water content with this method, undoubtedly ASTM D-2216 would be the only method of water content measurement used in the CQC and CQA processes for soil liners. However, field personnel cannot wait overnight to make decisions about continuation with the construction process.

2.3.1.2 Microwave Oven Drying (ASTM D-4643)

Soil samples can be dried in a microwave oven to obtain water contents much more quickly than can be obtained with conventional overnight oven drying. The main problem with microwave oven drying is that if the soil dries for too long in the microwave oven, the temperature of the soil will rise significantly above 110°C. If the soil is heated to a temperature greater than 110°C, one will measure a water content that is greater than the water content of the soil determined by drying at 110°C. Overheating the soil drives water out of the crystal structure of some minerals and thereby leads to too much loss of water upon oven drying.

To guard against overdrying the soil, ASTM method D-4643 requires that the soil be dried for three minutes and then weighed. The soil is then dried for an additional minute and reweighed. The process of drying for one minute and weighing the soil prevents overheating of the soil and forces the operator to cease the drying process once the weight of the soil has stabilized.

Under ideal conditions, microwave oven drying can yield water contents that are almost indistinguishable from values measured with conventional overnight oven drying. Problems that are sometimes encountered with microwave oven drying include problems in operating the oven if the soil contains significant metal and occasional problems with samples exploding from expansion of gas in the interior of the sample during microwave oven drying. Because errors can occasionally arise with microwave oven drying, the water content determined with microwave oven drying should be periodically checked with the value determined by conventional over-night oven drying (ASTM D-2216).

2.3.1.3 Direct Heating (ASTM D-4959)

Direct heating of the soil was common practice up until about two decades ago. To dry a soil with direct heating, one typically places a mass of soil into a metallic container (such as a cooking utensil) and then heats the soil over a flame, e.g., a portable cooking stove, until the soil first appears dry. The mass of the soil plus container is then measured. Next, the soil is heated some more and then re-weighed. This process is repeated until the mass ceases to decrease significantly (i.e., to change by < 0.1% or less).

The main problem with direct heating is that if the soil is overheated during drying, the water content that is measured will be too large. Although ASTM D-4959 does not eliminate this problem, the ASTM method does warn the user not to overheat the soil. Because errors can do arise with direct heating, the water content determined with direct heating should be regularly checked with the value determined by conventional over-night oven drying (ASTM D-2216).

2.3.1.4 Calcium Carbide Gas Pressure Tester (ASTM D-4944)

A known mass of moist soil is placed in a testing device and calcium carbide is introduced. Mixing is accomplished by shaking and agitating the soil with the aid of steel balls and a shaking apparatus. A measurement is made of the gas pressure produced. Water content is determined from a calibration curve. Because errors can occasionally arise with gas pressure testing, the water content determined with gas pressure testing should be periodically checked with the value determined by conventional over-night oven drying (ASTM D-2216).

2.3.1.5 Nuclear Method (ASTM D-3017)

The most widely used method of measuring the water content of compacted soil is the nuclear method. Measurement of water content with a nuclear device involves the moderation or thermalization of neutrons provided by a source of fast neutrons. Fast neutrons are neutrons with an energy of approximately 5 MeV. The radioactive source of fast neutrons is embedded in the interior part of a nuclear water content/density device (Fig. 2.24). As the fast neutrons move into the soil, they undergo a reduction in energy every time a hydrogen atom is encountered. A series of energy reductions takes place when a neutron sequentially encounters hydrogen atoms. Finally, after an average of nineteen collisions with hydrogen atoms, a neutron ceases to lose further energy and is said to be a "thermal" neutron with an energy of approximately 0.025 MeV. A detector in the nuclear device senses the number of thermal neutrons that are encountered. The number of thermal neutrons that are encountered over a given period of time is a function of the number of fast neutrons that are emitted from the source and the density of hydrogen atoms in the soil located immediately below the nuclear device. Through appropriate calibration, and with the assumption that the only source of hydrogen in the soil is water, the nuclear device provides a measure of the water content of the soil over an average depth of about 200 mm (8 in.).

There are a number of potential sources of error with the nuclear water content measuring device. The most important potential source of error is extraneous hydrogen atoms not associated with water. Possible sources of hydrogen other than water include hydrocarbons, methane gas, hydrous minerals (e.g., gypsum), hydrogen-bearing minerals (e.g., kaolinite, illite, and montmorillonite), and organic matter in the soil. Under extremely unfavorable conditions the nuclear device can yield water content measurements that are as much as ten percentage points in error (almost always on the high side). Under favorable conditions, measurement error is less than one percent. The nuclear device should be calibrated for site specific soils and changing conditions within a given site.

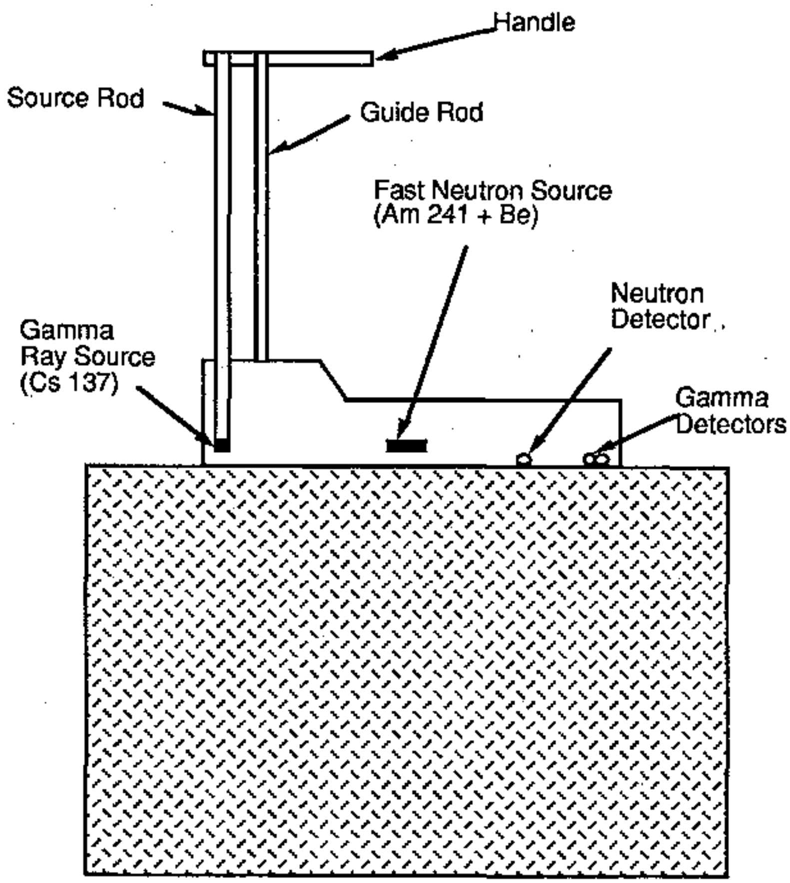


Figure 2.24 - Schematic Diagram of Nuclear Water Content - Density Device

Another potential source of error is the presence of individuals, equipment, or trenches located within one meter of the device (all of which can cause an error). The device must be warmed up for an adequate period of time or the readings may be incorrect. If the surface of the soil is improperly prepared and the device is not sealed properly against a smooth surface, erroneous measurements can result. If the standard count, which is a measure of the intensity of radiation from the source, has not been taken recently an erroneous reading may result. Finally, many nuclear devices allow the user to input a moisture adjustment factor to correct the water content reading by a fixed amount. If the wrong moisture adjustment factor is stored in the device's computer, the reported water content will be in error.

It is very important that the CQC and CQA personnel be well versed in the proper use of nuclear water content measurement devices. There are many opportunities for error if personnel are not properly trained or do not correctly use the equipment. As indicated later, the nuclear device should be checked with other types of equipment to ensure that site-specific variables are not influencing test results. Nuclear equipment may be checked against other nuclear devices (particularly new devices or recently calibrated devices) to minimize potential for errors.

2.3.2 Unit Weight

2.3.2.1 Sand Cone (ASTM D-1556)

The sand cone is a device for determining the volume of a hole that has been excavated into soil. The idea is to determine the weight of sand required to fill a hole of unknown volume. Through calibration, the volume of sand that fills the hole can be determined from the weight of sand needed to fill the hole. A schematic diagram of the sand cone is shown in Fig. 2.25.

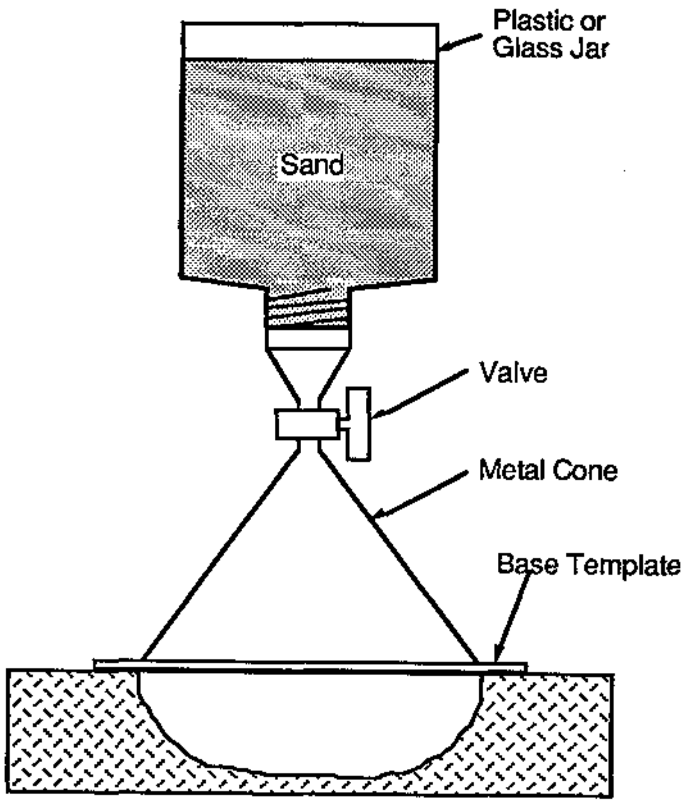


Figure 2.25 - Sand Cone Device

The sand cone is used as follows. First, a template is placed on the ground surface. A circle is scribed along the inside of the hole in the template. The template is removed and soil is excavated from within the area marked by the scribed circle. The soil that is excavated is weighed to determine the total weight (W) of the soil excavated. The excavated soil is oven dried (e.g., with a microwave oven) to determine the water content of the soil. The bottle in a sand cone device is filled with sand and the full bottle is weighed. The template is placed over the hole and the sand cone device is placed on top of the template. A valve on the sand cone device is opened, which allows sand to rain down through the inverted funnel of the device and inside the excavated hole.

When the hole and funnel are filled with sand, the valve is closed and the bottle containing sand is weighed. The difference in weight before and after the hole is dug is calculated. Through calibration, the weight of sand needed to fill the funnel is subtracted, and the volume of the hole is computed from the weight of sand that filled the hole. The total unit weight is calculated by dividing the weight of soil excavated by the computed volume of the excavated hole. The dry unit weight is then calculated from Eq. 2.1.

The sand cone device provides a reliable technique for determining the dry unit weight of the soil. The primary sources of error are improper calibration of the device, excavation of an uneven hole that has sharp edges or overhangs that can produce voids in the sand-filled hole, variations in the sand, excessively infrequent calibrations, contamination of the sand by soil particles if the sand is reused, and vibration as from equipment operating close to the sand cone.

2.3.2.2 Rubber Balloon (ASTM D-2167)

The rubber balloon is similar to the sand cone except that water is used to fill the excavated hole rather than sand. A rubber balloon device is sketched in Fig. 2.26. As with the sand cone test, the test is performed with the device located on the template over the leveled soil. Then a hole is excavated into the soil and the density measuring device is again placed on top of a template at the ground surface. Water inside the rubber balloon device is pressurized with air to force the water into the excavated hole. A thin membrane (balloon) prevents the water from entering the soil. The pressure in the water forces the balloon to conform to the shape of the excavated hole. A graduated scale on the rubber balloon device enables one to determine the volume of water required to fill the hole. The total unit weight is calculated by dividing the known weight of soil excavated from the hole by the volume of water required to fill the hole with the rubber balloon device. The dry unit weight is computed from Eq. 2.1.

The primary sources of error with the rubber balloon device are improper excavation of the hole (leaving small zones that cannot be filled by the pressurized balloon), excessive pressure that causes local deformation of the adjacent soil, rupture of the balloon, and carelessness in operating the device (e.g., not applying enough pressure to force the balloon to fill the hole completely).

2.3.2.3 Drive Cylinder (ASTM D-2937)

A drive cylinder is sketched in Fig. 2.27. A drop weight is used to drive a thin-walled tube sampler into the soil. The sampler is removed from the soil and the soil sample is trimmed flush to the bottom and top of the sampling tube. The soil-filled tube is weighed and the known weight of the sampling tube itself is subtracted to determine the gross weight of the soil sample. The dimensions of the sample are measured to enable calculation of volume. The unit weight is calculated by dividing the known weight by the known volume of the sample. The sample is oven dried (e.g., in a microwave oven) to determine water content. The dry unit weight is computed from Eq. 2.1.

The primary problems with the drive cylinder are sampling disturbance caused by rocks or stones in the soil, densification of the soil caused by compression resulting from driving of the tube into the soil, and nonuniform driving of the tube into the soil. The drive cylinder method is not recommended for stony or gravely soils. The drive cylinder method works best for relatively soft, wet clays that do not tend to densify significantly when the tube is driven into the soil and for soils that are free of gravel or stones. However, even under favorable circumstances, densification of the soil caused by driving the ring into the soil can cause an increase in total unit weight of 2 to 5 pcf (0.3 to 0.8 kN/m^3).

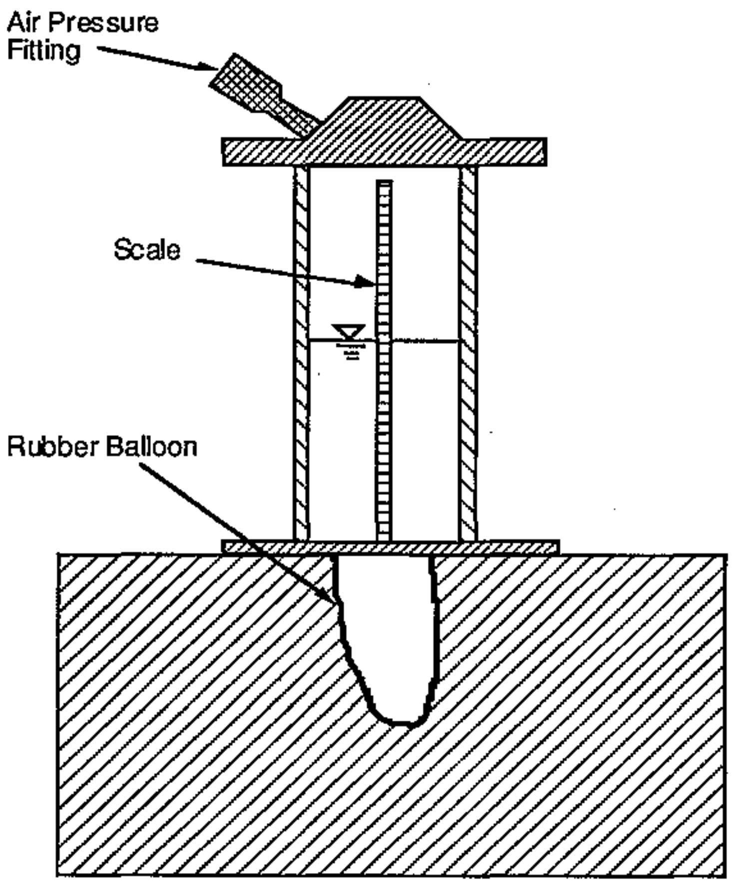


Figure 2.26 - Schematic Diagram of Rubber Balloon Device

2.3.2.4 Nuclear Method (ASTM D-2922)

Unit weight can be measured with a nuclear device operated in two ways as shown in Fig. 2.28. The most common usage is called *direct transmission* in which a source of gamma radiation is lowered down a hole made into the soil to be tested (Fig. 2.28a). Detectors located in the nuclear density device sense the intensity of gamma radiation at the ground surface. The intensity of gamma radiation detected at the surface is a function of the intensity of gamma radiation at the source and the total unit weight of the soil material. The second mode of operation of the nuclear density device is called *backscattering*. With this technique the source of gamma radiation is located at the ground surface (Fig. 2.28b). The intensity of gamma radiation detected at the surface is a function of the density of the soil as well as the radioactivity of the source. With the backscattering technique, the measurement is heavily dependent upon the density of the soil within the upper 25 to 50 mm of soil. The direct transmission method is the recommended technique for soil liners because direct transmission provides a measurement averaged over a greater depth than backscattering.

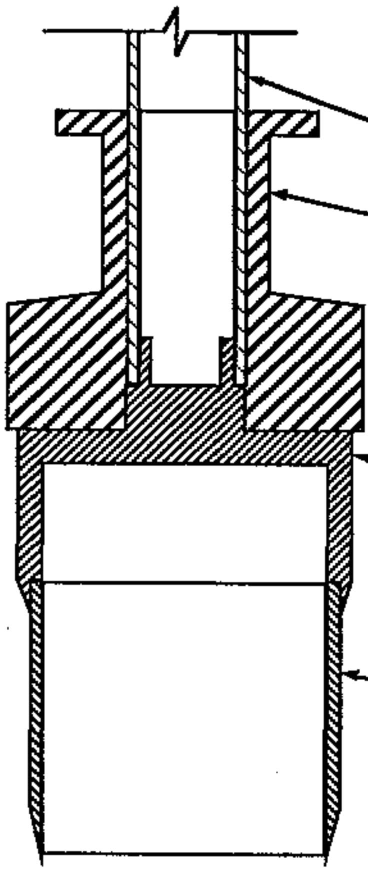


Figure 2.27 - Schematic Diagram of Drive Ring

The operation of a nuclear density device in the direct transmission mode is as follows. First, the area to be tested is smoothed, and a hole is made into the soil liner material by driving a rod (called the *drive rod*) into the soil. The diameter of the hole is approximately 25 mm (1 in.) and the depth of the hole is typically 50 mm (2 in.) greater than the depth to which the gamma radiation source will be lowered below the surface. The nuclear device is then positioned with the source rod directly over the hole in the soil liner material. The source rod is then lowered to a depth of approximately 50 mm (2 in.) above the base of the hole. The source is then pressed against the surface of the hole closest to the detector by pulling on the nuclear device and forcing the source to bear against the side of the hole closest to the detector. The intent is to have good contact between the source and soil along a direct line from source to detector. The intensity of radiation at the detector is measured for a fixed period of time, e.g., 30 or 60 s. The operator can select the period of counting. The longer the counting period, the more accurate the measurement. However, the counting period cannot be extended too much because productivity will suffer.

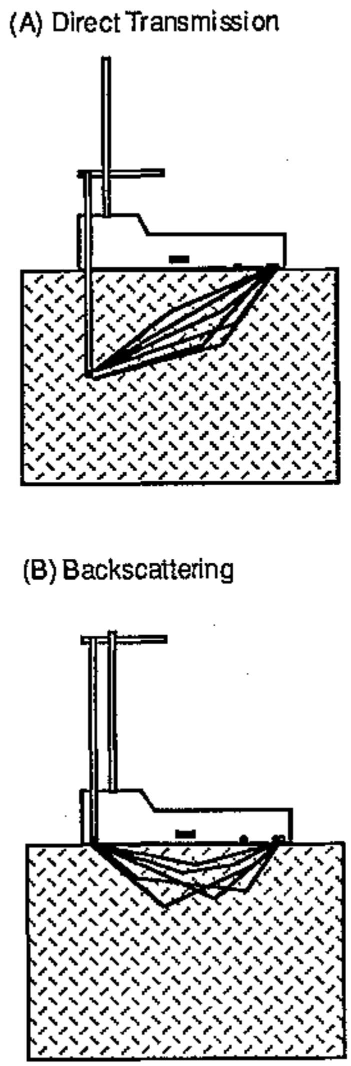


Figure 2.28 - Measurement of Density with Nuclear Device by (a) Direct Transmission and (B) Backscattering

After total unit weight has been determined, the measured water content is used to compute dry unit weight (Eq. 2.1). The potential sources of error with the nuclear device are fewer and less significant in the density-measuring mode compared to the water content measuring mode. The most serious potential source of error is improper use of the nuclear density device by the operator. One gross error that is sometimes made is to drive the source rod into the soil rather than inserting the source rod into a hole that had been made earlier with the drive rod. Improper separation of the source from the base of the hole, an inadequate period of counting, inadequate warm-up, spurious sources of gamma radiation, and inadequate calibration are other potential sources of error.

2.4 Inspection of Borrow Sources Prior to Excavation

2.4.1 Sampling for Material Tests

In order to determine the properties of the borrow soil, samples are often obtained from the potential borrow area for laboratory analysis prior to actual excavation but as part of the construction contract. Samples may be obtained in several ways. One method of sampling is to drill soil borings and recover samples of soil from the borings. This procedure can be very effective in identifying major strata and substrata within the borrow area. Small samples obtained from the borings are excellent for index property testing but often do not provide a very good indication of subtle stratigraphic changes in the borrow area. Test pits excavated into the borrow soil with a backhoe, frontend loader, or other excavation equipment can expose a large cross-section of the borrow soil. One can obtain a much better idea of the variability of soil in the potential borrow area by examining exposed cuts rather than viewing small soil samples obtained from borings.

Large bulk samples of soil are required for compaction testing in the laboratory. Small samples of soil taken with soil sampling devices do not provide a sufficient volume of soil for laboratory compaction testing. Some engineers combine samples of soil taken at different depths or from different borings to produce a composite sample of adequate volume. This technique is not recommended because a degree of mixing takes place in forming the composite laboratory test sample that would not take place in the field. Other engineers prefer to collect material from auger borings for use in performing laboratory compaction tests. This technique is likewise not recommended without careful borrow pit control because vertical mixing of material takes place during auguring in a way that would not be expected to occur in the field unless controlled vertical cuts are made. The best method for obtaining large bulk samples of material for laboratory compaction testing is to take a large sample of material from one location in the borrow source. A large, bulk sample can be taken from the wall or floor of a test pit that has been excavated into the borrow area. Alternatively, a large piece of drilling equipment such as a bucket auger can be used to obtain a large volume of soil from a discreet point in the ground.

2.4.2. Material Tests

Samples of soil must be taken for laboratory testing to ensure conformance with specifications for parameters such as percentage fines and plasticity index. The samples are sometimes taken in the borrow pit, are sometimes taken from the loose lift just prior to compaction, and are sometimes taken from both. If samples are taken from the borrow area, CQA inspectors track the approximate volumes of soil excavated and sample at the frequency prescribed in the CQA plan. Sometimes borrow-source testing is performed prior to issuing of a contract to purchase the borrow material. A CQA program cannot be implemented for work already completed. The CQA personnel will have ample opportunity to check the properties of soil materials later during excavation and placement of the soils. If the CQA personnel for a project did not observe borrow soil testing, the CQA personnel should review the results of borrow soil testing to ensure that the required tests have been performed. Additional testing of the borrow material may be required during excavation of the material.

The material tests that are normally performed on borrow soil are water content, Atterberg limits, particle size distribution, compaction curve, and hydraulic conductivity (Table 2.2). Each of these tests is discussed below.

Table 2.2 - Materials Tests

Parameter	ASTM Test Method	Title of ASTM Test
Water Content	D-2216	Laboratory Determination of Water (Moisture) Content of Soil and Rock
	D-4643	Determination of Water (Moisture) Content of Soil by the Microwave Oven Method
	D-4944	Field determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester Method
	D-4959	Determination of Water (Moisture) Content by Direct Heating Method
Liquid Limit, Plastic Limit, & Plasticity Index	D-4318	Liquid Limit, Plastic Limit, and Plasticity Index of Soils
Particle Size Distribution	D-422	Particle Size Analysis of Soil
Compaction Curve	D-698	Moisture-Density Relations for Soils and Soil-Aggregate Mixtures Using 5.5-lb. (2.48-kg) Rammer and 12-in. (305-mm) Drop
	D-1557	Moisture-Density Relations for Soils and Soil-Aggregate Mixtures Using 10-lb. (4.54-kg) Rammer and 18-in. (457-mm) Drop
Hydraulic Conductivity	D-5084	Measurement of Hydraulic Conductivity of Saturated Porous Materials Using A Flexible Wall Permeameter

2.4.2.1 Water Content

It is important to know the water content of the borrow soils so that the need for wetting or drying the soil prior to compaction can be identified. The water content of the borrow soil is normally measured following the procedures outlined in ASTM D-2216 if one can wait overnight for results. If not, other test methods described in Section 2.3.1 and listed in Table 2.2 can be used to produce results faster.

2.4.2.2 Atterberg Limits

Construction specifications for compacted soil liners often require a minimum value for the liquid limit and/or plasticity index of the soil. These parameters are measured in the laboratory with the procedures outlined in ASTM D-4318.

2.4.2.3 Particle Size Distribution

Construction specifications for soil liners often place limits on the minimum percentage of fines, the maximum percentage of gravel, and in some cases the minimum percentage of clay. Particle size analysis is performed following the procedures in ASTM D-422. Normally the requirements for the soil material are explicitly stated in the construction specifications. An experienced inspector can often judge the percentage of fine material and the percentage of sand or gravel in the soil. However, compliance with specifications is best documented by laboratory testing.

2.4.2.4 Compaction Curve

Compaction curves are developed utilizing the method of laboratory compaction testing required in the construction specifications. Standard compaction (ASTM D-698) and modified compaction (ASTM D-1557) are two common methods of laboratory compaction specified for soil liners. However, other compaction methods (particularly those unique to state highway or transportation departments) are sometimes specified.

Great care should be taken to follow the procedures for soil preparation outlined in the relevant test method. In particular, the drying of a cohesive material can change the Atterberg limits as well as the compaction characteristics of the soil. If the test procedure recommends that the soil not be dried, the soil should not be dried. Also, care must be taken when sieving the soil not to remove clods of cohesive material. Rather, clods of soil retained on a sieve should be broken apart by hand if necessary to cause them to pass through the openings of the sieve. Sieves should only be used to remove stones or other large pieces of material following ASTM procedures.

2.4.2.5 Hydraulic Conductivity

The hydraulic conductivity of compacted samples of borrow material may be measured periodically to verify that the soil liner material can be compacted to achieve the required low hydraulic conductivity. Several methods of laboratory permeation are available, and others are under development. ASTM D-5084 is the only ASTM procedure currently available. Care should be taken not to apply excessive effective confining stress to test specimens. If no value is specified in the CQA plan, a maximum effective stress of 35 kPa (5 psi) is recommended for both liner and cover systems.

Care should be taken to prepare specimens for hydraulic conductivity testing properly. In addition to water content and dry unit weight, the method of compaction and the compactive energy can have a significant influence on the hydraulic conductivity of laboratory-compacted soils. It is particularly important not to deliver too much compactive energy to attain a desired dry unit weight. The purpose of the hydraulic conductivity test is to verify that borrow soils can be compacted to the desired hydraulic conductivity using a reasonable compactive energy.

No ASTM compaction method exists for preparation of hydraulic conductivity test specimens. The following procedure is recommended:

1. Obtain a large, bulk sample of representative material with a mass of approximately 20 kg.

2. Develop a laboratory compaction curve using the procedure specified in the construction specifications for compaction control, e.g., ASTM D-698 or D-1557.

3. Determine the target water content (w_{target}) and dry unit weight ($\gamma_{d,target}$) for the hydraulic conductivity test specimen. The value of w_{target} is normally the lowest acceptable water content and $\gamma_{d,target}$ is normally the minimum acceptable dry unit weight (Fig. 2.29).

4. Enough soil to make several test specimens is mixed to w_{target}. The compaction procedure used in Step 2 is used to prepare a compacted specimen, except that the energy of compaction is reduced, e.g., by reducing the number of drops of the ram per lift. The dry unit weight (γ_d) is determined. If $\gamma_d \approx \gamma_{d,\ target}$, the compacted specimen may be used for hydraulic conductivity testing. If $\gamma_d \neq \gamma_{d,target}$, then another test specimen is prepared with a larger or smaller (as appropriate) compactive energy. Trial and error preparation of test specimens is repeated until $\gamma_d \approx \gamma_{d,\ target}$. The procedure is illustrated in Fig. 2.29. The actual compactive effort should be documented along with hydraulic conductivity.

5. Atterberg limits and percentage fines should be determined for each bulk sample. Water content and dry density should be reported for each compacted specimen.

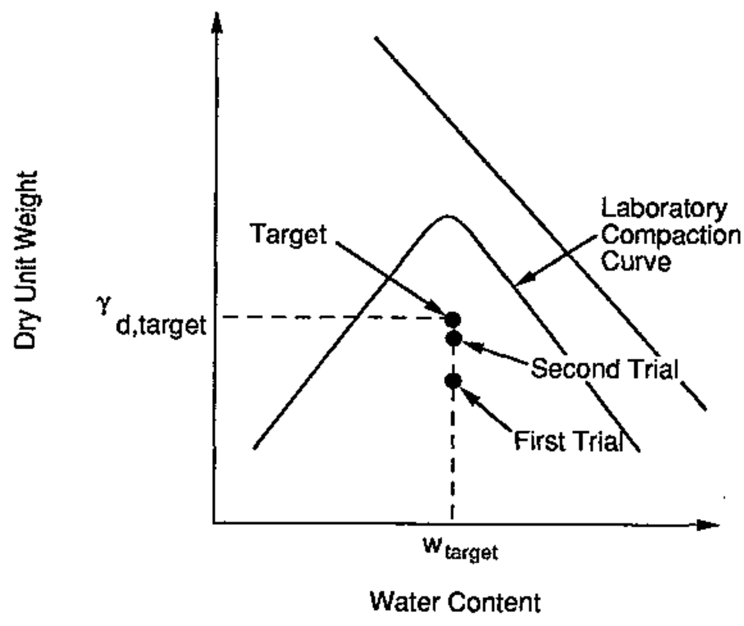


Figure 2.29 - Recommended Procedure for Preparation of a Test Specimen Using Variable (But Documented) Compactive Energy for Each Trial

2.4.2.6 Testing Frequency

The CQA plan should stipulate the frequency of testing. Recommended minimum values are shown in Table 2.3. The tests listed in Table 2.3 are normally performed prior to construction as part of the characterization of the borrow source. However, if time or circumstances do not permit characterization of the borrow source prior to construction, the samples for testing are obtained during excavation or delivery of the soil materials.

Table 2.3 - Recommended Minimum Testing Frequencies for Investigation of Borrow Source

Parameter	Frequency
Water Content	1 Test per 2000 m^3 or Each Change in Material Type
Atterberg Limits	1 Test per 5000 m^3 or Each Change in Material Type
Percentage Fines	1 Test per 5000 m^3 or Each Change in Material Type
Percent Gravel	1 Test per 5000 m^3 or Each Change in Material Type
Compaction Curve	1 Test per 5000 m^3 or Each Change in Material Type
Hydraulic Conductivity	1 Test per 10,000 m^3 or Each Change in Material Type

Note: 1 yd^3 = 0.76 m^3

2.5 Inspection during Excavation of Borrow Soil

It is strongly recommended that a qualified inspector who reports directly to the CQA engineer observe all excavation of borrow soil in the borrow pit. Often the best way to determine whether deleterious material is present in the borrow soil is to observe the excavation of the soil directly.

A key factor for inspectors to observe is the plasticity of the soil. Experienced technicians can often determine whether or not a soil has adequate plasticity by carefully examining the soil in the field. A useful practice for field identification of soils is ASTM D-2488, "Description and Identification of Soils (Visual-Manual Procedure)." The following procedure is used for identifying clayey soils.

- Dry strength: The technician selects enough soil to mold into a ball about 25 mm (1 in.) in diameter. Water is added if necessary to form three balls that each have a diameter of about 12 mm (1/2 in.). The balls are allowed to dry in the sun. The strength of the dry balls is evaluated by crushing them between the fingers. The dry strength is described with the criteria shown in Table 2.4. If the dry strength is none or low, inspectors should be alerted to the possibility that the soil lacks adequate plasticity.

- Plasticity: The soil is moistened or dried so that a test specimen can be shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about 3 mm (1/8 in.) in diameter. If the sample is too wet to roll easily it should be spread into a thin layer and allowed to lose some water by evaporation. The sample threads are re-rolled repeatedly until the thread crumbles at a diameter of about 3 mm (1/8 in.). The thread will crumble at a diameter of 3 mm when the soil is near the plastic limit. The plasticity is described from the criteria shown in Table 2.5, based upon observations made during the toughness test. Non-plastic soils are usually unsuitable for use as soil liner materials without use of amendments such as bentonite.

Table 2.4 - Criteria for Describing Dry Strength (ASTM D-2488)

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very High	The dry specimen cannot be broken between the thumb and a hard surface

Table 2.5 - Criteria for Describing Plasticity (ASTM D-2488)

Description	Criteria
Nonplastic	A 3 mm (1/8-in.) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	A thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

2.6 Preprocessing of Materials

Some soil liner materials are ready to be used for final construction immediately after they are excavated from the borrow pit. However, most materials require some degree of processing prior to placement and compaction of the soil.

2.6.1 Water Content Adjustment

Soils that are too wet must first be dried. If the water content needs to be reduced by no more than about three percentage points, the soil can be dried after it has been spread in a loose lift just prior to compaction. If the water content must be reduced by more than about 3 percentage points, it is recommended that drying take place in a separate processing area. The reason for drying in a separate processing area is to allow adequate time for the soil to dry uniformly and to facilitate mixing of the material during drying. The soil to be dried is spread in a lift about 225 to 300 mm (9 to 12 in.) thick and allowed to dry. Water content is periodically measured using one or more of the methods listed in Table 2.2. The contractor's CQC personnel should check the soil periodically to determine when the soil has reached the proper water content.

The CQA inspectors should check to be sure that the soil is periodically mixed with a disc or rototiller to ensure uniform drying. The soil cannot be considered to be ready for placement and compaction unless the water is uniformly distributed; water content measurements alone do not ensure that water is uniformly distributed within the soil.

If the soil must be moistened prior to compaction, the same principles discussed above for drying apply; water content adjustment in a separate preprocessing area is recommended if the water content must be increased by more than about 3 percentage points. Inspectors should be careful to verify that water is distributed uniformly to the soil (a spreader bar on the back of a water truck is the recommended device for moistening soil uniformly), that the soil is periodically mixed with a disc or rototiller, and that adequate time has been allowed for uniform hydration of the soil. If the water content is increased by more than three percentage points, at least 24 to 48 hours would normally be required for uniform absorption of water and hydration of soil particles. The construction specifications may limit the type of water that can be used; in some cases, contaminated water, brackish water, or sea water is not allowed.

2.6.2 Removal of Oversize Particles

Oversized stones and rocks should be removed from the soil liner material. Stones and rocks interfere with compaction of the soil and may create undesirable pathways for fluid to flow through the soil liner. The construction specifications should stipulate the maximum allowable size of particles in the soil liner material.

Oversized particles can be removed with mechanical equipment (e.g., large screens) or by hand. Inspectors should examine the loose lift of soil after the contractor has removed oversized particles to verify that oversized particles are not present. Sieve analyses alone do not provide adequate assurance that oversized materials have been removed -- careful visual inspection for oversized material should be mandatory.

2.6.3 Pulverization of Clods

Some specifications for soil liners place limitations on the maximum size of chunks or clods of clay present in the soil liner material. Discs, rototillers, and road recyclers are examples of mechanical devices that will pulverize clods in a loose lift. Visual inspection of the loose lift of material is normally performed to ensure that clods of soil have been pulverized to the extent required in the construction specifications. Inspectors should be able to visually examine the entire surface of a loose lift to determine whether clods have been adequately processed. No standard method exists for determining clod size. Inspectors normally measure the dimensions of an individual clod with a ruler.

2.6.4 Homogenizing Soils

CQC and CQA are very difficult to perform for heterogeneous materials. It may be necessary to blend and homogenize soils prior to their use in constructing soil liners in order to maintain proper CQC and CQA. Soils can be blended and homogenized in a pugmill. The best way to ensure adequate mixing of materials is through visual inspection of the mixing process itself.

2.6.5 Bentonite

Bentonite is a common additive to soil liner materials that do not contain enough clay to achieve the desired low hydraulic conductivity. Inspectors must ensure that the bentonite being used for a project is in conformance with specifications (i.e., is of the proper quality and gradation) and that the bentonite is uniformly mixed with soil in the required amounts.

The parameters that are specified for the bentonite quality vary considerably from project to project. The construction specifications should stipulate the criteria to be met by the bentonite and the relevant test methods. The quality of bentonite is usually measured with some type of measurement of water adsorption ability of the clay. Direct measurement of water adsorption can be accomplished using the plate water adsorption test (ASTM E-946). This test is used primarily in the taconite iron ore industry to determine the effectiveness of bentonite, which is used as a binder during the pelletizing process to soak up excess water in the ore. Brown (1992) reports that thousands of plate water adsorption tests have been performed on bentonite, but experience has been that the test is time consuming, cumbersome, and extremely sensitive to variations in the test equipment and test conditions. The plate water adsorption test is not recommended for CQC/CQA of soil liners.

Simple, alternative tests that provide an indirect indication of water adsorption are available. One indirect test for water adsorption is measurement of Atterberg (liquid and plastic) limits via ASTM D-4318. The higher the quality of the bentonite, the higher the liquid limit and plasticity index. Although liquid and plastic limits tests are very common for natural soils, they have not been frequently used as indicators of bentonite quality in the bentonite industry. A commonly-used test in the bentonite industry is the free swell test. The free swell test is used to determine the amount of swelling of bentonite when bentonite is exposed to water in a glass beaker. Unfortunately, there is currently no ASTM test for determining free swell of bentonite, although one is under development. Until such time as an ASTM standard is developed, the bentonite supplier may be consulted for a suggested testing procedure.

The liquid limit test and free swell test are recommended as the principal quality control tests for the quality of bentonite being used on a project. There are no widely accepted cutoff values for the liquid limit and free swell. However, the following is offered for the information of CQC and CQA inspectors. The liquid limit of calcium bentonite is frequently in the range of 100 to 150%. Sodium bentonite of medium quality is expected to have a liquid limit of approximately 300 to 500%. High-quality sodium bentonite typically has a liquid limit in the range of about 500 to 700%. According to Brown (1992), calcium bentonites usually have a free swell of less than 6 cc. Low-grade sodium bentonites typically have a free swell of 8 - 15 cc. High-grade bentonites often have free swell values in the range of 18 to 28 cc. If high-grade sodium bentonite is to be used on a project, inspectors should expect that the liquid limit will be ≥ 500% and the free swell will be ≥ 18 cc.

The bentonite must usually also meet gradational requirements. The gradation of the dry bentonite may be determined by carefully sieving the bentonite following procedures outlined in ASTM D-422. The CQA inspector should be particularly careful to ensure that the bentonite has been pulverized to the extent required in the construction specifications. The degree of pulverization is frequently overlooked. Finely-ground, powdered bentonite will behave differently when blended into soil than more coarsely ground, granular bentonite. CQC/CQA personnel should be particularly careful to make sure that the bentonite is sufficiently finely ground and is not delivered in too coarse a form (per project specifications); sieve tests on the raw bentonite received at a job site are recommended to verify gradation of the bentonite.

The bentonite supplier is expected to certify that the bentonite meets the specification requirements. However, CQA inspectors should perform their own tests to ensure compliance with the specifications. The recommended CQA tests and testing frequencies for bentonite quality and gradation are summarized in Table 2.6.

Table 2.6 - Recommended Tests on Bentonite to Determine Bentonite Quality and Gradation

Parameter	Frequency	Test Method
Liquid Limit	1 per Truckload or 2 per Rail Car	ASTM D-4318, "Liquid Limit, Plastic Limit, and Plasticity Index of Soils"
Free Swell	1 per Truckload or 2 per Rail Car	No Standard Procedure Is Available
Grain Size of Dry Bentonite	1 per Truckload or 2 per Rail Car	ASTM D-422, "Particle Size Analysis of Soil"

2.6.5.1 Pugmill Mixing

A pugmill is a device for mixing dry materials. A schematic diagram of a typical pugmill is shown in Fig. 2.30. A conveyor belt feeds soil into a mixing unit, and bentonite drops downward into the mixing unit. The materials are mixed in a large box that contains rotating rods with mixing paddles. Water may be added to the mixture in the pugmill, as well.

The degree of automation of pugmills varies considerably. The most sophisticated pugmills have computer-controlled devices to monitor the amounts of the ingredients being mixed. CQA personnel should monitor the controls on the mixing equipment.

2.6.5.2 In-Place Mixing

An alternative mixing technique is to spread the soil in a loose lift, distribute bentonite on the surface, and mix the bentonite and soil using a rototiller or other mixing equipment. There are several potential problems with in-place mixing. The mixing equipment may not extend to an adequate depth and may not fully mix the loose lift of soil with bentonite. Alternatively, the mixing device may dig too deeply into the ground and actually mix the loose lift in with underlying materials. Bentonite (particularly powdered bentonite) may be blown away by wind when it is placed on the surface of a loose lift, thus reducing the amount of bentonite that is actually incorporated into the soil. The mixing equipment may fail to pass over all areas of the loose lift and may inadequately mix certain portions of the loose lift. Because of these problems many engineers believe that pugmill mixing provides a more reliable means for mixing bentonite with soil. CQA personnel should carefully examine the mixing process to ensure that the problems outlined above, or other problems, do not compromise the quality of the mixing process. Visual examination of the mixture to verify plasticity (see Section 2.5 and Table 2.5) is recommended.

2.6.5.3 Measuring Bentonite Content

The best way to control the amount of bentonite mixed with soil is to measure the relative weights of soil and bentonite blended together at the time of mixing. After bentonite has been mixed with soil there are several techniques available to estimate the amount of bentonite in the soil. None of the techniques are particularly easy to use in all situations.

The recommended technique for measuring the amount of bentonite in soil is the methylene blue test (Alther, 1983). The methylene blue test is a type of titration test. Methylene blue is slowly titrated into a material and the amount of methylene blue required to saturate the material is determined. The more bentonite in the soil the greater the amount of methylene blue that must be added to achieve saturation. A calibration curve is developed between the amount of methylene blue needed to saturate the material and the bentonite content of the soil. The methylene blue test works very well when bentonite is added into a non-clayey soil. However, the amount of methylene blue that must be added to the soil is a function of the amount of clay present in the soil. If clay minerals other than bentonite are present, the clay minerals interfere with the determination of the bentonite content. There is no standard methylene blue test; the procedure outlined in Alther (1983) is suggested until such time as a standard test method is developed.

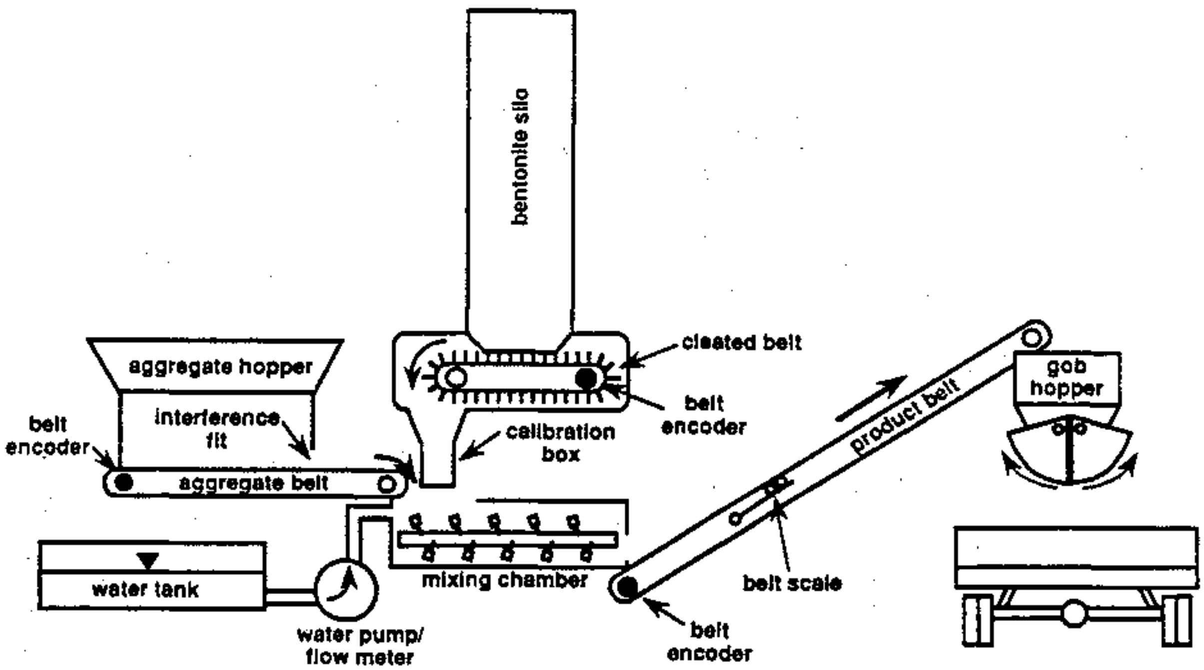


Figure 2.30 - Schematic Diagram of Pugmill

Another type of test that has been used to estimate bentonite content is the filter press test. This test is essentially a water absorbency test: the greater the amount of clay in a soil, the greater the water holding capacity. Like the methylene blue test, the filter press test works well if bentonite is the only source of clay in the soil. No specific test procedure was available at the time of this writing.

Measurement of hydraulic conductivity provides a means for verifying that enough bentonite has been added to the soil to achieve the desired low hydraulic conductivity. If insufficient bentonite has been added, the hydraulic conductivity should be unacceptably large. However, just because the hydraulic conductivity is acceptably low for a given sample does not necessarily mean that the required amount of bentonite has been added to the soil at all locations. Indeed, extra bentonite beyond the minimum amount required is added to soil so that there will be sufficient bentonite present even at those locations that are "lean" in bentonite.

The recommended tests and testing frequencies to verify proper addition of bentonite are summarized in Table 2.7. However, the CQA personnel must realize that the amount of testing depends on the degree of control in the mixing process: the more control during mixing, the less is the need for testing to verify the proper bentonite content.

Table 2.7 - Recommended Tests to Verify Bentonite Content

Parameter	Frequency	Test Method
Methylene Blue Test	1 per 1,000 m^3	Alther (1983)
Compaction Curve for Soil-Bentonite Mixture (Needed To Prepare Hydraulic Conductivity Test Specimen)	1 per 5,000 m^3	Per Project Specifications, e.g., ASTM D-698 or D-1557
Hydraulic Conductivity of Soil-Bentonite Mixture Compacted to Appropriate Water Content and Dry Unit Weight	3/ha/Lift (1/Acre/Lift)	ASTM D-5084, "Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter"

Note: 1 yd^3 = 0.76 m^3

2.6.6 Stockpiling Soils

After the soil has been preprocessed it is usually necessary to ensure that the water content does not change prior to use. The stockpiles can be of any size or shape. Small stockpiles should be covered so that the soil cannot dry or wet. For large stockpiles, it may not be necessary to cover the stockpile, particularly if the stockpile is sloped to promote drainage, moisture is added occasionally to offset drying at the surface, or other steps are taken to minimize wetting or drying of the stockpiled soil.

2.7 Placement of Loose Lift of Soil

After a soil has been fully processed, the soil is hauled to the final placement area. Soil should not be placed in adverse weather conditions, e.g., heavy rain. Inspectors are usually responsible for documenting weather conditions during all earthwork operations. The surface on which the soil will be placed must be properly prepared and the material must be inspected after placement to make sure that the material is suitable. Then the CQA inspectors must also verify that the lift is not too thick. For side slopes, construction specifications should clearly state whether lifts are parallel to the slope or horizontal. For slopes inclined at 3(H):1(V) or flatter, lifts are usually parallel to the slope. For slopes inclined at 2(H):1(V) or steeper, lifts are usually horizontal. However, horizontal lifts may present problems because the hydraulic conductivity for flow parallel to lifts is expected to be somewhat greater than for flow perpendicular to lifts. Details of testing are described in the following subsections.

Transport vehicles can pick up contaminants while hauling material from the borrow source or preprocessing area. If this occurs, measures should be taken to prevent contaminants from falling off transport vehicles into the soil liner material. These measures may include restricting vehicles to contaminant free haul roads or removing contaminants before the vehicle enters the placement area.

2.7.1 Surface Scarification

Prior to placement of a new lift of soil, the surface of the previously compacted lift of soil liner should be roughened to promote good contact between the new and old lifts. Inspectors should observe the condition of the surface of the previously compacted lift to make sure that the surface has been scarified as required in the construction specifications. When soil is scarified it is usually roughened to a depth of about 25 mm (1 in.). In some cases the surface may not require scarification if the surface is already rough after the end of compaction of a lift. It is very important that CQA inspectors ensure that the soil has been properly scarified if construction specifications require scarification. If the soil is scarified, the scarified zone becomes part of the loose lift of soil and should be counted in measuring the loose lift thickness.

2.7.2 Material Tests and Visual Inspection

2.7.2.1 Material Tests

After a loose lift of soil has been placed, samples are periodically taken to confirm the properties of the soil liner material. These samples are in addition to samples taken from the borrow area (Table 2.3). The types of tests and frequency of testing are normally specified in the CQA documents. Table 2.8 summarizes recommended minimum tests and testing frequencies. Samples of soils can be taken either on a grid pattern or on a random sampling pattern (see Section 2.8.3.2). Statistical tests and criteria can be applied but are not usually applied to soil liners in part because enough data have to be gathered to apply statistics, and yet decisions have to be made immediately, before very much data are collected.

2.7.2.2 Visual Observations

Inspectors should position themselves near the working face of soil liner material as it is being placed. Inspectors should look for deleterious materials such as stones, debris, and organic matter. Continuous inspection of the placement of soil liner material is recommended to ensure that the soil liner material is of the proper consistency.

2.7.2.3 Allowable Variations

Tests on soil liner materials may occasionally fail to conform with required specifications. It is unrealistic to think that 100% of a soil liner material will be in complete conformance with specifications. For example, if the construction documents require a minimum plasticity index it may be anticipated that a small fraction of the soil (such as pockets of sandy material) will fail to conform with specifications. It is neither unusual nor unexpected that occasional failing material will be encountered in soil liners. Occasional imperfections in soil liner materials are expected. Indeed, one of the reasons why multiple lifts are used in soil liners is to account for the inevitable variations in the materials of construction employed in building soil liners. Occasional deviations from construction specifications are not harmful. Recommended maximum allowable variations (failing tests) are listed in Table 2.9.

Table 2.8 - Recommended Materials Tests for Soil Liner Materials Sampled after Placement in a Loose Lift (Just Before Compaction)

Parameter	Test Method	Minimum Testing Frequency
Percent Fines (Note 1)	ASTM D-1140	1 per 800 m^3 (Notes 2 & 5)
Percent Gravel (Note 3)	ASTM D-422	1 per 800 m^3 (Notes 2 & 5)
Liquid & Plastic Limits	ASTM D-4318	1 per 800 m^3 (Notes 2 & 5)
Percent Bentonite (Note 4)	Alther (1983)	1 per 800 m^3 (Notes 2 & 5)
Compaction Curve	As Specified	1 per 4,000 m^3 (Note 5)
Construction Oversight	Observation	Continuous

Notes:

1. Percent fines is defined as percent passing the No. 200 sieve.
2. In addition, at least one test should be performed each day that soil is placed, and additional tests should be performed on any suspect material observed by CQA personnel.
3. Percent gravel is defined as percent retained on the No. 4 sieve.
4. This test is only applicable to soil-bentonite liners.
5. 1 $yd^3 = 0.76$ m^3.

Table 2.9 - Recommended Maximum Percentage of Failing Material Tests

Parameter	Maximum Allowable Percentage of Outliers
Atterberg Limits	5% and Outliers Not Concentrated in One Lift or One Area
Percent Fines	5% and Outliers Not Concentrated in One Lift or One Area
Percent Gravel	10% and Outliers Not Concentrated in One Lift or One Area
Clod Size	10% and Outliers Not Concentrated in One Lift or One Area
Percent Bentonite	5% and Outliers Not Concentrated in One Lift or One Area
Hydraulic Conductivity of Laboratory Compacted Soil	5% and Outliers Not Concentrated in One Lift or One Area

2.7.2.4 Corrective Action

If it is determined that the materials in an area do not conform with specifications, the first step is to define the extent of the area requiring repair. A sound procedure is to require the contractor to repair the lift of soil out to the limits defined by passing CQC/CQA tests. The contractor should not be allowed to guess at the extent of the area that requires repair. To define the limits of the area that requires repair, additional tests are often needed. Alternatively, if the contractor chooses not to request additional tests, the contractor should repair the area that extends from the failing test out to the boundaries defined by passing tests.

The usual corrective action is to wet or dry the loose lift of soil in place if the water content is incorrect. The water must be added uniformly, which requires mixing the soil with a disc or rototiller (see Section 2.6.1). If the soil contains oversized material, oversized particles are removed from the material (see Section 2.6.2). If clods are too large, clods can be pulverized in the loose lift (see Section 2.6.3). If the soil lacks adequate plasticity, contains too few fines, contains too much gravel, or lacks adequate bentonite, the material is normally excavated and replaced.

2.7.3 Placement and Control of Loose Lift Thickness

Construction specifications normally place limits on the maximum thickness of a loose lift of soil, e.g., 225 mm (9 in.). The thickness of a loose lift should not exceed this value with normal equipment. The thickness of a loose lift may be determined in several ways. One technique is for an inspector standing near the working face of soil being placed to observe the thickness of the lift. This is probably the most reliable technique for controlling loose lift thickness for CQA inspectors. If there is a question about loose lift thickness one should dig a pit through the loose lift of soil and into the underlying layer. A cross-beam is used to measure the depth from the surface of a loose lift to the top of the previously compacted lift. If the previously compacted lift was scarified, the zone of scarification should be counted in the loose lift thickness for the new layer of soil. Continuous observation of loose lift thickness is recommended during placement of soil liners.

Some earthwork contractors control lift thickness by driving grade stakes into the subsoil and marking the grade stake to indicate the proper thickness of the next layer. This practice is very convenient for equipment operators because they can tell at a glance whether the loose lift thickness is correct. However, this practice is strongly discouraged for the second and subsequent lifts of a soil liner because the penetrations into the previously-compacted lift made by the grade stakes must be repaired. Also, any grade stakes or fragments from grade stakes left in a soil liner could puncture overlying geosynthetics. Repair of holes left by grade stakes is very difficult because one must dig through the loose lift of soil to expose the grade stake, remove the grade stake without breaking the stake and leaving some of the stake in the soil, backfill the hole left by the grade stake, and then replace the loose soil in the freshly-placed lift. For the first lift of soil liner, repair of grade stake holes may not be relevant (depending on the subgrade and what its function is), but grade stakes are discouraged even for the first lift of soil because the stakes may be often broken off and incorporated into the soil. Grade stakes resting on a small platform or base do not need to be driven into the underlying material and are, therefore, much more desirable than ordinary grade stakes. If grade stakes are used, it is recommended that they be numbered and accounted for at the end of each shift; this will provide verification that grade stakes are not being abandoned in the fill material.

The recommended survey procedure for control of lift thickness involves laser sources and receivers. A laser beam source is set at a known elevation, and reception devices held by hand on rods or mounted to grading equipment are used to monitor lift thickness. However, lasers cannot be used at all sites. For instance, the liner may need to be a minimum distance above rock, and the grade lines may follow the contours of underlying rock. Further, every site has areas such as corners, sumps, and boundaries of cells, which preclude the use of lasers.

For those areas where lasers cannot be used, it is recommended that either flexible plastic grade stakes or metallic grade stakes (numbered and inventoried as part of the QA/QC process) be used. It is preferable if the stakes are mounded on a base so that the stakes do not have to be driven into the underlying lift. Repair of grade stake holes should be required; the repairs should be periodically inspected and the repairs documented. Alternatively (and preferably for small areas), spot elevations can be obtained on the surface of a loose lift with conventional level and rod equipment, and adjustments made by the equipment operator based on the levels.

When soil is placed, it is usually dumped into a heap at the working face and spread with dozers. QA/QC personnel should stand in front of the working face to observe the soil for oversized materials or other deleterious material, to visually observe loose lift thickness, and to make sure that the dozer does not damage an underlying layer.

2.8 Remolding and Compaction of Soil

2.8.1 Compaction Equipment

The important parameters concerning compaction equipment are the type and weight of the compactor, the characteristics of any feet on the drum, and the weight of the roller per unit length of drummed surface. Sometimes construction specifications will stipulate a required type of compactor or minimum weight of compactor. If this is the case inspectors should confirm that the compaction equipment is in conformance with specifications. Inspectors should be particularly cognizant of the weight of compactor and length of feet on drummed rollers. Heavy compactors with long feet that fully penetrate a loose lift of soil are generally thought to be the best type of compactor to use for soil liners. Footed rollers may not be necessary or appropriate for some bentonite-soil mixes; smooth-drum rollers or rubber tired rollers may produce best results for soil-bentonite mixtures that do not require kneading or remolding to achieve low hydraulic conductivity but only require densification.

Some compactors are self-propelled while other compactors are towed. Towed, footed rollers are normally ballasted by filling the drum with water to provide weight that will enable significant compactive effort to be delivered to the soil. Inspectors should be very careful to determine whether or not all drums on towed rollers have been filled with liquid.

Compacting soil liners on side slopes can present special challenges, particularly for slopes inclined at 3(H):1(V) or steeper. Inspectors should observe side-slope compaction carefully and watch for any tendency for the compactor to slip down slope or for slippage or cracking to take place in the soil. Inspectors should also be watchful to make sure that adequate compactive effort is delivered to the soil. For soils compacted in lifts parallel to the slope, the first lift of soil should be "knitted" into existing subgrade to minimize a preferential flow path along the interface and to minimize development of a potential slip plane.

Footed rollers can become clogged with soil between the feet. Inspectors should examine the condition of the roller to make sure that the space between feet is not plugged with soil. In addition, compaction equipment is intended to be operated at a reasonable speed. The maximum speed of the compactor should be specified in the construction specifications. CQC and CQA personnel should make sure the speed of the equipment is not too great.

When soils are placed directly on a fragile layer, such as a geosynthetic material, or a drainage material, great care must be taken in placing and compacting the first lift so as not to damage the fragile material or mix clay in with the underlying drainage material. Often, the first lift of soil is considered a sacrificial lift that is placed, spread with dozers, and only nominally compacted with the dozers or a smooth-drum or rubber-tire roller. QA/QC personnel should be particularly careful to observe all placement and compaction operations of the first lift of soil for compacted soil liners placed directly on a geosynthetic material or drainage layer.

It is not uncommon for a contractor to use more than one type of compaction equipment on a project. For example, initial compaction may be with a heavy roller having long feet that fully penetrate a loose lift of soil. Later, the upper part of a lift may be compacted with a heavy rubber-tired roller or other equipment that is particularly effective in compacting near-surface materials.

2.8.2 Number of Passes

The compactive effort delivered by a roller is a function of the number of passes of the roller over a given area of soil. A pass may defined as one pass of the construction equipment or one pass of a drum over a given point in the soil liner. It does not matter whether a pass is defined as a pass of the equipment or a pass of a drum, but the construction specifications and/or CQA plan should define what is meant by a pass. Normally, one pass of the vehicle constitutes a pass for self-propelled rollers and one pass of a drum constitutes a pass for towed rollers.

Some construction documents require a minimum coverage. Coverage (C) is defined as follows:

$$C = [A_f/A_d] \times N \times 100\% \qquad (2.4)$$

where N is the number of passes of the roller, A_f is the sum of the area of the feet on the drums of the roller, and A_d is the area the drum itself. Construction specifications sometimes require 150% -

200% coverage of the roller. For a given roller and minimum percent coverage, the minimum number of passes (N) may be computed.

The number of passes of a compactor over the soil can have an important influence on the overall hydraulic conductivity of the soil liner. It is recommended that periodic observations be made of the number of passes of the roller over a given point. Approximately 3 observations per hectare per lift (one observation per acre per lift) is the recommended frequency of measurement. The minimum number of passes that is reasonable depends upon many factors and cannot be stated in general terms. However, experience has been that at least 5 to 15 passes of a compactor over a given point is usually necessary to remold and compact clay liner materials thoroughly.

2.8.3 Water Content and Dry Unit Weight

2.8.3.1 Water Content and Unit Weight Tests

One of the most important CQA tests is measurement of water content and dry unit weight. Methods of measurement were discussed in Section 2.3. Recommended testing frequencies are listed in Table 2.10. It is stressed that the recommended testing frequencies are the minimum values. Some judgment should be applied to these numbers, and the testing frequencies should be increased or kept at the minimum depending on the specific project and other QA/QC tests and observations. For example, if hydraulic conductivity tests are not performed on undisturbed samples (see Section 2.8.4.2), more water content/density tests may be required than the usual minimum.

2.8.3.2 Sampling Patterns

There are several ways in which sample locations may be selected for water content and unit weight tests. The simplest and least desirable method is for someone in the field to select locations at the time samples must be taken. This is undesirable because the selector may introduce a bias into the sampling pattern. For example, perhaps on the previous project soils of one particular color were troublesome. If the individual were to focus most of the tests on the current project on soils of that same color a bias might be introduced.

A common method of selecting sample locations is to establish a grid pattern. The grid pattern is simple and ensures a high probability of locating defective areas so long as the defective areas are of a size greater than or equal to the spacing between the sampling points. It is important to stagger the grid patterns in successive lifts so that sampling points are not at the same location in each lift. One would not want to sample at the same location in successive lifts because repaired sample penetrations would be stacked on top of one another. The grid pattern sampling procedure is the simplest one to use that avoids the potential for bias described in the previous paragraph.

A third alternative for selecting sampling points is to locate sampling points randomly. Tables and examples are given in Richardson (1992). It is recommended that no sampling point be located within 2 meters of another sampling point. If a major portion of the area to be sampled has been omitted as a result of the random sampling process, CQA inspectors may add additional points to make sure the area receives some testing. Random sampling is sometimes preferred on large projects where statistical procedures will be used to evaluate data. However, it can be demonstrated that for a given number of sampling points, a grid pattern will be more likely to detect a problem area provided that the dimensions of the problem area are greater than or equal to the spacing between sampling points. If the problem area is smaller than the spacing between sampling points, the probability of locating the problem area is approximately the same with both a grid pattern and a random pattern of sampling.

Table 2.10 - Recommended Tests and Observations on Compacted Soil

Parameter	Test Method	Minimum Testing Frequency
Water Content (Rapid) (Note 1)	ASTM D-3017 ASTM D-4643 ASTM D-4944 ASTM D-4959	13/ha/lift (5/acre/lift) (Notes 2 & 7)
Water Content (Note 3)	ASTM D-2216	One in every 10 rapid water content tests (Notes 3 & 7)
Total Density (Rapid) (Note 4)	ASTM D-2922 ASTM D-2937	13/ha/lift (5/acre/lift) (Notes 2, 4 & 7)
Total Density (Note 5)	ASTM D-1556 ASTM D-1587 ASTM D-2167	One in every 20 rapid density tests (Notes 5, 6, & 7)
Number of Passes	Observation	3/ha/lift (1/acre/lift) (Notes 2 & 7)
Construction Oversight	Observation	Continuous

Notes:

1. ASTM D-3017 is a nuclear method, ASTM D-4643 is microwave oven drying, ASTM D-4944 is a calcium carbide gas pressure tester method, and ASTM D-4959 is a direct heating method. Direct water content determination (ASTM D-2216) is the standard against which nuclear, microwave, or other methods of measurements are calibrated for on-site soils.

2. In addition, at least one test should be performed each day soil is compacted and additional tests should be performed in areas for which CQA personnel have reason to suspect inadequate compaction.

3. Every tenth sample tested with ASTM D-3017, D-4643, D-4944, or D-4959 should be also tested by direct oven drying (ASTM D-2216) to aid in identifying any significant, systematic calibration errors.

4. ASTM D-2922 is a nuclear method and ASTM D-2937 is the drive cylinder method. These methods, if used, should be calibrated against the sand cone (ASTM D-1556) or rubber balloon (ASTM D-2167) for on-site soils. Alternatively, the sand cone or rubber balloon method can be used directly.

5. Every twentieth sample tested with D-2922 should also be tested (as close as possible to the same test location) with the sand cone (ASTM D-1556) or rubber balloon (ASTM D-2167) to aid in identifying any systematic calibration errors with D-2922.

6. ASTM D-1587 is the method for obtaining an undisturbed sample. The section of undisturbed sample can be cut or trimmed from the sampling tube to determine bulk density. This method should not be used for soils containing any particles > 1/6-th the diameter of the sample.

7. 1 acre = 0.4 ha.

No matter which method of determining sampling points is selected, it is imperative that CQA inspectors have the responsibility to perform additional tests on any suspect area. The number of additional testing locations that are appropriate varies considerably from project to project.

2.8.3.3 Tests with Different Devices to Minimize Systematic Errors

Some methods of measurement may introduce a systematic error. For example, the nuclear device for measuring water content may consistently produce a water content measurement that is too high if there is an extraneous source of hydrogen atoms besides water in the soil. It is important that devices that may introduce a significant systematic error be periodically correlated with measurements that do not have such error. Water content measurement tests have the greatest potential for systematic error. Both the nuclear method as well as microwave oven drying can produce significant systematic error under certain conditions. Therefore, it is recommended that if the nuclear method or any of the rapid methods of water content measurement (Table 2.2) are used to measure water content, periodic correlation tests should be made with conventional overnight oven drying (ASTM D-2216).

It is suggested that at the beginning of a project, at least 10 measurements of water content be determined on representative samples of the site-specific soil using any rapid measurement method to be employed on the project as well as ASTM D-2216. After this initial correlation, it is suggested (see Tables 2.10) that one in ten rapid water content tests be crossed check with conventional overnight oven drying. At the completion of a project a graph should be presented that correlates the measured water content with a rapid technique against the water content from conventional overnight oven drying.

Some methods of unit weight measurement may also introduce bias. For example, the nuclear device may not be properly calibrated and could lead to measurement of a unit weight that is either too high or too low. It is recommended that unit weight be measured independently on occasion to provide a check against systematic errors. For example, if the nuclear device is the primary method of density measurement being employed on a project, periodic measurements of density with the sand cone or rubber balloon device can be used to check the nuclear device. Again, a good practice is to perform about 10 comparative tests on representative soil prior to construction. During construction, one in every 20 density tests (see Table 2.10) should be checked with the sand cone or rubber balloon. A graph should be made of the unit weight measured with the nuclear device versus the unit weight measured with the sand cone or rubber balloon device to show the correlation. One could either plot dry unit weight or total unit weight for the correlation. Total unit weight in some ways is more sensible because the methods of measurement are actually total unit weight measurements; dry unit weight is calculated from the total unit weight and water content (Eq. 2.1.).

2.8.3.4 Allowable Variations and Outliers

There are several reasons why a field water content or density test may produce a failing result, i.e., value outside of the specified range. Possible causes for a variation include a human error in measurement of water content or dry unit weight, natural variability of the soil or the compaction process leading to an anomaly at an isolated location, limitations in the sensitivity and repeatability of the test methods, or inadequate construction procedures that reflect broader-scale deficiencies.

Measurement errors are made on every project. From time to time it can be expected that CQC and CQA personnel will incorrectly measure either the water content or the dry unit weight.

Periodic human errors are to be expected and should be addressed in the CQA plan.

If it is suspected that a test result is in error, the proper procedure for rectifying the error should be as follows. CQC or CQA personnel should return to the point where the questionable measurement was obtained. Several additional tests should be performed in close proximity to the location of the questionable test. If all of the repeat tests provide satisfactory results the questionable test result may be disregarded as an error. Construction quality assurance documents should specify the number of tests required to negate a blunder. It is recommended that approximately 3 passing tests be required to negate the results of a questionable test.

One of the main reasons why soil liners are built of multiple lifts is a realization that the construction process and the materials themselves vary. With multiple lifts no one particular point in any one lift is especially significant even if that point consists of unsatisfactory material or improperly compacted material. It should be expected that occasional deviations from construction specifications will be encountered for any soil liner. In fact, if one were to take enough soil samples, one can rest assured that a failing point on some scale would be located.

Measurement techniques for compacted soils are imperfect and produce variable results. Turnbull et al. (1966) discuss statistical quality control for compacted soils. Noorany (1990) describes 3 sites in the San Diego area for which 9 testing laboratories measured water content and percent compaction on the same fill materials. The ranges in percent compaction were very large: 81-97% for Site 1, 77-99% for Site 2, and 89-103% for Site 3.

Hilf (1991) summarizes statistical data from 72 earth dams; the data show that the standard deviation in water content is typically 1 to 2%, and the standard deviation in dry density is typically 0.3 to 0.6 kN/m^3 (2 to 4 pcf). Because the standard deviations are themselves on the same order as the allowable range of these parameters in many earthwork specifications, it is statistically inevitable that there will be some failing tests no matter how well built the soil liner is.

It is unrealistic to expect that 100% of all CQA tests will be in compliance with specifications. Occasional deviations should be anticipated. If there are only a few randomly-located failures, the deviations in no way compromise the quality or integrity of a multiple-lift liner.

The CQA documents may provide an allowance for an occasional failing test. The documents may stipulate that failing tests not be permitted to be concentrated in any one lift or in any one area. It is recommended that a small percentage of failing tests be allowed rather than insisting upon the unrealistic requirement that 100% of all tests meet project objectives. Statistically based requirements provide a convenient yet safe and reliable technique for handling occasional failing test results.. However, statistically based methods require that enough data be generated to apply statistics reliably. Sufficient data to apply statistical methods may not be available, particularly in the early stages of a project.

Another approach is to allow a small percentage of outliers but to require repair of any area where the water content is far too low or high or the dry unit weight is far too low. This approach is probably the simplest to implement -- recommendations are summarized in Table 2.11.

Table 2.11 - Recommended Maximum Percentage of Failing Compaction Tests

Parameter	Maximum Allowable Percentage of Outliers
Water Content	3% and Outliers Not Concentrated in One Lift or One Area, and No Water Content Less than 2% or More than 3% of the Allowable Value
Dry Density	3% and Outliers Not Concentrated in One Lift or One Area, and No Dry Density Less than 0.8 kN/m^3 (5 pcf) Below the Required Value
Number of Passes	5% and Outliers Not Concentrated in One Lift or One Area

2.8.3.5 Corrective Action

If it is determined that an area does not conform with specifications and that the area needs to be repaired, the first step is to define the extent of the area requiring repair. The recommended procedure is to require the contractor to repair the lift of soil out to the limits defined by passing CQC and CQA tests. The contractor should not be allowed to guess at the extent of the area that requires repair. To define the limits of the area that requires repair, additional tests are often needed. Alternatively, if the contractor chooses not to request additional tests, the contractor should repair the area that extends from the failing test out to the boundaries defined by passing tests.

The usual problem requiring corrective action at this stage is inadequate compaction of the soil. The contractor is usually able to rectify the problem with additional passes of the compactor over the problem area.

2.8.4 Hydraulic Conductivity Tests on Undisturbed Samples

Hydraulic conductivity tests are often performed on "undisturbed" samples of soil obtained from a single lift of compacted soil liner. Test specimens are trimmed from the samples and are permeated in the laboratory. Compliance with the stated hydraulic conductivity criterion is checked.

This type of test is given far too much weight in most QA programs. Low hydraulic conductivity of samples taken from the liner is necessary for a well-constructed liner but is not sufficient to demonstrate that the large-scale, field hydraulic conductivity is adequately low. For example, Elsbury et al. (1990) measured hydraulic conductivities on undisturbed samples of a poorly constructed liner that averaged 1×10^{-9} cm/s, and yet the actual in-field value was 1×10^{-5} cm/s. The cause for the discrepancy was the existence of macro-scale flow paths in the field that were not simulated in the small-sized (75 mm or 3 in. diameter) laboratory test specimens.

Not only does the flow pattern through a 75-mm-diameter test specimen not necessarily reflect flow patterns on a larger field scale, but the process of obtaining a sample for testing inevitably disturbs the soil. Layers are distorted, and gross alterations occur if significant gravel is present in the soil. The process of pushing a sampling tube into the soil densifies the soil, which lowers its hydraulic conductivity. The harder and drier the soil, the greater the disturbance. As a result of these various factors, the large-scale, field hydraulic conductivity is almost always greater than or equal to the small-scale, laboratory-measured hydraulic conductivity. The difference between values from a small laboratory scale and a large field scale depends on the quality of construction -- the better the quality of construction, the less the difference.

Laboratory hydraulic conductivity tests on undisturbed samples of compacted liner can be valuable in some situations. For instance, for soil-bentonite mixes, the laboratory test provides a check on whether enough bentonite has been added to the mix to achieve the desired hydraulic conductivity. For soil liners in which a test pad is not constructed, the laboratory tests provide some verification that appropriate materials have been used and compaction was reasonable (but hydraulic conductivity tests by themselves do not prove this fact).

Laboratory hydraulic conductivity tests constitute a major inconvenience because the tests usually take at least several days, and sometimes a week or two, to complete. Their value as QA tools is greatly diminished by the long testing time -- field construction personnel simply cannot wait for the results of the tests to proceed with construction, nor would the QA personnel necessarily want them to wait because opportunities exist for damage of the liner as a result of desiccation. Thus, one should give very careful consideration as to whether the laboratory hydraulic conductivity tests are truly needed for a given project and will serve a sufficiently useful purpose to make up for the inconvenience of this type of test.

Research is currently underway to determine if larger-sized samples from field-compacted soils can give more reliable results than the usual 75-mm (3 in.) diameter samples. Until further data are developed, the following recommendations are made concerning the approach to utilizing laboratory hydraulic conductivity tests for QA on field-compacted soils:

1. For gravely soils or other soils that cannot be consistently sampled without causing significant disturbance, laboratory hydraulic conductivity tests should not be a part of the QA program because representative samples cannot realistically be obtained. A test pad (Section 2.10) is recommended to verify hydraulic conductivity.

2. If a test pad is constructed and it is demonstrated that the field-scale hydraulic conductivity is satisfactory on the test pad, the QA program for the actual soil liner should focus on establishing that the actual liner is built of similar materials and to equal or better standards compared to the test pad -- laboratory hydraulic conductivity testing is not necessary to establish this.

3. If no test pad is constructed and it is believed that representative samples can be obtained for hydraulic conductivity testing, then laboratory hydraulic conductivity tests on undisturbed samples from the field are recommended.

2.8.4.1 Sampling for Hydraulic Conductivity Testing

A thin-walled tube is pushed into the soil to obtain a sample. Samples of soil should be taken in the manner that minimizes disturbance such as described in ASTM D-1587. Samples should be sealed and carefully stored to prevent drying and transported to the laboratory in a manner that minimizes soil disturbance as described in ASTM D-4220.

It is particularly important that the thin-walled sampling tube be pushed into the soil in the direction perpendicular to the plane of compaction. Many CQA inspectors will push the sampling tube into the soil using the blade of a dozer or compactor. This practice is not recommended because the sampling tube tends to rotate when it is pushed into the soil. The recommended way of sampling the soil is to push the sampling tube straight into the soil using a jack to effect a smooth, straight push.

Sampling of gravely soils for hydraulic conductivity testing is often a futile exercise. The gravel particles that are encountered by the sampling tube tend to tumble and shear during the push, which caused major disturbance of the soil sample. Experience has been that QA/QC personnel may take several samples of gravely soil before a sample that is sufficiently free of gravel to enable proper sampling is finally obtained; in these cases, the badly disturbed, gravely samples are discarded. Clearly, the process of discarding samples because they contain too much gravel to enable proper sampling introduces a bias into the process. Gravely soils are not amenable to undisturbed sampling.

2.8.4.2 Hydraulic Conductivity Testing

Hydraulic conductivity tests are performed utilizing a flexible wall permeameter and the procedures described in ASTM D-5084. Inspectors should be careful to make sure that the effective confining stress utilized in the hydraulic conductivity test is not excessive. Application of excessive confining stress can produce an artificially low hydraulic conductivity. The CQA plan should prescribe the maximum effective confining stress that will be used; if none is specified a value of 35 kPa (5 psi) is recommended for both liner and cover systems.

2.8.4.3 Frequency of Testing

Hydraulic conductivity tests are typically performed at a frequency of 3 tests/ha/lift (1 test/acre/lift) or, for very thick liners (≥ 1.2 m or 4 ft) per every other lift. This is the recommended frequency of testing, if hydraulic conductivity testing is required. The CQA plan should stipulate the frequency of testing.

2.8.4.4 Outliers

The results of the above-described hydraulic conductivity tests are often given far too much weight. A passing rate of 100% does not necessarily prove that the liner was well built, yet some inexperienced individuals falsely believe this to be the case. Hydraulic conductivity tests are performed on small samples; even though small samples may have low hydraulic conductivity, inadequate construction or CQA can leave remnant macro-scale defects such as fissures and pockets of poorly compacted soil. The fundamental problem is that laboratory hydraulic conductivity tests are usually performed on 75-mm (3 in.) diameter samples, and these samples are too small to contain a representative distribution of macro-scale defects (if any such defects are present). By the same token, an occasional failing test does not necessarily prove that a problem exists. An occasional failing test only shows that either: (1) there are occasional zones that fail to meet performance criteria, or (2) sampling disturbance (e.g., from the sampling tube shearing stones in the soil) makes confirmation of low hydraulic conductivity difficult or impossible. Soil liners built of multiple lifts are expected to have occasional, isolated imperfections -- this is why the liners are constructed from multiple lifts. Thus, occasional failing hydraulic conductivity tests by themselves do not mean very much. Even on the best built liners, occasional failing test results should be anticipated.

It is recommended that a multiple-lift soil liner be considered acceptable even if a small percentage (approximately 5%) of the hydraulic conductivity tests fail. However, one should allow a small percentage of hydraulic conductivity failures only if the overall CQA program is thorough. Further, it is recommended that failing samples have a hydraulic conductivity that is no greater than one-half to one order of magnitude above the target maximum value. If the hydraulic conductivity at a particular point is more than one-half to one order of magnitude too high, the zone should be retested or repaired regardless of how isolated it is.

2.8.5 Repair of Holes from Sampling and Testing

A number of tests, e.g., from nuclear density tests and sampling for hydraulic conductivity, require that a penetration be made into a lift of compacted soil. It is extremely important that all penetrations be repaired. The recommended procedure for repair is as follows. The backfill material should first be selected. Backfill may consist of the soil liner material itself, granular or pelletized bentonite, or a mixture of bentonite and soil liner material. The backfill material should be placed in the hole requiring repair with a loose lift thickness not exceeding about 50 mm (2 in.). The loose lift of soil should be tamped several times with a steel rod or other suitable device that compacts the backfill and ensures no bridging of material that would leave large air pockets. Next, a new lift of backfill should be placed and compacted. The process is repeated until the hole has been filled.

Because it is critical that holes be properly repaired, it is recommended that periodic inspections and written records made of the repair of holes. It is suggested that approximately 20% of all the repairs be inspected and that the backfill procedures be documented for these inspections. It is recommended that the inspector of repair of holes not be the same person who backfilled the hole.

2.8.6 Final Lift Thickness

Construction documents may place restrictions on the maximum allowable final (after-compaction) lift thickness. Typically, the maximum thickness is 150 mm (6 in.). Final elevation surveys should be used to establish thicknesses of completed earthwork segments. The specified maximum lift thickness is a nominal value. The actual value may be determined by surveys on the surface of each completed lift, but an acceptable practice (provided there is good CQA on loose lift thickness) is to survey the liner after construction and calculate the average thickness of each lift by dividing the total thickness by the number of lifts.

Tolerances should be specified on final lift thickness. Occasional outliers from these tolerances are not detrimental to the performance of a multi-lift liner. It is recommended by analogy to Table 2.9 that no more than 5% of the final lift thickness determinations be out of specification and that no out-of-specification thickness be more than 25 mm (1 in.) more than the maximum allowable lift thickness.

2.8.7 Pass/Fail Decision

After all CQA tests have been performed, a pass/fail decision must be made. Procedures for dealing with materials problems were discussed in Section 2.7.2.4. Procedures for correcting deficiencies in compaction of the soil were addressed in Section 2.8.3.5. A final pass/fail decision is made by the CQA engineer based upon all the data and test results. The hydraulic conductivity test results may not be available for several days after construction of a lift has been completed. Sometimes the contractor proceeds at risk with placement of additional lifts before all test results are available. On occasion, construction of a liner proceeds without final results from a test pad on the assumption that results will be acceptable. If a "fail" decision is made at this late stage, the defective soil plus any overlying materials that have been placed should be removed and replaced.

2.9 Protection of Compacted Soil

2.9.1 Desiccation

2.9.1.1 Preventive Measures

There are several ways to prevent compacted soil liner materials from desiccating. The soil may be smooth rolled with a steel drummed roller to produce a thin, dense skin of soil on the surface. This thin skin of very dense soil helps to minimize transfer of water into or out of the underlying material. However, the smooth-rolled surface should be scarified prior to placement of a new lift of soil.

A far better preventive measure is to water the soil periodically. Care must be taken to deliver water uniformly to the soil and not to create zones of excessively wet soil. Adding water by hand is not recommended because water is not delivered uniformly to the soil.

An alternative preventive measure is to cover the soil temporarily with a geomembrane, moist geotextile, or moist soil. The geomembrane or geotextile should be weighted down with sand bags or other materials to prevent transfer of air between the geosynthetic cover and soil. If a geomembrane is used, care should be taken to ensure that the underlying soil does not become heated and desiccate; a light-colored geomembrane may be needed to prevent overheating. If moist soil is placed over the soil liner, the moist soil is removed using grading equipment.

2.9.1.2 Observations

Visual observation is the best way to ensure that appropriate preventive measures have been taken to minimize desiccation. Inspectors should realize that soil liner materials can dry out very quickly (sometimes in a matter of just a few hours). Inspectors should be aware that drying may occur over weekends and provisions should be made to provide appropriate observations.

2.9.1.3 Tests

If there are questions about degree of desiccation, tests should be performed to determine the water content of the soil. A decrease in water content of one to two percentage points is not considered particularly serious and is within the general accuracy of testing. However, larger reductions in water content provide clear evidence that desiccation has taken place.

2.9.1.4 Corrective Action

If soil has been desiccated to a depth less than or equal to the thickness of a single lift, the desiccated lift may be disked, moistened, and recompacted. However, disking may produce large, hard clods of clay that will require pulverization. Also, it should be recognized that if the soil is wetted, time must be allowed for water to be absorbed into the clods of clay and hydration to take place uniformly. For this reason it may be necessary to remove the desiccated soil from the construction area, to process the lift in a separate processing area, and to replace the soil accordingly.

2.9.2 Freezing Temperatures

2.9.2.1 Compacting Frozen Soil

Frozen soil should never be used to construct soil liners. Frozen soils form hard pieces that cannot be properly remolded and compacted. Inspectors should be on the lookout for frozen chunks of soil when construction takes place in freezing temperatures.

2.9.2.2 Protection After Freezing

Freezing of soil liner materials can produce significant increases in hydraulic conductivity. Soil liners must be protected from freezing before and after construction. If superficial freezing takes place on the surface of a lift of soil, the surface may be scarified and recompacted. If an entire lift has been frozen, the entire lift should be disked, pulverized, and recompacted. If the soil is frozen to a depth greater than one lift, it may be necessary to strip away and replace the frozen material.

2.9.2.3 Investigating Possible Frost Damage

Inspectors usually cannot determine from an examination of the surface the depth to which freezing took place in a completed or partially completed soil liner that has been exposed to freezing. In such cases it may be necessary to investigate the soil liner material for possible frost damage. The extent of damage is difficult to determine. Freezing temperatures cause the development of tiny microcracks in the soil. Soils that have been damaged due to frost action develop fine cracks that lead to the formation of chunks of soil when the soil is excavated. The pushing of a sampling tube into the soil will probably close these cracks and mask the damaging effects of frost upon hydraulic conductivity. The recommended procedure for evaluating possible frost damage to soil liners involves three steps:

1. Measure the water content of the soil within and beneath the zone of suspected frost damage. Density may also be measured, but freeze/thaw has little effect on density and may actually cause an increase in dry unit weight. Freeze/thaw is often accompanied by desiccation; water content measurements will help to determine whether drying has taken place.

2. Investigate the morphology of the soil by digging into the soil and examining its condition. Soil damaged by freezing usually contains hairline cracks, and the soil breaks apart in chunks along larger cracks caused by freeze/thaw. Soil that has not been frozen should not have tiny cracks nor should it break apart in small chunks. The morphology of the soil should be examined by excavating a small pit into the soil liner and peeling off sections from the wall of the pit. One should not attempt to cut pieces from the sidewall; smeared soil will mask cracks. A distinct depth may be obvious; above this depth the soil breaks into chunks along frost-induced cracks, and below this depth there is no evidence of cracks produced by freezing.

3. One or more samples of soil should be carefully hand trimmed for hydraulic conductivity testing. The soil is usually trimmed with the aid of a sharpened section of tube of the appropriate inside diameter. The tube is set on the soil surface with the sharpened end facing downward, soil is trimmed away near the sharpened edge of the trimming ring, the tube is pushed a few millimeters into the soil, and the trimming is repeated. Samples may be taken at several depths to delineate the depth to which freeze/thaw damage occurred. The minimum diameter of a cylindrical test specimen should be 300 mm (12 in.). Small test specimens, e.g., 75 mm (3 in.) diameter specimens, should not be used because freeze/thaw can create morphological structure in the soil on a scale too large to permit representative testing with small samples. Hydraulic conductivity tests should be performed as described in ASTM D-5084. The effective confining stress should not exceed the

smallest vertical effective stress to which the soil will be subjected in the field, which is usually the stress at the beginning of service for liners. If no compressive stress is specified, a value of 35 kPa (5 psi) is recommended for both liner and cover system.

The test pit and all other penetrations should be carefully backfilled by placing soil in lifts and compacting the lifts. The sides of the test pit should be sloped so that the compactor can penetrate through to newly placed material without interference from the walls of the pit.

2.9.2.4 Repair

If it is determined that soil has been damaged by freezing, the damaged material is usually repaired as follows. If damage is restricted to a single lift, the lift may be disked, processed to adjust water content or to reduce clod size if necessary, and recompacted. If the damage extends deeper, damaged materials should be excavated and replaced.

2.9.3 Excess Surface Water

In some cases exposed lifts of liner material, or the completed liner, are subjected to heavy rains that soften the soil. Surface water creates a problem if the surface is uneven (e.g., if a footed roller has been used and the surface has not been smooth-rolled with a smooth, steel wheeled roller) -- numerous small puddles of water will develop in the depressions low areas. Puddles of water should be removed before further lifts of material, or other components of the liner or cover system, are constructed. The material should be disked repeatedly to allow the soil to dry, and when the soil is at the proper water content, the soil should be compacted. Alternatively, the wet soil may be removed and replaced.

Even if puddles have not formed, the soils may be too soft to permit construction equipment to operate on the soil without creating ruts. To deal with this problem, the soil may be allowed to dry slightly by natural processes (but care must be taken to ensure that it does not dry too much and does not crack excessively during the drying process). Alternatively, the soil may be disked, allowed to dry while it is periodically disked, and then compacted.

If soil is reworked and recompacted, QA/QC tests should be performed at the same frequency as for the rest of the project. However, if the area requiring reworking is very small, e.g., in a sump, tests should be performed in the confined area to confirm proper compaction even if this requires sampling at a greater frequency.

2.10 Test Pads

2.10.1 Purpose of Test Pads

The purpose of a test pad is to verify that the materials and methods of construction proposed for a project will lead to a soil liner with the required large-scale, in-situ, hydraulic conductivity. Unfortunately, it is impractical to perform large-scale hydraulic conductivity tests on the actual soil liner for two reasons: (1) the testing would produce significant physical damage to the liner, and the repair of the damage would be questionable; and (2) the time required to complete the testing would be too long -- the liner could become damaged due to desiccation while one waited for the test results.

A test pad may also be used to demonstrate that unusual materials or construction procedures will work. The process of constructing and testing a test pad is usually a good learning experience for the contractor and CQC/CQA personnel; overall quality of a project is usually elevated as a result of building and testing the test pad.

A test pad is constructed with the soil liner materials proposed for a project utilizing preprocessing procedures, construction equipment, and construction practices that are proposed for the actual liner. If the required hydraulic conductivity is demonstrated for the test pad, it is assumed that the actual liner will have a similar hydraulic conductivity, provided the actual liner is built of similar materials and to standards that equal or exceed those used in building the test pad. If a test pad is constructed and hydraulic conductivity is verified on the test pad, a key goal of CQA/CQC for the actual liner is to verify that the actual liner is built of similar materials and to standards that equal or exceed those used in building the test pad.

2.10.2 Dimensions

Test pads (Fig. 2.31) normally measure about 10 to 15 m in width by 15 to 30 m in length. The width of the test pad is typically at least four times the width of the compaction equipment, and the length must be adequate for the compactor to reach normal operating speed in the test area. The thickness of a test pad is usually no less than the thickness of the soil liner proposed for a facility but may be as little as 0.6 to 0.9 m (2 to 3 feet) if thicker liners are to be employed at full scale. A freely draining material such as sand is often placed beneath the test pad to provide a known boundary condition in case infiltrating water from a surface hydraulic conductivity test (e.g., sealed double ring infiltrometer) reaches the base of the liner. The drainage layer may be drained with a pipe or other means. However, infiltrating water will not reach the drainage layer if the hydraulic conductivity is very low; the drainage pipe would only convey water if the hydraulic conductivity turns out to be very large. The sand drainage material may not provide adequate foundation support for the first lift of soil liner unless the sand is compacted sufficiently. Also, the first lift of soil liner material on the drainage layer is often viewed as a sacrificial lift and is only compacted nominally to avoid mixing clayey soil in with the drainage material.

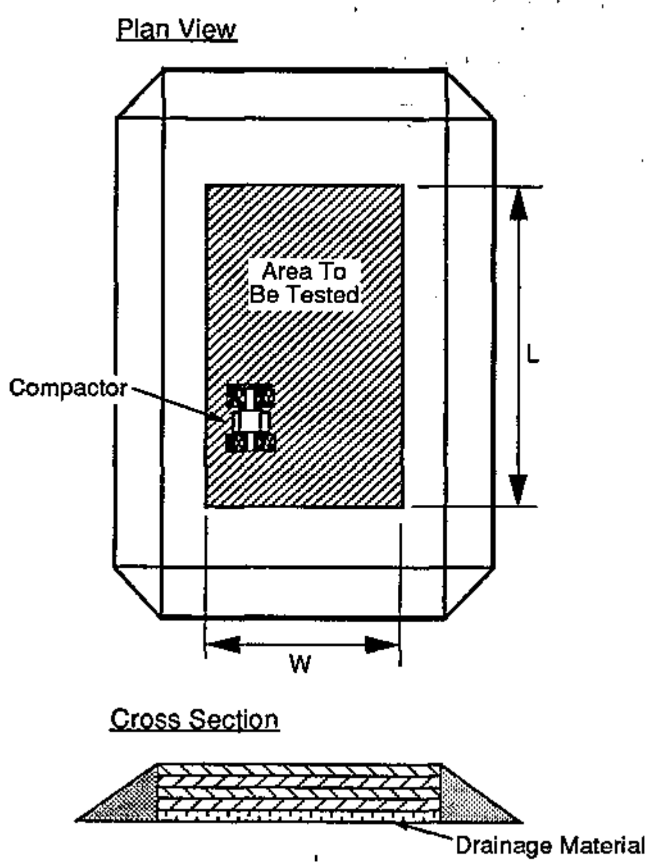
2.10.3 Materials

The test pad is constructed of the same materials that are proposed for the actual project. Processing equipment and procedures should be identical, too. The same types of CQC/CQA tests that will be used for the soil liner are performed on the test pad materials. If more than one type of material will be used, one test pad should be constructed for each type of material.

2.10.4 Construction

It is recommended that test strips be built before constructing the test pad. Test strips allow for the detection of obvious problems and provide an opportunity to fine-tune soil specifications, equipment selection, and procedures so that problems are minimized and the probability of the required hydraulic conductivity being achieved in the test pad is maximized. Test strips are typically two lifts thick, one and a half to two equipment widths wide, and about 10 m (30 ft) long.

The test pad is built using the same loose lift thickness, type of compactor, weight of compactor, operating speed, and minimum number of passes that are proposed for the actual soil liner. It is important that the test pad not be built to standards that will exceed those used in building the actual liner. For example, if the test pad is subjected to 15 passes of the compactor, one would want the actual soil liner to be subjected to at least 15 passes as well. It is critical that CQA personnel document the construction practices that are employed in building the test pad. It is best if the same contractor builds the test pad and actual liner so that experience gained from the test pad process is not lost. The same applies to CQC and CQA personnel.



W = 3 Compaction Vehicle Widths, Minimum
L = A Value No Smaller than W and Sufficient for Equipment to Reach Proper Operating Speed in Test Area

Figure 2.31 - Schematic Diagram of Soil Liner Test Pad

2.10.5 Protection

The test pad must be protected from desiccation, freezing, and erosion in the area where in situ hydraulic conductivity testing is planned. The recommended procedure is to cover the test pad with a sheet of white or clear plastic and then either spread a thin layer of soil on the plastic if no rain is anticipated or, if rain may create an undesirably muddy surface, cover the plastic with hay or straw.

2.10.6 Tests and Observations

The same types of CQA tests that are planned for the actual liner are usually performed on the test pad. However, the frequency of testing is usually somewhat greater for the test pad. Material tests such as liquid limit, plastic limit, and percent fines are often performed at the rate of one per lift. Several water content-density tests are usually performed per lift on the compacted soil. A typical rate of testing would be one water content-density test for each 40 m^2 (400 ft^2). The CQA plan should describe the testing frequency for the test pad.

There is a danger in over testing the test pad -- excessive testing could lead to a greater degree of construction control in the test pad than in the actual liner. The purpose of the test pad is to verify that the materials and methods of construction proposed for a project can result in compliance with performance objectives concerning hydraulic conductivity. Too much control over the construction of the test pad runs counter to this objective.

2.10.7 In Situ Hydraulic Conductivity

2.10.7.1 Sealed Double-Ring Infiltrometer

The most common method of measuring in situ hydraulic conductivity on test pads is the sealed double-ring infiltrometer (SDRI). A schematic diagram of the SDRI is shown Fig. 2.32. The test procedure is described in ASTM D-5093.

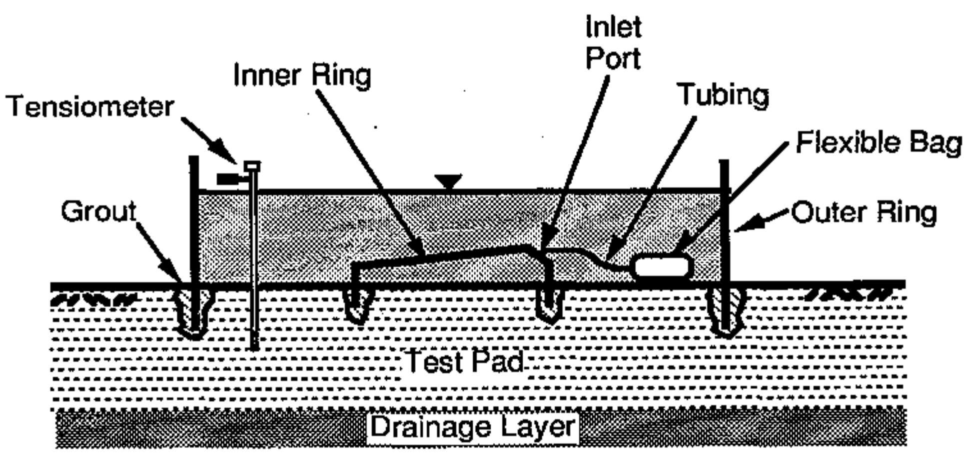


Figure 2.32 - Schematic Diagram of Sealed Double Ring Infiltrometer (SDRI)

With this method, the quantity of water that flows into the test pad over a known period of time is measured. This flow rate, which is called the infiltration rate (I), is computed as follows:

$$I = Q/At \qquad (2.5)$$

where Q is the quantity of water entering the surface of the soil through a cross-sectional area A and over a period of time t.

Hydraulic conductivity (K) is computed from the infiltration rate and hydraulic gradient (i) as follows:

$$K = I/i \tag{2.6}$$

Three procedures have been used to compute the hydraulic gradient. The procedures are called (1) apparent gradient method; (2) wetting front method; and (3) suction head method. The equation for computing hydraulic gradient from each method is shown in Fig. 2.33.

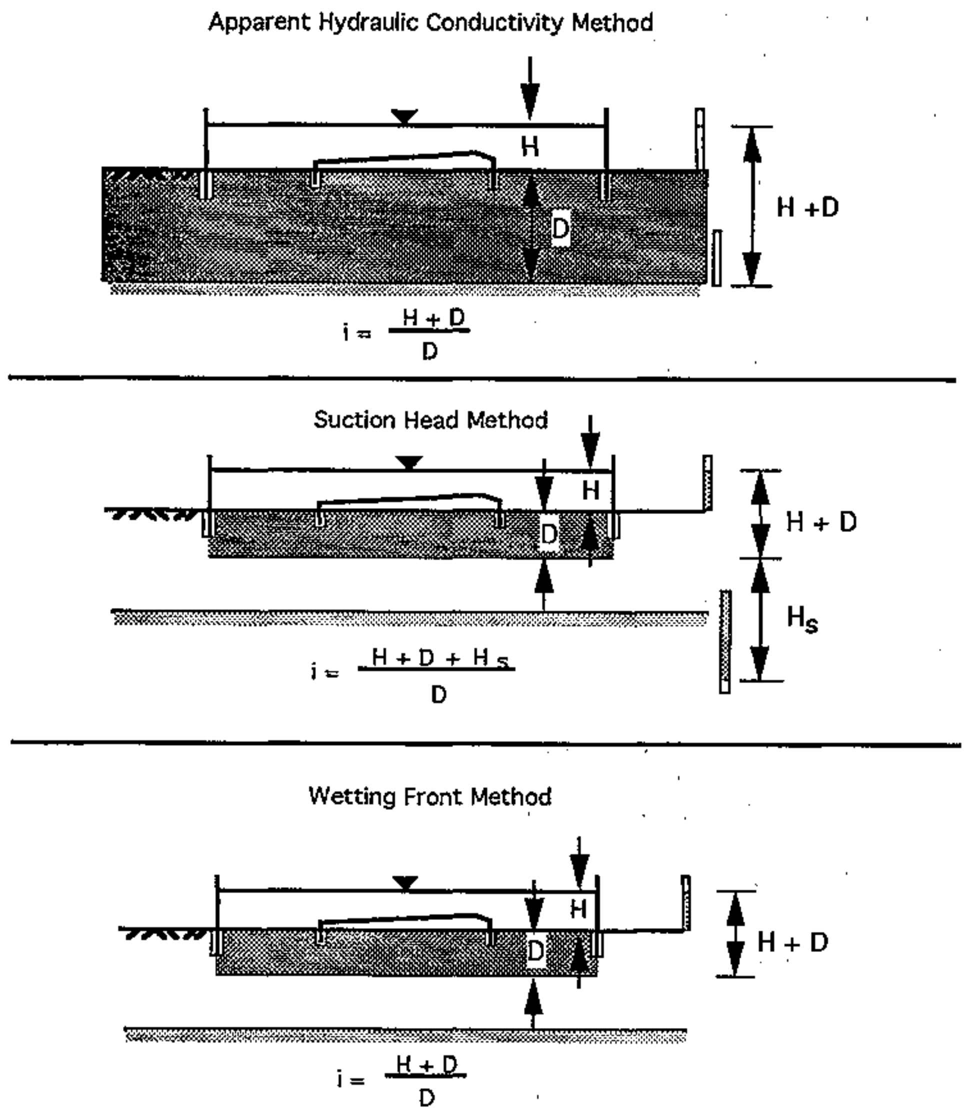


Figure 2.33 - Three Procedures for Computing Hydraulic Gradient from Infiltration Test

The apparent gradient method is the most conservative of the three methods because this method yields the lowest estimate of i and, therefore, the highest estimate of hydraulic conductivity. The apparent gradient method assumes that the test pad is fully soaked with water over the entire depth of the test pad. For relatively permeable test pads, the assumption of full soaking is reasonable, but for soil liners with $K < 1 \times 10^{-7}$ cm/s, the assumption of full soaking is excessively conservative and should not be used unless verified.

The second and most widely used method is the wetting front method. The wetting front is assumed to partly penetrate the test pad (Fig. 2.33) and the water pressure at the wetting front is conservatively assumed to equal atmospheric pressure. Tensiometers are used to monitor the depth of wetting of the soil over time, and the variation of water content with depth is determined at the end of the test. The wetting front method is conservative but in most cases not excessively so. The wetting front method is the method that is usually recommended.

The third method, called the suction head method, is the same as the wetting front method except that the water pressure at the wetting front is not assumed to be atmospheric pressure. The suction head (which is defined as the negative of the pressure head) at the wetting front is H_s and is added to the static head of water in the infiltration ring to calculate hydraulic gradient (Fig. 2.37). The suction head H_s is identical to the wetting front suction head employed in analyzing water infiltration with the Green-Ampt theory. The suction head H_s is not the ambient suction head in the unsaturated soil and is generally very difficult to determine (Brakensiek, 1977). Two techniques available for determining H_s are:

1. Integration of the hydraulic conductivity function (Neuman, 1976):

$$H_s = \int_{h_{sc}}^{0} K_r dh_s \qquad (2.7)$$

   where h_{sc} is the suction head at the initial (presoaked) water content of the soil, K_r is the relative hydraulic conductivity (K at particular suction divided by the value of K at full saturation), and h_s is suction.

2. Direct measurement with air entry permeameter (Daniel, 1989, and references therein).

Reimbold (1988) found that H_s was close to zero for two compacted soil liner materials. Because proper determination of H_s is very difficult, the suction head method cannot be recommended, unless the testing personnel take the time and make the effort to determine H_s properly and reliably.

Corrections may be made to account for various factors. For example, if the soil swells, some of the water that infiltrated into the soil was absorbed into the expanded soil. No consensus exists on various corrections and these should be evaluated case by case.

2.10.7.2 Two-Stage Borehole Test

The two-stage borehole hydraulic conductivity was developed by Boutwell (the test is sometimes called the Boutwell Test) and was under development as an ASTM standard at the time of this writing. The device is installed by drilling a hole (which is typically 100 to 150 mm in diameter), placing a casing in the hole, and sealing the annular space between the casing and borehole with grout as shown in Fig. 2.34. A series of falling head tests is performed and the hydraulic conductivity from this first stage (k_1) is computed. Stage one is complete when k_1 ceases to change significantly. The maximum vertical hydraulic conductivity may be computed by assuming that the vertical hydraulic conductivity is equal to k_1. However, the test may be continued for a second stage by removing the top of the casing and extending the hole below the casing as shown in Fig. 2.34. The casing is reassembled, the device is again filled with water, and falling head tests are performed to determine the hydraulic conductivity from stage two (k_2). Both horizontal and vertical hydraulic conductivity may be computed from the values of k_1 and k_2. Further details on methods of calculation are provided by Boutwell and Tsai (1992), although the reader is advised to refer to the ASTM standard when it becomes available.

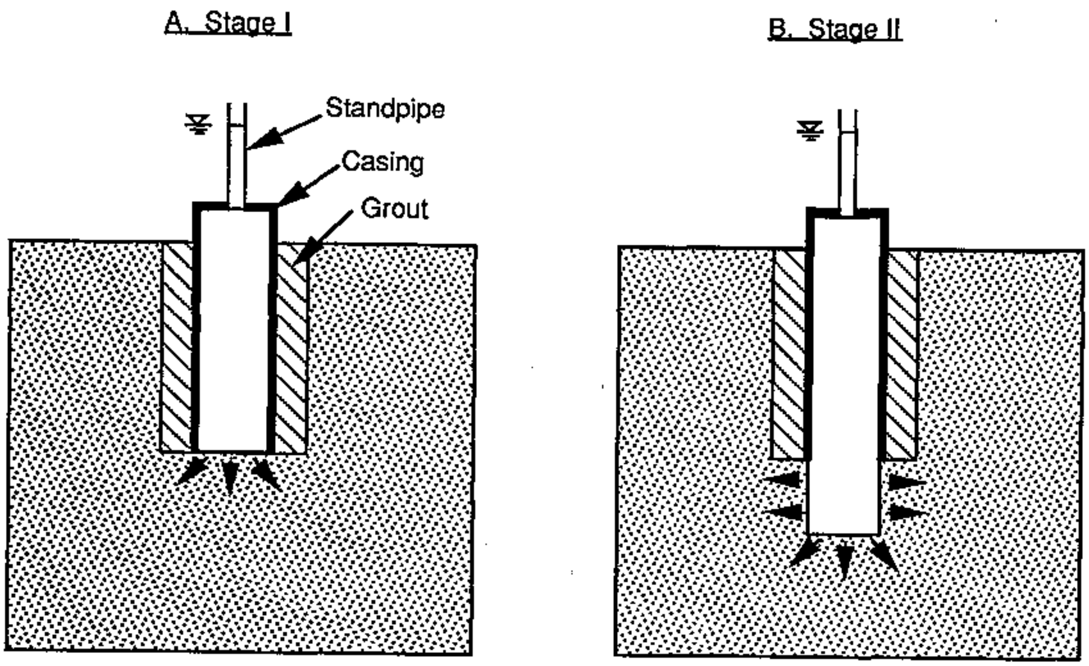


Figure 2.34 - Schematic Diagram of Two-Stage Borehole Test

The two-stage borehole test permeates a smaller volume of soil than the sealed double-ring infiltrometer. The required number of two-stage borehole tests for a test pad is a subject of current research. At the present time, it is recommended that at least 5 two-stage borehole tests be performed on a test pad if the two-stage test is used. If 5 two-stage borehole tests are performed, then one would expect that all five of the measured vertical hydraulic conductivities would be less than or equal to the required maximum hydraulic conductivity for the soil liner.

2.10.7.3 Other Field Tests

Several other methods of in situ hydraulic conductivity testing are available for soil liners. These methods include open infiltrometers, borehole tests with a constant water level in the borehole, porous probes, and air-entry permeameters. The methods are described by Daniel (1989) but are much less commonly used than the SDRI and two-stage borehole test.

2.10.7.4 Laboratory Tests

Laboratory hydraulic conductivity tests may be performed for two reasons:

1. If a very large sample of soil is taken from the field and permeated in the laboratory, the result may be representative of field-scale hydraulic conductivity. The question of how large the laboratory test specimen needs to be is currently a matter of research, but preliminary results indicate that a specimen with a diameter of approximately 300 mm (12 in.) may be sufficiently large (Benson et al., 1993).

2. If laboratory hydraulic conductivity tests are a required component of QA/QC for the actual liner, the same sampling and testing procedures are used for the test pad. Normally, undisturbed soil samples are obtained following the procedures outlined in ASTM D-1587, and soil test specimens with diameters of approximately 75 mm (3 in.) are permeated in flexible-wall permeameters in accordance with ASTM D-5084.

2.10.8 Documentation

A report should be prepared that describes all of the test results from the test pad. The test pad documentation provides a basis for comparison between test pad results and the CQA data developed on an actual construction project.

2.11 Final Approval

Upon completion of the soil liner, the soil liner should be accepted and approved by the CQA engineer prior to deployment or construction of the next overlying layer.

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ASTM D-4944, "Field Determination of Water (Moisture) Content of Soil by Calcium Carbide Gas Pressure Tester Method"

ASTM D-4959, "Determination of Water (Moisture) Content of Soil by Direct Heating Method"

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Chapter 3

Geomembranes

This chapter focuses upon the manufacturing quality assurance (MQA) aspects of geomembrane formulation, manufacture and fabrication, and on the construction quality assurance (CQA) of the complete installation of the geomembranes in the field. Note that in previous literature these liner materials were called *flexible membrane liners* (*FML's*), but the more generic name of geomembranes will be used throughout this document.

The geomembrane materials discussed in this document are those used most often at the time of writing. However, there are other polymer types that are also used. Aspects of quality assurance of these materials can be inferred from information contained in this document. In the future, new materials will be developed and the reader is advised to seek the appropriate information for evaluation of such new or modified materials.

3.1 Types of Geomembranes and Their Formulations

It must be recognized that all geomembranes are actually formulations of a parent resin (from which they derive their generic name) and several other ingredients. The most commonly used geomembranes for solid and liquid waste containment are listed below. They are listed according to their commonly referenced acronyms which will be explained in the text to follow. Other geomembranes in limited use or under initial field trials will also be mentioned where appropriate but will be covered in less detail than the types listed below.

Table 3.1 - Types of Commonly Used Geomembranes and Their Approximate Weight Percentage Formulations*

Geomembrane Type	Resin	Plasticizer	Filler	Carbon Black or Pigment	Additives
HDPE	95-98	0	0	2-3	0.25-1.0
VLDPE	94-96	0	0	2-3	1-4
Other Extruded Types **	95-98	0	0	2-3	1-2
PVC	50-70	25-35	0-10	2-5	2-5
CSPE***	40-60	0	40-50	5-40	5-15
Other Calendered Types**	40-97	0-30	0-50	2-30	0-7

* Note that this Table should not be directly used for MQA or CQA Documents, since neither the Agency nor the Authors of the Report intend to provide prescriptive formulations for manufacturers and their respective geomembranes.

** Other geomembranes than those listed in this Table will be described in the appropriate Section.

*** CSPE geomembranes are generally fabric (scrim) reinforced.

It must be recognized that Table 3.1 and the references to it in the text to follow are meant to reflect on the current state-of-the-art. The values mentioned are not meant to be prescriptive and future research and development may result in substantial changes.

3.1.1 High Density Polyethylene (HDPE)

As noted in Table 3.1, high density polyethylene (HDPE) geomembranes are made from polyethylene resin, carbon black and additives.

3.1.1.1 Resin

The polyethylene resin used for HDPE geomembranes is prepared by low pressure polymerization of ethylene as the principal monomer and having the characteristics listed in ASTM D-1248. As seen in Fig. 3.1, the resin is usually supplied to the manufacturer or formulator in an opaque pellet form.

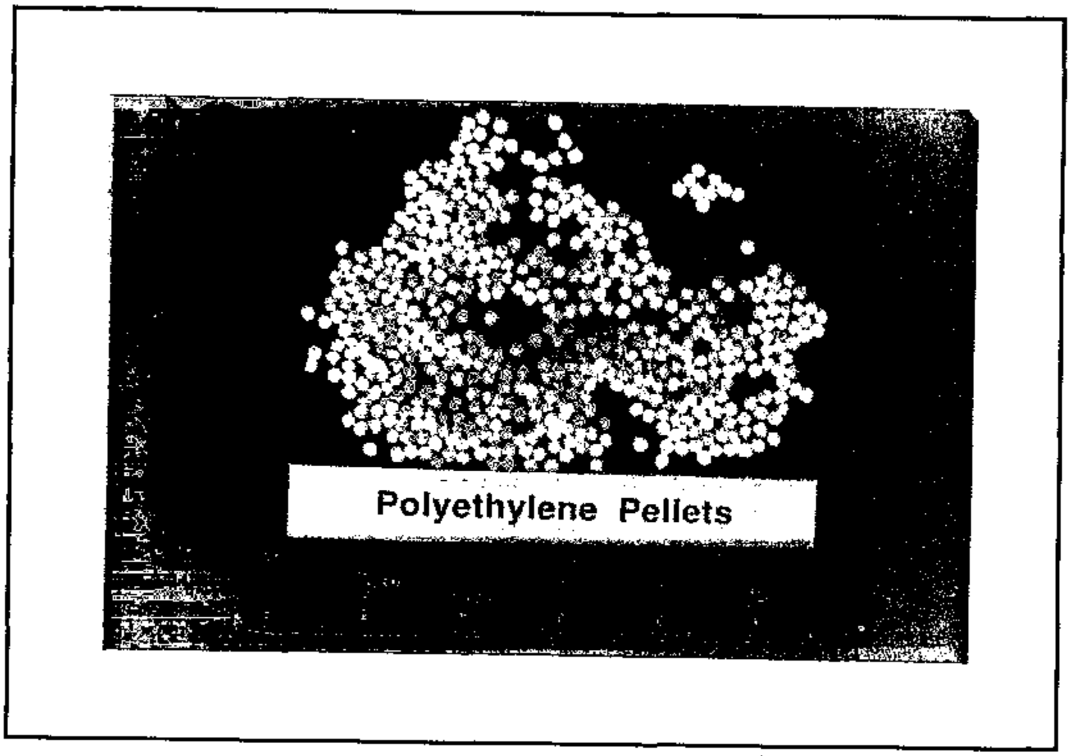


Figure 3.1 - HDPE Resin Pellets

Regarding the preparation of a specification or MQA document for the resin component of an HDPE geomembrane, the following items should be considered:

1. The polyethylene resin, which is covered in ASTM D-1248, is to be made from virgin, uncontaminated ingredients.

2. The quality control tests performed on the incoming resin will typically be density (either ASTM D-792 or D1505) and melt flow index which is ASTM D-1238.

3. Typical natural densities of the various resins used are between 0.934 and 0.940 g/cc. Note that according to ASTM D-1248 this is Type II polyethylene and is classified as medium density polyethylene.

4. Typical melt flow index values are between 0.1 and 1.0 g/10 min as per ASTM D-1238, Cond. 190/2.16.

5. Other tests which can be considered for quality control of the resin are melt flow ratio (comparing high-to-low weight melt flow values), notched constant tensile load test as per ASTM D-5397, and a single point notched constant load test, see Hsuan and Koerner (1992) for details. The latter tests would require a plaque to be made from the resin from which test specimens are taken. The single point notched constant load test is then performed at 30% yield strength and the test specimens are currently recommended not to fail within 200 hours.

6. Additional quality control certification procedures by the manufacturer (if any) should be implemented and followed.

7. The frequency of performing each of the preceding tests should be covered in the MQC plan and it should be implemented and followed.

8. An HDPE geomembrane formulation should consist of at least 97% of polyethylene resin. As seen in Table 3.1 the balance is carbon black and additives. No fillers, extenders, or other materials should be mixed into the formulation.

9. It should be noted that by adding carbon black and additives to the resin, the density of the final formulation is generally 0.941 to 0.954 g/cc. Since this numeric value is now in the high density polyethylene category according to ASTM D-1248, geomembranes of this type are commonly referred to as high density polyethylene (HDPE).

10. Regrind or rework chips (which have been previously processed by the same manufacturer but never used as a geomembrane, or other) are often added to the extruder during processing. This topic will be discussed in section 3.2.2.

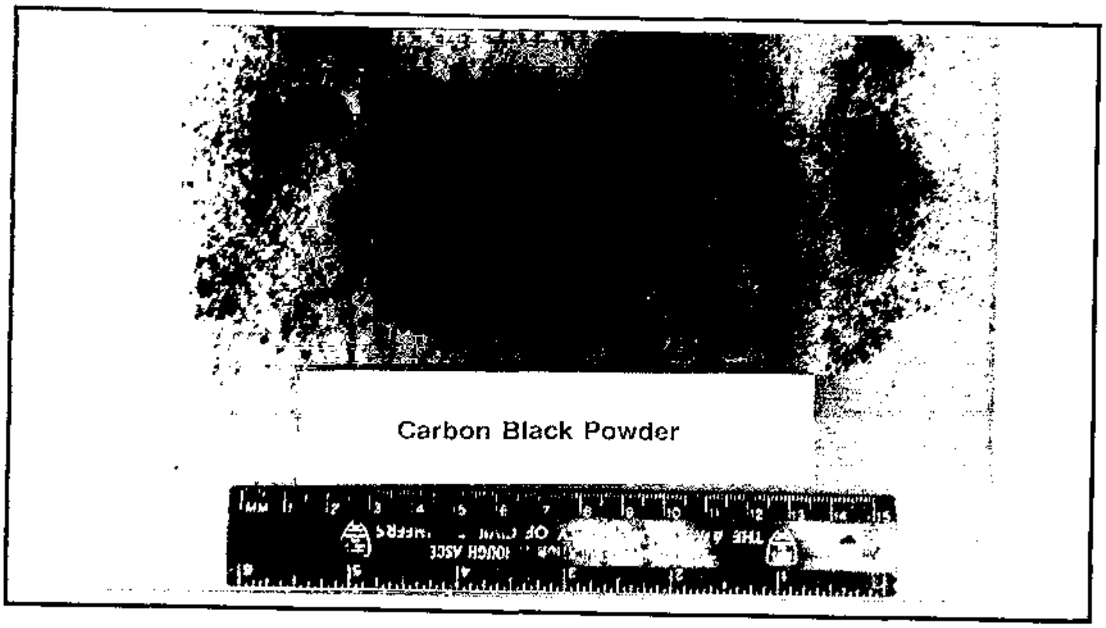
11. Reclaimed material (which is polymer material that has seen previous service life and is recycled) should never be allowed in the formulation in any quantity. This topic will be discussed in section 3.2.2.

3.1.1.2 Carbon Black

Carbon black is added into an HDPE geomembrane formulation for general stabilization purposes, particularly for ultraviolet light stabilization. It is sometimes added in a powder form at the geomembrane manufacturing facility during processing, or (generally) it is added as a preformulated concentrate in pellet form. The latter is the usual case. Figure 3.2 shows photographs of carbon black powder and of concentrate pellets consisting of approximately 25% carbon black in a polyethylene resin carrier.

Regarding the preparation of a specification or MQA document for the carbon black component of HDPE geomembranes, the following items should be considered.

1. The carbon black used in HDPE geomembranes should be a Group 3 category, or lower, as defined in ASTM D-1765.



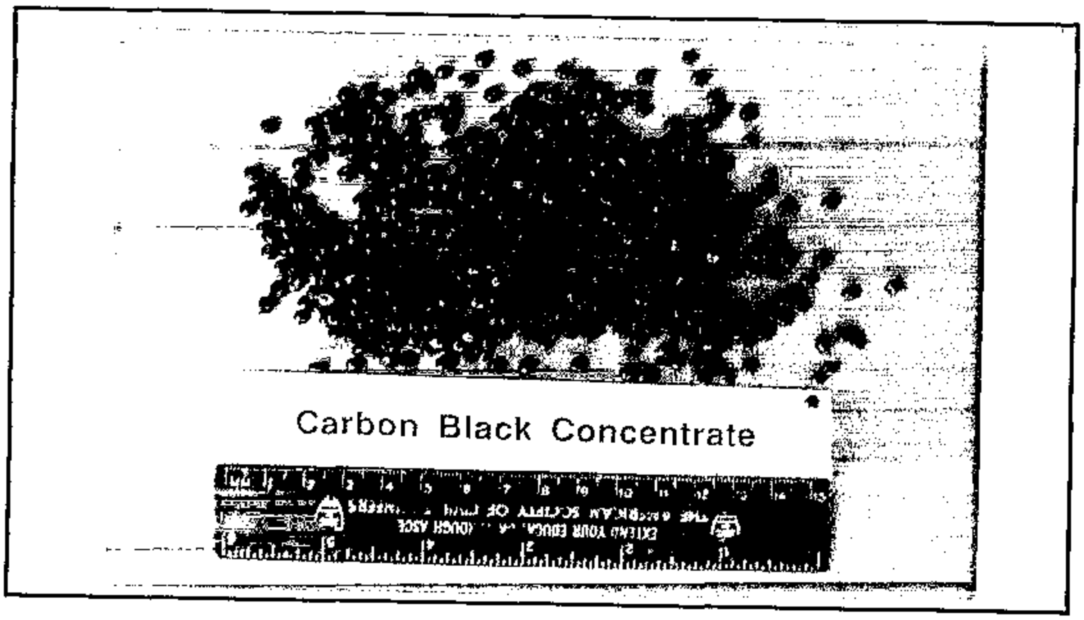


Figure 3.2 - Carbon Black in Particulate Form (Upper Photograph) and as a Concentrate (Lower Photograph)

2. Typical amounts of carbon black are from 2.0% to 3.0% by weight per ASTM D-1603. Values less than 2.0% do not appear to give adequate long-term ultraviolet protection; values greater than 3.0% begin to adversely effect physical and mechanical properties.

3. Current carbon black dispersion requirements in the final HDPE geomembrane are usually required to be A-1, A-2 or B-1 according to ASTM D-2663. Sample preparation is via ASTM D-3015. It should be noted, however, that this test method is directed at polymeric materials containing relatively large amounts of carbon black, e.g., thermoset elastomers with carbon black contents of approximately 18% by volume. ASTM D-35 Committee on Geosynthetics has a Task Group formulating a new standard focused at carbon black dispersion for formulations containing less than 5% carbon black. Thus this standard will be applicable for the 2 to 3% carbon black currently used in polyethylene formulations.

4. In the event that the carbon black is mixed into the formulation in the form of a concentrate rather than a powder, the carrier resin of the concentrate should be the same generic type as the base polyethylene resin.

3.1.1.3 Additives

Additives are introduced into an HDPE geomembrane formulation for the purposes of oxidation prevention, long-term durability and as a lubricant and/or processing aid during manufacturing. It is quite difficult to write a specification for HDPE geomembranes around a particular additive, or group of additives, because they are generally proprietary. Furthermore, there is research and development ongoing in this area and thus additives are subject to change over time.

If additives are included in a specification or MQA document, the description must be very general as to the type and amount. However, the amount can probably be bracketed as to an upper value.

1. The nature of the additive package used in the HDPE compound may be requested of the manufacturer.

2. The maximum amount of additives in a particular formulation should not exceed 1.0% by weight.

3.1.2 Very Low Density Polyethylene (VLDPE)

As seen in Table 3.1, very low density polyethylene (VLDPE) geomembranes are made from polyethylene resin, carbon black and additives. It should be noted that there are similarities between VLDPE and certain types of linear low density polyethylene (LLDPE). The linear structure and lack of long-chain branching in both LLDPE and VLDPE arise from their similar polymerization mechanisms although the catalyst technology is different. In the low-pressure polymerization of LLDPE, the random incorporation of alpha olefin comonomers produces sufficient short-chain branching to yield densities in the range of 0.915 to 0.930 g/cc. The even lower densities of VLDPE resins (from 0.890 to 0.912 g/cc) are achieved by adding more comonomer (which produces more short-chain branching than occurs in LLDPE, and thus a lower level of crystallinity) and using proprietary catalysts and reactor technology. Since VLDPE is more commonly used than LLDPE for geomembranes in waste containment applications, this section is written around VLDPE. It can be used for LLDPE if the density is at the low end of the above mentioned range. The situation is under discussion by many groups as of the writing of this document.

3.1.2.1 Resin

The polyethylene resin used for VLDPE geomembranes is a linear polymer of ethylene with other alpha-olefins. As with HDPE, the resin is generally supplied to the manufacturer in the form of pellets, recall Fig. 3.1.

Some specification or MQA document items for VLDPE resins follow:

1. The very low density polyethylene resin is to be made from completely virgin materials. The natural density of the resin is less than 0.912 g/cc, however, a unique category is not yet designated by ASTM.

2. A VLDPE geomembrane formulation should consist of approximately 94-96% polymer resin. As seen in Table 3.1, the balance is carbon black and additives.

3. Typical quality control tests for VLDPE resin will be density, via ASTM D-792 or D1505, and melt flow index via ASTM D-1238.

4. Additional quality control certification procedures of the manufacturer (if any) should be implemented and followed.

5. The frequency of performing each of the preceding tests should be covered in the MQC plan and it should be implemented and followed.

6. Regrind or rework chips (which have been previously processed by the same manufacturer but never used as a geomembrane, or other) are often added to the formulation during processing. This topic will be discussed in section 3.2.2.

7. Reclaimed material (which is polymer that has seen previous service life and is recycled) should never be allowed in any quantity. This topic will be discussed in section 3.2.2.

3.1.2.2 Carbon Black

Carbon black is added to VLDPE geomembrane formulations for general stabilization purposes, particularly for ultraviolet light stabilization. It is added either in a powder form at the geomembrane manufacturing facility, or it is added as a preformulated concentrate in pellet form, recall Fig. 3.2.

Some items to be included in a specification or MQA document follow:

1. The carbon black used in VLDPE geomembranes should be a Group 3 category, or lower, as defined in ASTM D-1765.

2. Typical amounts of carbon black are from 2.0% to 3.0% by weight as per ASTM D-1603. Values less than 2.0% do not appear to give adequate long-term ultraviolet protection, while values greater than 3.0% begin to negatively effect physical and mechanical properties.

3. Current carbon black dispersion requirements in the final HDPE geomembrane are usually required to be A-1, A-2 or B-1 according to ASTM D-2663[8]. Sample

preparation is via ASTM D-3015. It should be noted, however, that this test method was directed at polymeric materials containing relatively large amounts of carbon black, e.g., thermoset elastomers with carbon black contents of approximately 18% by volume. ASTM D-35 Committee on Geosynthetics has a Task Group formulating a new standard focused at carbon black dispersion for formulations containing less than 5% carbon black which is the amount used in formulation of VLDPE geomembranes.

4. In the event that the carbon black is mixed into the formulation in the form of a concentrate rather than a powder, the carrier resin of the concentrate should be identified.

3.1.2.3 Additives

Additives are introduced into a VLDPE formulation for the purposes of anti-oxidation, long-term durability and as a lubricant and/or processing aid during manufacturing. It is quite difficult to write a specification for VLDPE geomembranes around a particular additive, or group of additives, because they are generally proprietary. Furthermore, there is research and development ongoing in this area and thus additives are subject to change over time.

If additives were included in a specification or MQA document, the description must be very general as to the type and amount. However, the amount can probably be bracketed as to an upper value.

1. The nature of the additive package used in the VLDPE compound may be requested of the manufacturer.

2. The maximum amount of additives in a particular formulation should not exceed 2.0% for smooth sheet or 4.0% for textured sheet by weight.

3.1.3 Other Extruded Geomembranes

Recently, there have been developed other variations of extruded geomembranes. Four have seen commercialization and will be briefly mentioned.

One variation is a coextruded light colored surface layer onto a black base layer for the purpose of reduced surface temperatures when the geomembrane is exposed for a long period of time. The usual application for this material is as a liner for surface impoundments which have no soil covering or sacrificial sheet covering. In the formulation of the light colored surface layer the carbon black is replaced by a pigment (often metal oxides, such as titanium dioxide) which acts as an ultraviolet screening agent. This results in a white, or other light colored surface. The coextruded surface layer is usually relatively thin, e.g., 5 to 10 percent of the total geomembrane's thickness.

A second coextrusion variation is HDPE/VLDPE/HDPE sheet where the two surface layers of HDPE are relatively thin with respect to the VLDPE core. Thickness percentages of 20/60/20 are sometimes used. The interface of these coextruded layers cannot be visually distinguished since the polymers merge into one another while they are in the molten state, i.e., such geomembranes are not laminated together after processing, but are coextruded during processing.

A third variation of coextrusion is to add a foaming agent, such as nitrogen gas, into the surface layer extruder(s). This foaming agent expands and bursts at the surface of the sheet as it cools. The resulting surface is very rough and is generally referred to as *textured*. This variation will be described in Sections 3.2.3.4 and 3.2.4.4 for HDPE and VLDPE, respectively.

A fourth variation of extruded geomembranes is a generic polymer group under the classification of fully crosslinked elastomeric alloys (FCEA). This group of polymers is described in ASTM D-5046. The particular geomembrane type that has been used in waste containment applications is a thermoplastic elastomeric alloy of polypropylene (PP) and ethylene-propylene diene monomer (EPDM). The EPDM is fully crosslinked and suspended in a PP matrix in a process called dynamic vulcanization. The mixed polymer is extruded in a manner similar to the geomembrane types discussed in this section.

3.1.4 Polyvinyl Chloride (PVC)

As seen in Table 3.1, polyvinyl chloride (PVC) geomembranes are made from polyvinyl chloride resin, plasticizer(s), fillers and additives.

3.1.4.1 Resin

The polyvinyl chloride resin used for PVC geomembranes is made by cracking ethylene dichloride into a vinyl chloride monomer. It is then polymerized to make PVC resin. The PVC resin (in the form of a white powder) is then compounded with other components to form a PVC compound.

In the preparation of a specification or MQA document, the following items concerning the PVC resin should be considered.

1. The polyvinyl chloride resin should be made from completely virgin materials.
2. A PVC compound will generally consist of 50-70% PVC resin, by weight.
3. Typical quality control tests on the resin powder will be contamination, relative viscosity, resin gels, color and dry time. The specific test procedures will be specified by the manufacturer. Often they are other than ASTM tests.
4. The frequency of performing each of the preceding tests should be covered in the MQC plan and it should be implemented and followed.
5. Quality control certification procedures used by the manufacturer should be implemented and followed.

3.1.4.2 Plasticizer

Plasticizers are added to PVC formulations to impart flexibility, improve handling and modify physical and mechanical properties. When blended with the PVC resin the plasticizer(s) must be completely mixed into the resin. Since the resin is a powder, and the plasticizers are liquid, mixing of the two components continues until the liquid is completely absorbed by the powder. The result is usually a powder which can be readily conveyed. However, it is also possible to wet blend with acceptable results. There are two general categories of possible plasticizers; monomeric plasticizers and polymeric plasticizers. There are many specific types within each category. For example, monomeric plasticizers are sometimes phthalates, epoxides and phosphates, while polymeric plasticizers are sometimes polyesters, ethylene copolymers and nitrile rubber.

For a specification or MQA document written around PVC plasticizer(s), the following items should be considered.

1. If more than one type of plasticizer is used in a PVC formulation they must be compatible with one another.

2. The plasticizer(s) in a PVC compound are generally from 25-35% of the total compound by weight.

3. The exact type of plasticizer(s) used by the manufacturers are rarely identified. This is industry-wide practice and due to the long history of PVC is generally considered to be acceptable.

4. The plasticizer(s) should be certified by the manufacturer as having a successful past performance or as having been used on a specific number of projects.

3.1.4.3 Filler

The filler used in a PVC formulation is a relatively small component (recall Table 3.1), and (if used at all) is generally not identified. Calcium carbonate, in powder form, has been used but other options also exist. Certification as to successful past performance could be requested.

3.1.4.4 Additives

Other additives for the purpose of ease of manufacturing, coloring and stabilization are also added to the formulation. They are generally not identified. Certification as to successful past performance may be requested.

3.1.5 Chlorosulfonated Polyethylene (CSPE-R)

As seen in Table 3.1, chlorosulfonated polyethylene (CSPE) geomembranes consist of chlorosulfonated polyethylene resin, fillers, carbon black (or colorants) and additives. The finished geomembrane is usually fabricated with a fabric reinforcement, called a "scrim", between the individual plys of the material. It is then designated as CSPE-R.

3.1.5.1 Resin

There are two different types of chlorosulfonated polyethylene resin used to make CSPE geomembranes. One is a completely amorphous polymer while the other is a thermoplastic material containing a controlled amount of crystallinity to provide useful physical properties in the uncured state while maintaining flexibility without the need of any plasticizers. The second type is generally used to manufacture geomembranes. CSPE is made directly from branched polyethylene by adding chlorine and sulfur dioxide. The chlorosulfonic groups act as preferred cross-linking sites during the polymer aging process. In the typical commercial polymer there is one chlorosulfonyl group for each 200 backbone carbon atoms.

CSPE resin pieces usually arrive at the sheet manufacturing facility in large cartons. They are somewhat pillow shaped (about 1 cm diameter) and 2 cm in length. The resin pieces (see Fig. 3.3) are relatively spongy in their resistance to finger pressure. Alternatively, CSPE can be premixed with carbon black in slab form which is then referred to as a master batch. The master batch is usually made by a formulator and shipped to the manufacturing facility in a prepared form.

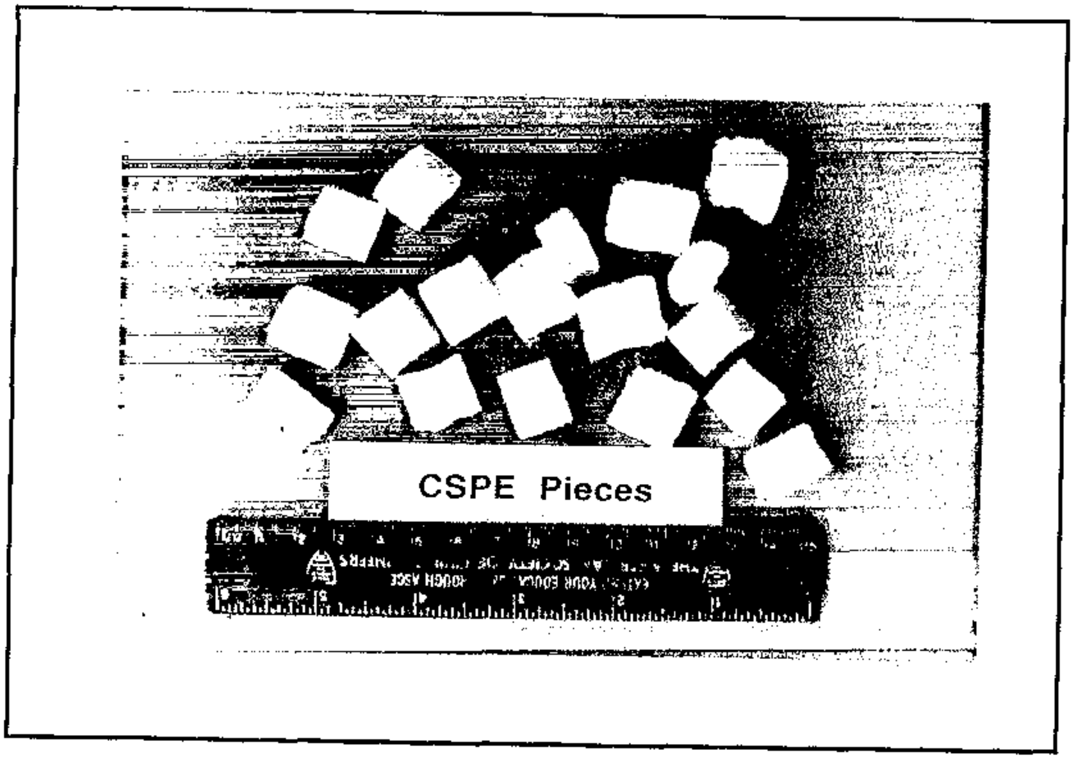


Fig. 3.3 - CSPE Resin Pieces

In preparation of a specification or MQA document, the following items concerning the CSPE resin should considered.

1. The CSPE resin should be made from completely virgin materials.
2. The formulation will usually be based on 40 to 60% of resin, by weight.
3. Typical MQC tests on the CSPE resin will be Mooney viscosity, chlorine content, sulfur content and a series of vulcanization properties (e.g., rheometry and high temperature behavior).
4. The CSPE resin can be premixed with carbon black in slab form (referred to as a "master batch") and shipped to the manufacturers facility.
5. Additional quality control certification procedures used by the manufacturer should be implemented and followed.
6. The frequency of performing each of the preceding tests should be covered in the MQC plan and it should be implemented and followed.

3.1.5.2 Carbon Black

The amount of carbon black in CSPE geomembranes varies from 5 to 36%. The carbon black functions as an ultraviolet light blocking agent, as a filler and aids in processing. The usual types of carbon black used in CSPE formulations are N 630, N 774, N 762 and N 990 as per ASTM D-1765. When low percentages of carbon black are used N 110 to N 220 should be used. When the carbon black is premixed with the resin and produced in the form of a master batch of pellets, it is fed directly into the mixer with the other components, such as fillers, stabilizers and processing aids.

A specification on carbon black in CSPE geomembranes, could be framed around the type and amount of carbon black as just described, but this is rarely the case. Typical MQC certification procedures should be available and implemented.

3.1.5.3 Fillers

The purposes of blending fillers into the CSPE compound are to provide workability and processability. The common types of fillers are clay and calcium carbonate. Both are added in powder form and in quantities ranging from 40 to 50%.

Specifications are rarely written around this aspect of the material, however MQC certification procedures should be available and implemented.

3.1.5.4 Additives

Additives are used in CSPE compounds for the purpose of stabilization which is used to distinguish the various grades. The industrial grade of CSPE geomembranes uses lead oxide as a stabilizer, whereas the potable water grade uses magnesium oxide or magnesium hydroxide. These stabilizers function as acid acceptors during the polymer aging process. During aging, hydrogen chloride or sulfur dioxide releases from the polymer and the metal oxides react with these substances inducing cross linking over time.

Specifications are rarely written around the type and quantity of additives used in CSPE, however MQC certification procedures should be written around each additive, be available and be implemented.

3.1.5.5 Reinforcing Scrim

CSPE geomembranes are usually fabricated with a reinforcing "scrim" between two plys of polymer sheets. This results in a three-ply laminated geomembrane consisting of geomembrane, scrim, geomembrane which is sealed together, under pressure, to form a unitized system. The geomembrane is said to be reinforced and then carries the designation CSPE-R. Other options of multiple plys are also available. The scrim imparts dimensional stability to the material which is important during storage, placement and seaming. It also imparts a major increase in mechanical properties over the unreinforced type, particularly in the tensile strength, modulus of elasticity and tear resistance of the final geomembrane.

The reinforcing scrim for CSPE geomembranes is a woven fabric made from polyester yarns in a standard "basket" weave. Note that there are usually many fine fibers (of very fine diameter) per individual yarn, e.g., 100 to 200 fibers per yarn depending on the desired strength. The yarns, or "strands" as they are referenced in the industry, are spaced close enough to one another to achieve the desired properties, but far apart enough to allow open space between them so that the opposing geomembrane sheet surfaces can adhere together. This is sometimes referred to as "strike-through" and is measured by a ply-adhesion test. The designation of reinforcing scrim is based on the number of yarns, or strands, per inch of woven fabric. The general range is from 6 x 6 to 20 x 20, with 10 x 10 being the most common. A 10 x 10 scrim refers to 10 strands per inch in the machine (or warp) direction and an equal number of 10 strands per inch in the cross machine (or weft) direction.

It must also be mentioned that the polyester scrim yarns must be coated for them to have good bonding to the upper and lower CSPE sheets. Various coatings, including latex, polyvinyl chloride and others, have been used. The exact formulation of the coating material (or "ply enhancer") is usually proprietary.

Regarding a specification or MQA document for the fabric scrim in CSPE-R geomembranes the following applies.

1. The type of polymer used for the scrim is usually specified as polyester, although nylon has been used in the past. It should be identified accordingly.

2. The strength of the fabric scrim can be specified and, when done, is best accomplished in tensile strength units of pounds per individual yarn rather than individual fiber strength.

3. The strike-through is indirectly quantified in specifications on the basis of ply adhesion requirements. This will be discussed later.

3.1.6 Other Calendered Geomembranes

Within the category of calendered geomembranes there are other types that have not been described thus far. They will be briefly noted here along with similarities and/or differences to those just described.

Chlorinated polyethylene (CPE) has been used as a polymer resin in the past for either non-reinforced or scrim reinforced geomembranes. Its production and ingredients are similar to CSPE, or CSPE-R, with the obvious exception of the nature of the resin itself. In contrast to CSPE, CPE contains no sulfur in its formulation.

Ethylene interpolymer alloy (EIA) is always used as a reinforced geomembrane, thus EIA-R is its proper designation. The resin is a blend of ethylene vinyl acetate and polyvinyl chloride resulting in a thermoplastic elastomer. The fabric reinforcement is a tightly woven polyester which requires the polymer to be individually spread coated on both sides of the fabric. Note, however, that there are other related products being developed under different trademarks in this general category.

Among the newer geomembranes is polypropylene (PP) which is a very flexible olefinic polymer based on new polypropylene resin technology. This polymer has been converted into sheet by calendering, with and without scrim reinforcement, and by flat die and blown film extrusion processes. Factory fabrication of large panels is possible. The initial field trials of this type of geomembrane are currently ongoing.

3.2 Manufacturing

Once the specific type of geomembrane formulation that is specified has been thoroughly mixed it is then manufactured into a continuous sheet. The two major processes used for manufacturing of the various types of sheets of geomembranes are variations of either extrusion (e.g., for HDPE, VLDPE, and LLDPE) or calendering (e.g., for PVC, CSPE and PP). Spread coating (the least used process) will be briefly mentioned in section 3.2.8.

3.2.1 Blending, Compounding, Mixing and/or Masticating

Blending, compounding, mixing and/or masticating of the various components described in Section 3.1 is conventionally done on a weight percentage basis. However, each geomembrane's processing is somewhat unique in its equipment and procedures. Even for a particular type of geomembrane, manufacturers will use different procedures, e.g., batch methods versus continuous feed systems, for blending or mixing.

Nevertheless, a few general considerations are important to follow in the preparation of a specification or MQA document.

1. The blending, compounding, mixing and/or masticating equipment must be clean and completely purged from previously mixed materials of a different formulation. This might require sending a complete cycle of purging material through the system, sometimes referred to as a "blank".

2. The various components of the formulation are added on a weight percentage basis to an accuracy set by industry standards. Different components are often added to the mixture at different locations in the processing, i.e., the entire batch is not necessarily added at the outset.

3. By the time the complete formulation is ready for extrusion or calendering it must be completely homogenized. No traces of segregation, agglomeration, streaking or discoloration should be visually apparent in the finished product.

3.2.2 Regrind, Reworked or Trim Reprocessed Material

"Regrind", "reworked" or "trim" are all terms which can be defined as finished geomembrane sheet material which has been cut from edges or ends of rolls, or is off-specification from a surface blemish, thickness or other property point of view. Figure 3.4(a) shows a photograph of HDPE regrind chips. VLDPE chips appear similar to HDPE. Figure 3.4(b) shows a photograph of PVC edge strips i.e., edge of sheet material cut off to meet specific roll width requirements. Excess edge trimmings of PVC sheet is fed back into the production system. CSPE-R trim can be added similarly, however without any reinforcing scrim.

These materials are reintroduced during the blending, compounding and/or mixing stage in controlled amounts as a matter of cost efficiency on the part of the manufacturer. Note that regrind, rework and trim material must be clearly distinguished from "recycled", or "reclaimed", material which is finished sheet material that has actually seen some type of service performance and has subsequently been returned to the manufacturing facility for reuse into new sheet material.

In preparing a specification or MQA document on the use of reprocessed material, the following items should be considered:

1. Regrind, reworked or trim materials in the form of chips or edge strips may be added if the material is from the same manufacturer and is exactly the same formulation as the geomembrane being produced.

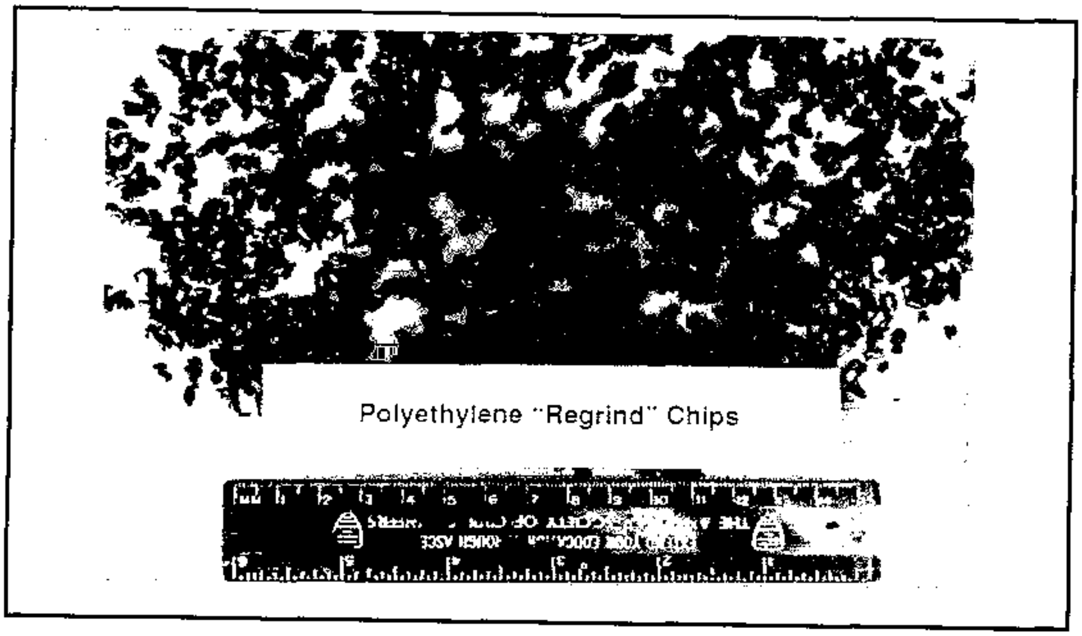


Figure 3.4(a) - HDPE Regrind Chips

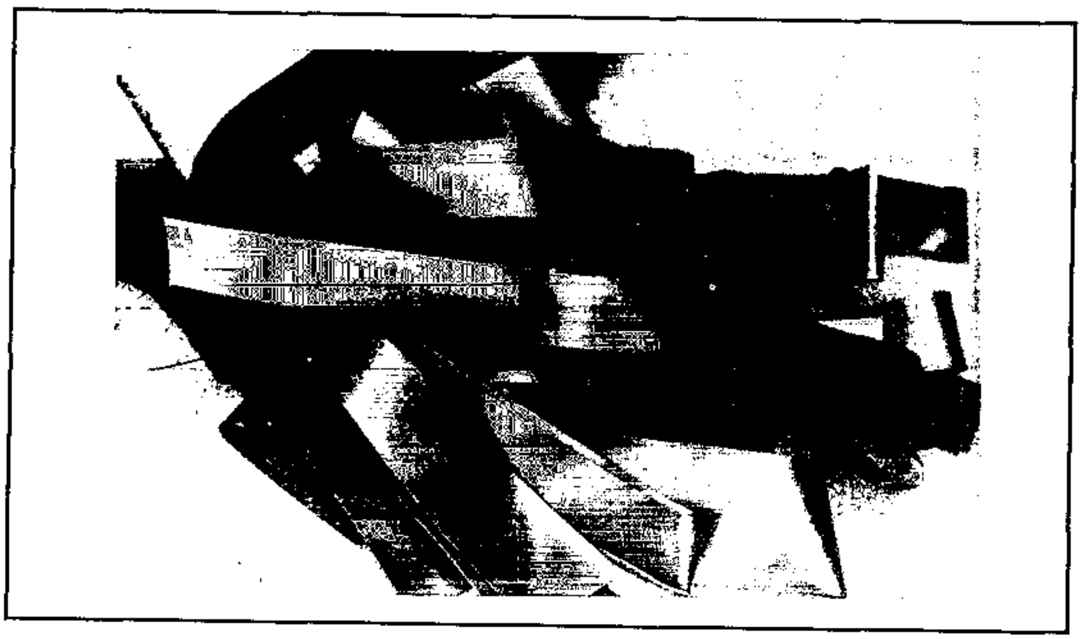


Figure 3.4(b) - PVC Edge Strips

Figure 3.4 - Photographs of Materials to be Reprocessed

2. Generally HDPE and VLDPE will be added in chip form as "regrind" in controlled amounts into the hopper of the extruder.

3. Generally PVC, CSPE and PP will be added in the form of a continuous strip of edge trimmings into the roll mill which precedes calendering. For scrim reinforced geomembranes it is important that the edge trim does not contain any portion of the fabric scrim.

4. The maximum amount of regrind, reworked or trim material to be added is a topic of considerable debate. Its occurrence in the completed sheet is extremely difficult, if not impossible, to identify much less to quantify by current chemical fingerprinting methods. Thus its maximum amount is not suggested in this manual. It should be mentioned that if regrind is not permitted to be used, the manufacturer may charge a premium over current practice.

5. It is generally accepted that no amount of "recycled", or "reclaimed" sheet material (in any form whatsoever) should be added to the formulation.

3.2.3 High Density Polyethylene (HDPE)

High density polyethylene (HDPE) geomembranes are manufactured by taking the mixed components described earlier and feeding them into a hopper which leads to a horizontal extruder, see Fig. 3.5. In the manufacturing of HDPE geomembranes many extruders are 200 mm (8.0 inch) diameter systems which are quite large, e.g., up to 9 m (30 ft. long). In an extruder, the components enter a feed hopper and are transported via a continuous screw through a feed section, compression stage, metering stage, filtering screen and are then pressure fed into a die. The die options currently used for HDPE geomembrane production are either flat horizontal dies or circular vertical dies, the latter production technique often being referred to as "blown film" extrusion. The length of flat dies and the circumference of circular dies determine the width of the finished sheet and vary greatly from manufacturer to manufacturer. Some detail is given below.

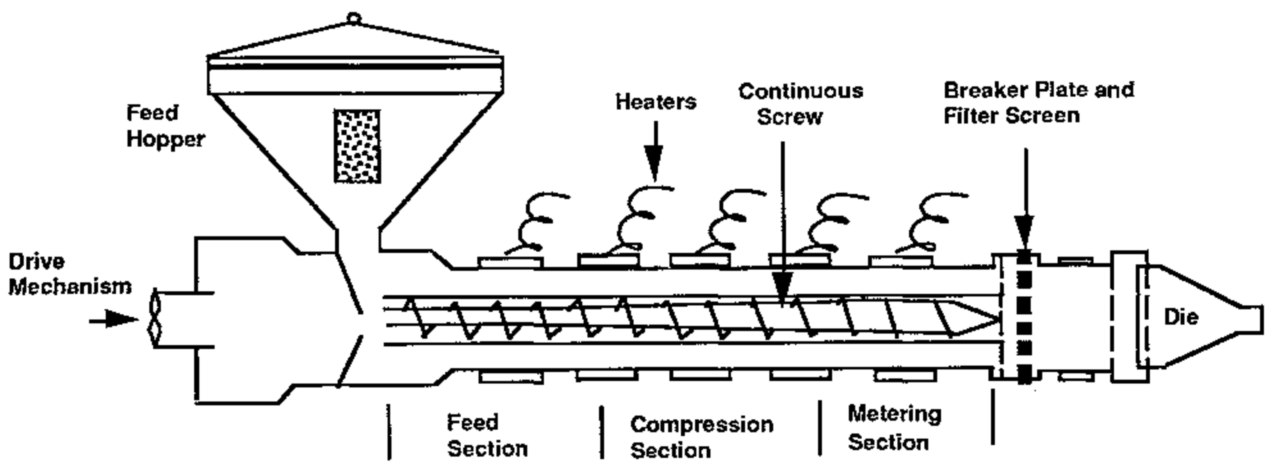


Figure 3.5 - Cross-Section Diagram of a Horizontal Single-Screw Extruder for Polyethylene

3.2.3.1 Flat Die - Wide Sheet

A conventional HDPE geomembrane sheet extruder can feed enough polymer to produce sheet up to approximately 4.5 m (15 ft.) wide in typical HDPE thicknesses of 0.75 to 3.0 mm (30 to 120 mils), see Fig. 3.6. Recently, one manufacturer has used two such extruders in parallel to produce sheet approximately 9.0 m (30 ft.) wide.

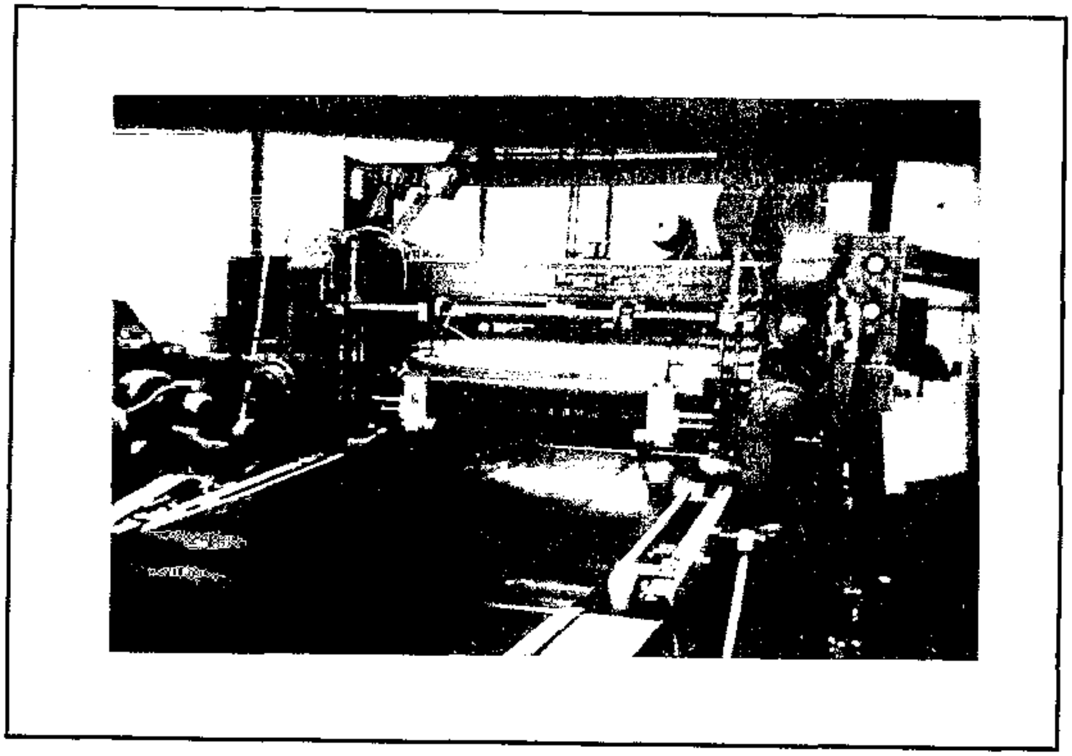


Figure 3.6 - Photograph of a Polyethylene Geomembrane Exiting from a Relatively Narrow Flat Horizontal Die

Insofar as a specification or MQA document for finished HDPE geomembranes made by flat die extrusion, the following items should be considered.

1. The finished geomembrane sheet must be free from pinholes, surface blemishes, scratches or other defects (e.g., nonuniform color, streaking, roughness, carbon black agglomerates, visually discernible regrind, etc.).

2. The nominal and minimum thicknesses of the sheet should be specified. The minimum value is usually related to the nominal thickness as a percentage. Values range from 5% to 10% less than nominal.

3. The maximum thickness of the sheet is rarely, if ever, specified. This is for the obvious reason that if a manufacturer wishes to supply sheet thicker than specified it is generally acceptable. It is also done, however, to allow for those manufacturers with unique variations of flat die extrusion (such as horizontal ribs or factory fabricated seams) to not be excluded from the market.

4. The finished sheet width should be controlled to be within a set tolerance. This is usually done by creating a sheet larger than called for, and trimming the edges immediately before final rolling onto the wind-up core. (The edge trim is subsequently ground into chips and used as regrind as previously described). Flat die extrusion of HDPE sheet should meet a ± 2.0% width specification.

5. Other MQC tests such as strength, puncture, tear, etc. should be part of a certification program which should be available and implemented.

6. The frequency of performing each of the preceding tests should be covered in the MQC plan and it should be implemented and followed.

7. The trimmed and finished sheet is wound onto a hollow wind-up core which is usually heavy cardboard or (sometimes) plastic pipe. The outside diameter of the core should be at least 150 mm (6.0 in). It obviously must be stable enough to support the roll without buckling or otherwise failing during handling, storage and transportation.

8. Partial rolls for site specific project details may be cut and prepared for shipment per the contract drawings.

3.2.3.2 Flat Die - Factory Seamed

Since there are commercial extruders which produce sheets less than 6 m (20 ft) wide, the resulting sheet widths can be factory seamed into wider panels before shipment to the field. All of the specification details just described apply to narrow sheets as well as to wide sheets.

The method of factory seaming should be left to the discretion of the manufacturer. The factory seams, however, must meet the same specifications as the field seams (to be described later).

3.2.3.3 Blown Film

By using a vertically oriented circular die the extruder can feed molten polymer in an upward orientation creating a large cylinder of polyethylene sheet, see Fig. 3.7. Since the cylinder of polymer is closed at the top where it passes over a set of nip rollers which advances the cylinder, air is generally blown within it to maintain its dimensional stability. Note that upward moving air is also outside of the cylinder to further aid in stability. After passing through the nip rollers, the collapsed cylinder is cut longitudinally, opened to its full width, brought down to floor level and rolled onto a wind-up core. Note that collapsing the cylinder and passing it through the nip rollers results in two creases. After slitting the collapsed cylinder and opening it to full width, remnants of the two creases remain.

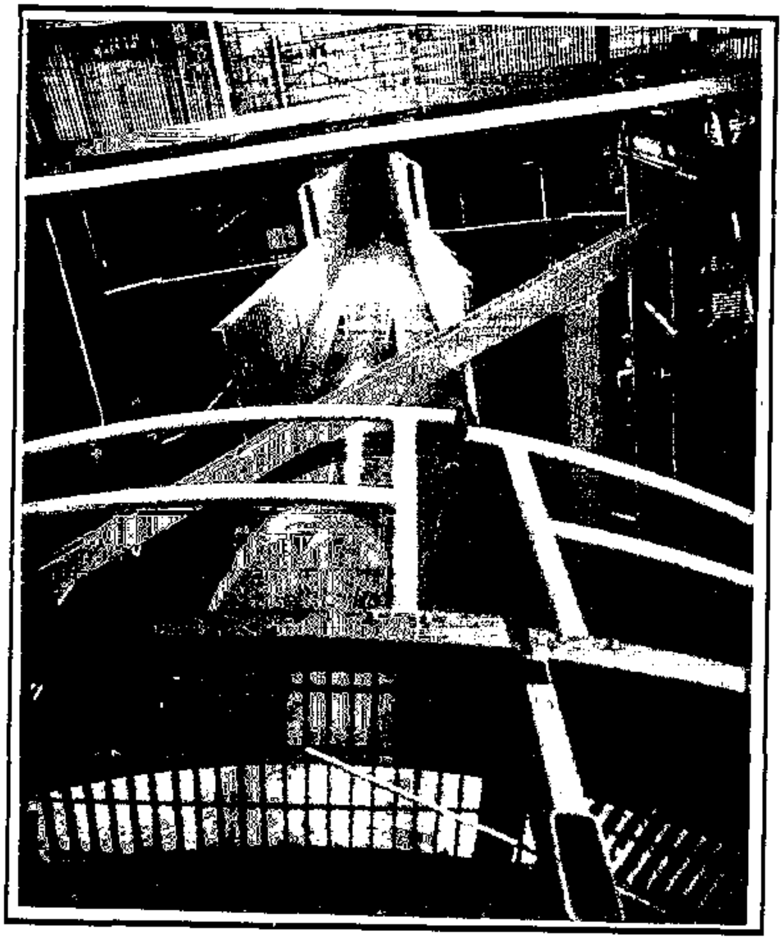


Figure 3.7 (a) - Photograph of Blown Film Manufacturing of Polyethylene Geomembranes

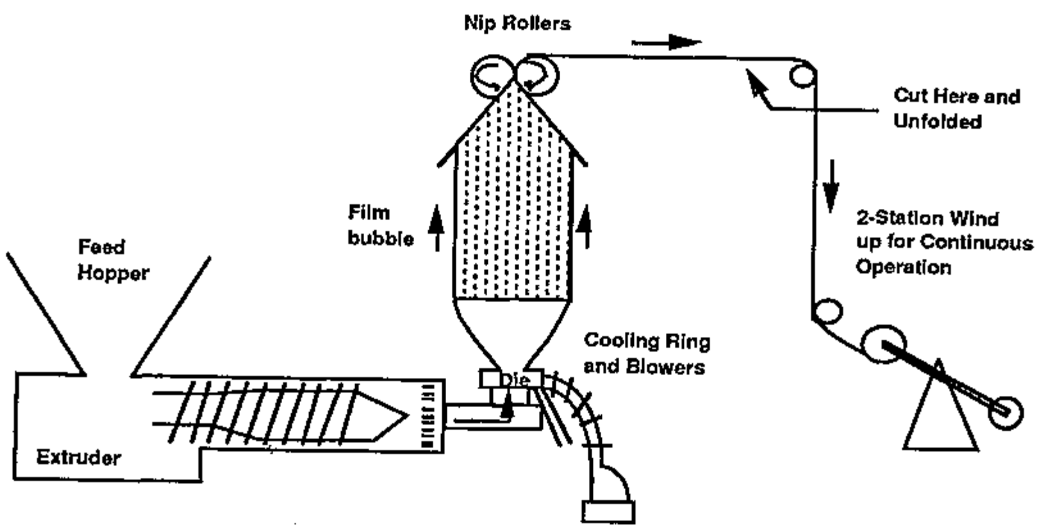


Fig. 3.7(b) - Sketch of Blown Film Manufacturing of Polyethylene Geomembranes

Regarding a specification or MQA document for blown film produced HDPE geomembranes, the following applies:

1. The finished geomembrane sheet shall be free from pinholes, surface blemishes, scratches or other defects (e.g., nonuniform color, streaking, roughness, carbon black agglomerates, visually discernible regrind, etc.). Note that two machine direction creases from nip rollers are automatically induced into the finished sheet at the 1/4 distances from each edge.

2. The nominal and minimum thickness of the sheet should be specified. The minimum value is usually related to the nominal thickness as a percentage. Values referenced range from 5% to 10% less than nominal.

3. The maximum thickness of the sheet is rarely, if ever, specified. This is for the obvious reason that if a manufacturer wishes to supply sheet thicker than specified it is generally acceptable.

4. The finished sheet width should be controlled to be within a set tolerance. HDPE geomembrane made from the blown film extrusion method should meet a ± 2.0% width specification.

5. Other MQC tests such as tensile strength, puncture, tear, etc., should be part of a certification program which should be available and implemented.

6. The finished sheet is wound onto a hollow wind-up core which is usually heavy cardboard or sometimes plastic pipe. The outside diameter of the core should be at least 150 mm (6.0 in.). It must be stable enough to support the roll without buckling or otherwise failing during handling, storage and transportation.

7. It is important that the two creases located at the 1/4-points from the edges of the sheet are wound on the core such that they will face upward when deployed in the field. The reason for this is so that scratches will not occur on the creases if the sheets are shifted on the soil subgrade when in an open and flat position.

8. Partial rolls for site specific project details may be cut and prepared for shipment as per the contract drawings.

3.2.3.4 Textured Sheet

By creating a roughened surface on a smooth HDPE sheet, a process called "texturing" in this document, a high friction surface can be created. There are currently three methods used to texturize smooth HDPE geomembranes: coextrusion, impingement and lamination, see Fig. 3.8.

The *coextrusion* method utilizes a blowing agent in the molten extrudate and delivers it from a small extruder immediately adjacent to the main extruder. When both sides of the sheet are to be textured, two small extruders (one internal and one external to the main extruder) are necessary. As the extrudate from these smaller extruders meets the cool air the blowing agent expands, opens to the atmosphere and creates the textured surface(s).

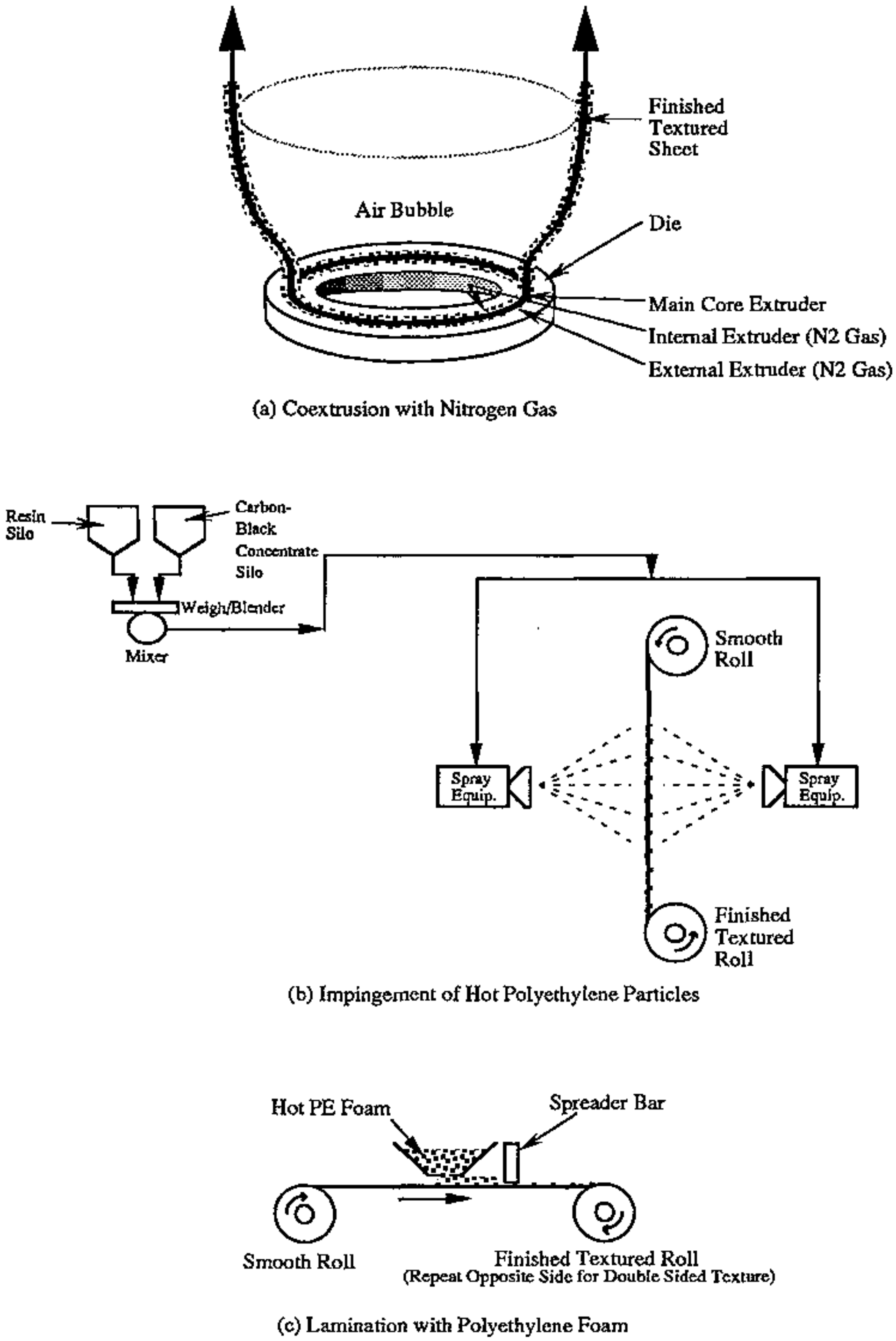


Figure 3.8 - Various Methods Currently Used to Create Textured Surfaces on HDPE Geomembranes

Impingement of hot HDPE particles against the finished HDPE sheet is a second method of texturing. In this case, hot particles are actually projected onto the previously prepared sheet on one or both of its surfaces in a secondary operation. The adhesion of the hot particles to the cold surface(s) should be as great, or greater, than the shear strength of the adjacent soil or other abutting material. The lengthwise edges of the sheets can be left non-textured for up to 300 mm (12 in.) so that thickness measurements and field seaming can be readily accomplished.

The third method for texturizing HDPE sheet is by *lamination* of an HDPE foam on the previously manufactured smooth sheet in a secondary operation. In this method a foaming agent contained within molten HDPE provides a froth which produces a rough textured laminate adhered to the previously prepared smooth sheet. The degree of adhesion is important with respect to the shear strength of the adjacent soil or other abutting material. If texturing on both sides of the geomembrane is necessary, the roll must go through another cycle but now on its opposite side. The lengthwise edges of the sheets can be left non-textured for up to 300 mm (12 in.) so that thickness measurements and field seaming can be readily accomplished.

Regarding the writing of a specification or MQA document on textured HDPE geomembranes the following points should be considered.

1. The surface texturing material should be of the same type of polymer and formulation as the base sheet polymer and its formulation. If other chemicals are added to the texturing material they must be identified in case of subsequent seaming difficulties.

2. The degree of texturing should be sufficient to develop the amount of friction as needed per the manufacturers specification and/or the project specifications.

3. The quality control of the texturing process can be assessed for uniformity using an inclined plane test method, e.g., GRI GS-7*.

4. The actual friction angle for design purposes should come from a large scale direct shear test simulating site specific conditions as closely as possible, e.g., ASTM D-5321.

5. The thickness of the base geomembrane should be micrometer measured (according to ASTM D-751) along the smooth edge strips of textured geomembranes made by impingement or lamination. For those textured geomembranes with no smooth edge strips, i.e., for blown film coextruded materials, an overall average thickness can be estimated on the basis of the roll weight divided by total area with suitable incorporation of the density of the material. Alternatively, a tapered point micrometer for measuring screw threads has also been used for point-to-point measurements.

6. Other MQC tests such as tensile strength, puncture, tear, etc., should be part of a certification program which should be available and implemented.

7. The frequency of performing each of the preceding tests should be covered in the MQC plan and it should be implemented and followed.

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* The Geosynthetic Research Institute (GRI) provides interim test methods for a variety of geosynthetic related topics until such time as consensus organizations (like ASTM) adopt a standard on the same topic. At that time the GRI standard is abandoned.

3.2.4 Very Low Density Polyethylene (VLDPE)

Very low density polyethylene (VLDPE) geomembranes are manufactured by taking the mixed components described earlier and feeding them into a hopper which leads to a horizontal extruder, recall Fig. 3.5. In the extruder, the blended components enter via a feed hopper and are transported via a continuous screw, through a feed section, compression stage, metering stage, filtering screen and are then pressure fed into a die. The die options currently used for VLDPE geomembrane production are either flat horizontal dies or circular vertical dies, the latter often being referred to as "blown film" extrusion. The width of flat dies and the circumference of circular dies vary greatly from manufacturer to manufacturer. The techniques are the same as were described in the manufacture of HDPE geomembranes.

3.2.4.1 Flat Die - Wide Sheet

A conventional VLDPE sheet extruder can feed enough polymer to produce sheet up to approximately 4.5 m (15 ft.) wide in typical VLDPE thicknesses of 0.75 to 3.0 mm (30 to 120 mils), recall Fig. 3.6. In developing a specification or MQA document for the manufacture of VLDPE geomembranes the following should be considered:

1. The finished geomembrane sheet must be free from pinholes, surface blemishes, scratches or other defects (e.g, carbon black agglomerates, visually discernible regrind, etc.).

2. The minimum thickness of the sheet should be specified. It is usually related to the nominal thickness as a percentage. Values range from 5% to 10% less than nominal.

3. The maximum thickness of the sheet is rarely, if ever, specified. This is for the obvious reason that if a manufacturer wishes to supply sheet thicker than specified it is generally acceptable. It is also done, however, to allow for those manufacturers with unique variations of flat die extrusion (such as horizontal ribs or factory fabricated seams) to not be excluded from the market.

4. The finished sheet width should be controlled to be within a set tolerance. This is usually done by creating a sheet larger than called for, and trimming the edges immediately before final rolling onto the wind-up core. (The edge trim is subsequently ground into chips and used as regrind as previously described). Flat die extrusion of VLDPE sheet can readily meet a ± 0.25% width specification.

5. Other MQC tests such as tensile strength, puncture, tear, etc. should be part of a certification program which should be available and implemented.

6. The trimmed and finished sheet is wound onto a hollow wind-up core which is usually heavy cardboard or sometimes plastic pipe. The outside diameter of the core should be at least 150 mm (6.0 in). It obviously must be stable enough to support the roll without buckling or otherwise failing.

7. Partial rolls for site specific project details may be cut and prepared for shipment as per contract drawings.

3.2.4.2 Flat Die - Factory Seamed

Since there are commercial extruders which produce significantly narrower sheet than just discussed, the resulting narrow sheet widths can be factory seamed into wider panels before shipment to the field. All of the specification details just described apply to narrow sheets as well as to wide sheets.

The method of factory seaming should be left to the discretion of the manufacturer. The factory seams, however, must be held to the same destructive and nondestructive testing procedures as with field seams (to be described later).

3.2.4.3 Blown Film

By using a circular die oriented vertically the extruder can feed molten polymer in an upward orientation creating a large cylinder of polymer, recall Fig. 3.7. Since the cylinder is closed at the top where it passes over a set of nip rollers which advances the cylinder, air is generally contained within it maintaining its dimensional stability. Note that upward moving air is also outside of the cylinder to further aid in stability. After passing beyond the nip rollers the cylinder is cut longitudinally, opened to its full width, brought down to floor level and rolled onto a stable core.

The following items should be considered in preparing a specification or MQA document for blown film VLDPE geomembranes.

1. The finished geomembrane sheet shall be free from pinholes, surface blemishes, scratches or other defects (carbon black agglomerates, visually discernible regrind, etc.). Note that two machine direction creases from nip rollers are automatically induced into the finished sheet at the 1/4 distances from each edge.

2. The minimum thickness of the sheet should be specified. It is usually related to the nominal thickness as a percentage. Values referenced range from 5% to 10% less than nominal.

3. The maximum thickness of the sheet is rarely, if ever, specified. This is for the obvious reason that if a manufacturer wishes to supply sheet thicker than specified it is generally acceptable.

4. The finished sheet width should be controlled to be within a set tolerance. VLDPE geomembrane made from the blown film extrusion method should meet a ± 2.0% width specification.

5. Other MQC tests such as tensile strength, puncture, tear, etc. should be part of a certification program which should be available and implemented.

6. The finished sheet is wound onto a hollow wind-up core which is usually heavy cardboard or sometimes plastic pipe. The outside diameter of the core should be at least 150 mm (6.0 in.). It obviously must be stable enough to support the roll without buckling or otherwise failing.

7. Partial rolls for site specific project details may be cut and prepared for shipment as per contract drawings.

3.2.4.4 Textured Sheet

By creating a roughened surface on a smooth VLDPE sheet, a process called "texturing" in this document, a high friction surface can be created. There are currently three methods used to texturize smooth VLDPE geomembranes: coextrusion, impingement and lamination, recall Fig. 3.8.

The *coextrusion* method utilizes a blowing agent in the molten extrudate and delivers it from a small extruder immediately adjacent to the main extruder. When both sides of the sheet are to be textured, two small extruders, one internal and one external to the main extruder, are necessary. As the extrudate from these smaller extruders meets the cool air the blowing agent expands, opens to the atmosphere and creates the textured surface(s).

Impingement of hot polyethylene particles against the finished VLDPE sheet is a second method of texturing. In this case, hot particles are actually projected onto the previously prepared sheet on one or both of its surfaces in a secondary operation. The adhesion of the hot particles to the cold surface(s) should be as great, or greater, than the shear strength of the adjacent soil or other abutting material. The lengthwise edges of the sheets can be left non-textured for up to 30 cm (12 in.) so that thickness measurements and field seaming can be readily accomplished.

The third method for texturizing VLDPE sheet is by *lamination* of a hot polyethylene foam on the previously manufactured smooth sheet in a secondary operation. In this method a foaming agent contained in molten polyethylene provides a froth which produces a rough textured laminate adhered to the previously prepared smooth sheet. The degree of adhesion is important with respect to the shear strength of the adjacent soil or other abutting material. If texturing of both sides of the geomembrane is necessary the roll must go through another cycle but now on its opposite side. The lengthwise edges of the sheets can be left non-textured for up to 300 mm (12 in.) so that thickness measurements and field seaming can be readily accomplished.

Regarding the writing of a specification or MQA document on textured VLDPE geomembranes the following points should be considered.

1. The surface texturing material should be polyethylene of density equal to the VLDPE, or greater. The latter is often the case. If other chemicals are added to the texturing material they must be identified in case of subsequent seaming difficulties.

2. The degree of texturing should be sufficient to develop the amount of friction as needed per the manufacturers specification and/or the project specifications.

3. The quality control of the texturing process can be assessed for uniformity using an inclined plane test method, e.g., GRI GS-7.

4. The actual friction angle for design purposes should come from a large scale direct shear test simulating site specific conditions as closely as possible, e.g., ASTM D-5321.

5. The thickness of the base geomembrane should be micrometer measured (according to ASTM D-751) along the smooth edge strips of textured geomembranes made by impingement or lamination. For those textured VLDPE geomembranes with no smooth edge strips, i.e., for blown film coextruded materials, an overall average thickness can be estimated on the basis of the roll weight divided by total area with suitable incorporation of the density of the material. Alternatively, a tapered point micrometer for measuring screw threads has also been used for point-to-point measurements. Care must be exercised, however, because VLDPE thickness measurements with a point micrometer are very sensitive to pressure.

6. Other MQC tests such as tensile strength, puncture, tear, etc., should be part of a certification program which should be available and implemented.

7. The frequency of performing each of the preceding tests should be covered in the MQC plan and it should be implemented and followed.

3.2.5 Coextrusion Processes

As mentioned previously in Section 3.1.3, there are other variations of manufacturing polyethylene geomembranes. The basic manufacturing principle of adding the desired components to an extruder and having the molten polymer exit a flat horizontal die or a circular vertical die is always the same. What is different between these variations and the single component HDPE or VLDPE just described is the coextrusion process along with the idiosyncrasies of the particular materials utilized.

In coextrusion, two or three extruders simultaneously introduce molten polymer into the same die. As the different materials exit the die and are cooled they commingle with one another such that local blending and molecular entanglement occur and no discrete separation layer exists. Thus coextrusion is fundamentally different from the lamination of different surfaces together or of preformed sheets together under heat and pressure. Different variations of coextrusion of polyethylene geomembranes are described as follows.

Since polyethylene resin is supplied as a opaque pellet, the addition of colorants (rather than carbon black) can produce white, blue, green, etc., colored geomembranes. The benefit for geomembranes having these light colors is to reduce the surface temperature of the geomembrane when it is required to be exposed, e.g., as liners for surface impoundments or floating covers for reservoirs. Figure 3.9 shows how the temperature differences between white and black can be very significant. The white (or light) colors generally utilize titanium dioxide (or other metal oxides) in amounts not exceeding 1.0% by weight. Note that only a thin surface layer (approximately 10-20% of the total thickness) is treated in this manner. The balance of the geomembrane contains carbon black and is treated in the same manner as described previously.

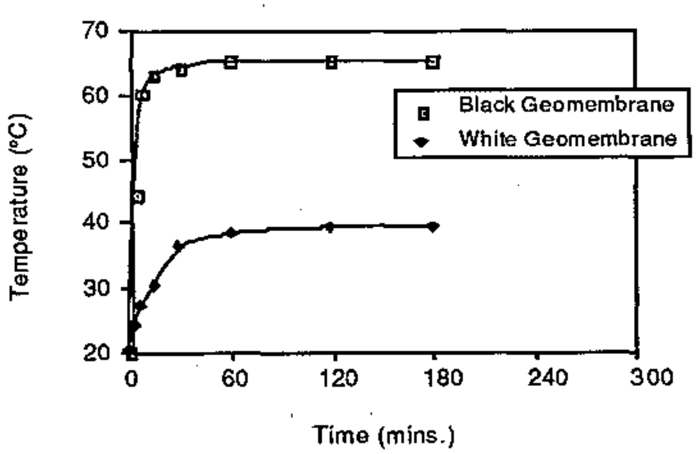


Figure 3.9 - Geomembrane Surface Temperature Differences Between Black and White Colors

A second variation of polyethylene is to coextrude a "sandwich" of HDPE on each side of VLDPE in the center. The purpose of such a combination is to provide high chemical resistance on the top and bottom of the sheet (via the HDPE) and to have high flexibility and out-of-plane elongation properties within the core (via the VLDPE). The thickness percentages of these components are approximately 20%, 60% and 20% of the total thickness of the sheet, respectively.

Third, it is possible to coextrude a surface layer to conventional HDPE or VLDPE which contains a gas that expands when cooled. Thus the molten polymer moves through the die in a regular manner only to have the expanding gas rapidly exit on its surface(s). This forms a roughened, or textured, surface which depends on the amount of gas and thickness of the coextruded surface layer. Similar extruders can be used on both sides of the parent sheet. The purpose of such texturing is to increase the interface friction between the textured geomembrane and the material above and/or below it, refer to Sections 3.2.3.4 and 3.2.4.4.

Lastly, it is possible to coextrude other polymers than polyethylene. As noted in Section 3.1.3, fully crosslinked elastomeric alloys (FCEA) can be extruded or could be coextruded with other polymers.

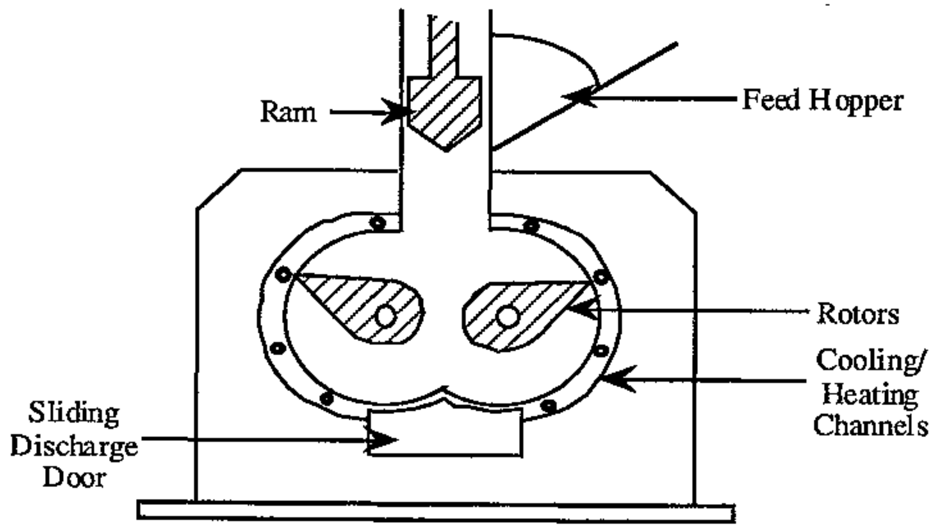
3.2.6 Polyvinyl Chloride (PVC)

Polyvinyl chloride (PVC) geomembranes are manufactured by taking proportional weight amounts of PVC resin (a dry powder) and plasticizer (a liquid) and premixing them until the plasticizer is absorbed into the resin. Filler (in the form of a dry powder) and other additives (also usually dry powders) are then added to the plasticized resin and the total formulation is mixed in a blender. Various types of high intensity or low intensity blenders can be used. Note that PVC rework in the form of chips, rather than edge trim, can be introduced at this point.

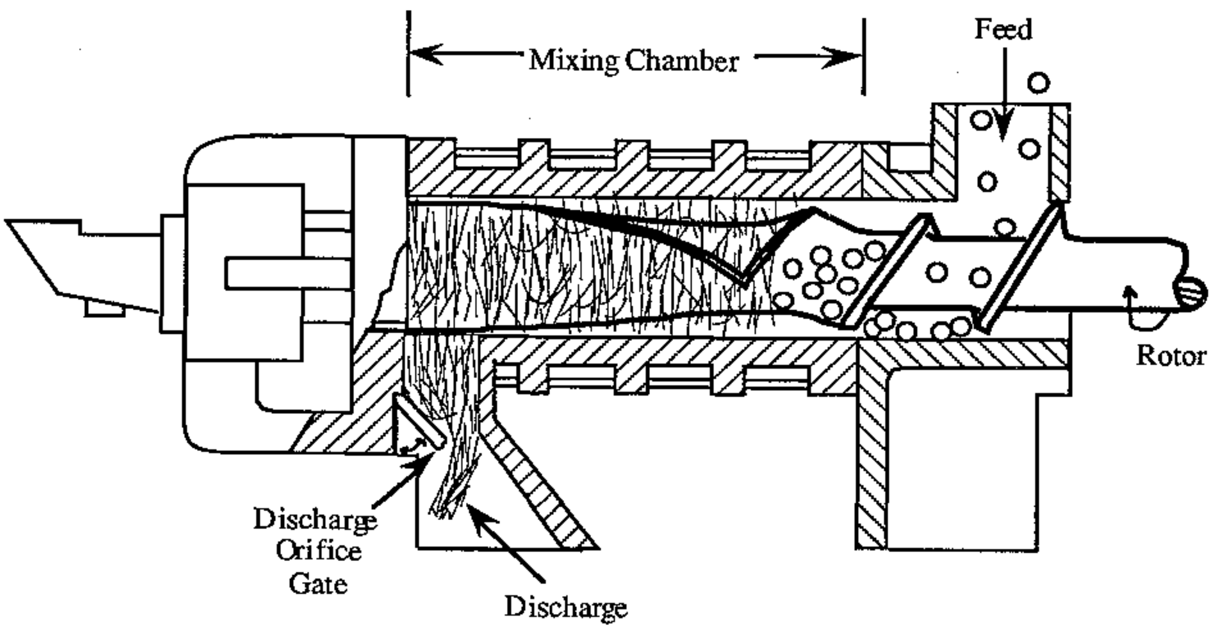
The resulting free-flowing powder compound is fed into a mixer which has heat introduced thereby initiating a reaction between the various components. These mixers can be either batch type (e.g., Banbury) or continuous types (e.g., Farrel), see Figs. 3.10(a) and (b), respectively. In these mixers, the temperature is approximately 180°C (350°F) which melts the mixture into a viscous mass. The mixed material is then removed from the discharge door or port onto a conveyor belt. From the conveyor belt the viscous material is further worked (called "masticating") in a rolling mill (or mills) into a smooth, consistent, uniform color, continuous mass of 100-150 mm (4-6 in.) in diameter. Finished product edge trim can also be introduced into the rolling mill at this point. The fully mixed formulation is then fed by conveyor directly into the sizing calender.

3.2.6.1 Calendering

PVC formulations, irrespective of the pre-processing procedures, are manufactured into continuous geomembrane sheets by a calendering process. The viscous feed of polymer coming from the rolling mill(s) is worked and flattened between counter-rotating rollers into a geomembrane sheet. Most calenders are "inverted-L" configurations, see Fig. 3.11, but other options also exist. The rollers are usually smooth surfaced (they can be slightly textured) stainless steel cylinders and are up to 200 cm (80 in.) in width. The opening distance between adjacent cylinders is set for the desired thickness of the final sheet. A rolling bank of molten material is formed between adjacent rolls. In an inverted four roll "L" calender, 3 such banks are formed. They act as reservoirs for the molten material, and help to fill the sheet to full thickness as it passes between the rolls. As the geomembrane exits from the calender, it enters an additional series of rollers for the purposes of pickoff, embossing, stripping, cooling and cutting. At least one, and perhaps two, rollers in PVC manufacturing are embossed so as to impart a surface texture on the geomembrane. The purpose of this embossing is to prevent the rolled geomembrane from sticking together, i.e., "blocking", during wind-up, storage and transportation.



(a) Batch Process Mixer



(b) Continuous Type Mixer

Figure 3.10 - Sketches of Various Process Mixers

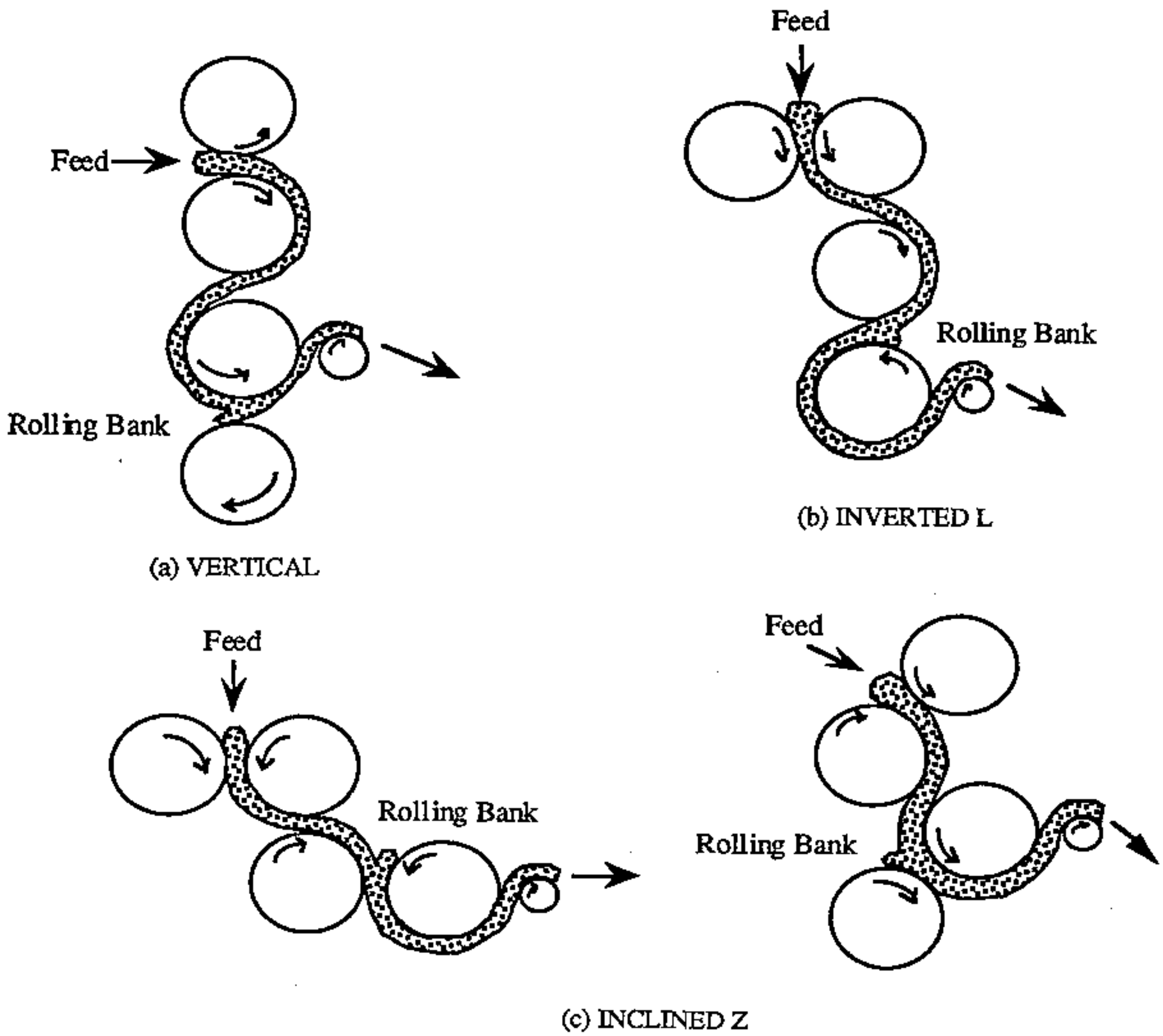


Figure 3.11 - Various Types of Four-Roll Calenders

In developing a specification or MQA document for the manufacturing of PVC geomembranes the following considerations are important:

1. The finished geomembrane sheet should be free from pinholes, surface blemishes, scratches or other defects (agglomerates of various additives or fillers, visually discernible rework, etc.)

2. The finished geomembrane sheet surfaces should be of a uniform color.

3. The addition of a dusting powder, such as talc, to eliminate blocking is <u>not</u> an acceptable practice. The powder will invariably attach to the sheet or be trapped within

the embossed irregularities and eventually be contained in the seamed area as a potential contaminant which could effect the adequacy of the seam.

4. The nominal and minimum thickness of the sheet should be specified. The minimum thickness of the finished geomembrane sheet is usually limited to the nominal thickness minus 5%.

5. The maximum thickness of the finished geomembrane sheet is generally not specified.

6. The width of the finished PVC geomembrane is dependent on the type of calender used by the manufacturer.

7. The geomembrane sheet should be edge trimmed to result in a specified width. This should be controlled to within ± 0.25%.

8. Various MQC tests such as tensile strength, puncture, tear, etc. should be part of a certification program which should be available and implemented.

9. The frequency of performing each of the preceding tests should be covered in the MQC plan and it should be implemented and followed.

10. The finished geomembrane sheet should be rolled onto stable wind-up cores of at least 75 mm (3.0 in.) in diameter.

3.2.6.2 Panel Fabrication

PVC geomembranes as just described are typically 100 to 200 cm (40 to 80 in.) wide and are transported in rolls weighing up to 6.7 kN (1500 pounds) to a panel fabrication facility, see Fig. 3.12 (upper photo). When a specific job order is placed, the rolls are unwound and placed directly on top of one another for factory seaming into a panel, see Fig. 3.12 (lower photo). A panel will typically consist of 5 to 10 rolls which are accordion seamed to one another, i.e., the left side of a particular roll is seamed to the underlying roll while the right side is seamed to the overlying roll. After seaming, the completed panel is again accordion folded (now in a lengthwise direction) and placed on a wooden pallet. It is then covered with a protective wrapper and shipped to the job site for deployment. To be noted is that some fabricators use other procedures for panel preparation.

Regarding a specification or MQA document for factory fabrication of PVC geomembrane panels, the following items should be considered.

1. The factory seaming of PVC rolls into panels should be performed by thermal or chemical seaming methods, see ASTM D-4545. It should be noted that dielectric seaming is a factory seaming method for joining PVC rolls. This is a thermal (or heat fusion) method that is acceptable and is unique to factory seaming of flexible thermoplastic geomembranes. It is currently not a field seaming method.

2. Factory seams should be subjected to the same type of destructive and nondestructive tests as field seams (to be described later).

3. When factory seams are made by chemical methods they are generally protected against blocking by covering them with a 100 mm (4 in.) wide strip of thin polyethylene film. When the panels are unfolded in the field these strips are discarded.

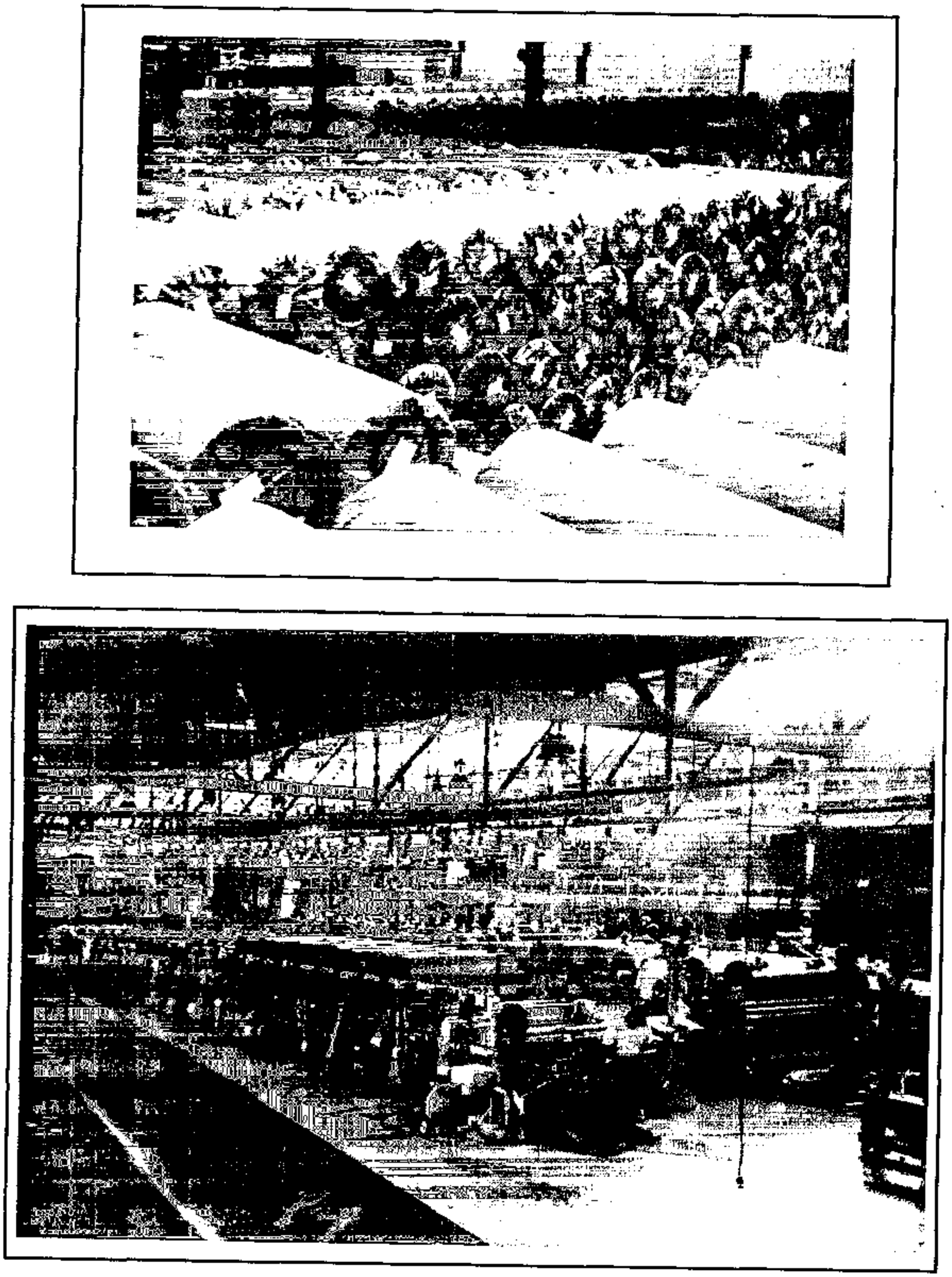


Figure 3.12 - Photographs of Calendered Rolls of Geomembranes After Manufacturing (Upper) and Factory Fabrication of Rolls into Large Panels for Field Deployment (Lower)

4. The finished and folded panels must be protected against accidental damage and excessive exposure during handling, transportation and storage. Usually they are protected by covering them in a heavy cardboard enclosure and placed on a wooden pallet for shipping.

5. The cardboard enclosures should be labeled and coded according to the specific job specifications.

3.2.7 Chlorosulfonated Polyethylene-Scrim Reinforced (CSPE-R)

Chlorosulfonated polyethylene geomembranes are made by mixing CSPE resin with carbon black (or their colorants) thereby making a "master batch" of these two components. Added to this master batch are fillers, additives and lubricants in a batch type mixer, e.g., a Banbury mixer, recall Fig. 3.10(a). Within the mixer the shearing action of the rotors against the ingredients generates enough heat to cause melting and subsequent chemical reactions to occur. After the mixing cycle is complete, the batch is dropped from the Banbury onto a two-roll mill, then to a conveyor leading to a second two-roll mill. In moving through the roll mill it is further mixed into a completely homogenized material having a uniform color and texture. It should be noted that edge trim is often taken from finished sheet and routed back to the roll mill for mixing and reuse.

A conveyor now transports the material directly to the calender, as shown in Fig. 3.11, and feeds it between the appropriate calender rolls.

3.2.7.1 Calendering

All CSPE formulations are manufactured into geomembrane sheets by a calendering process. Here the viscous ribbon of polymer is worked and flattened into a geomembrane sheet. Most calenders are "inverted-L" configurations, recall Fig. 3.11, but other options also exist. As the geomembrane exits the calender, it enters a series of rollers for the purposes of pickoff, stripping, cooling and cutting.

The inverted-L type calender provides an opportunity to introduce two simultaneous ribbons of the mixed and masticated polymeric compound thereby making two individual sheets of geomembranes. While this section of the manual is written around CSPE, it should be recognized that many other geomembrane types which are calendered can be made in multiple ply form as well. Since they are separately formed geomembrane sheets, they are brought together immediately upon exiting the calender to provide a laminated geomembrane consisting of two plys. Additional plys can also be added as desired, but this is not usually done in the manufacture of CSPE geomembranes.

While producing the two separate plys in an inverted-L calender as mentioned above, a woven fabric, called a reinforcing scrim, can be introduced between the two plys, see Fig. 3.13. The CSPE geomembrane is then said to be reinforced and is designed CSPE-R. It is common practice, however, to just use the acronym CSPE when referring to either the nonreinforced or reinforced variety of CSPE. The scrim is usually a woven polyester yarn with 6 x 6, 10 x 10 or 20 x 20 count. These numbers refer to the number of yarns per inch in the machine and cross machine directions, respectively. Other scrim counts are also possible.

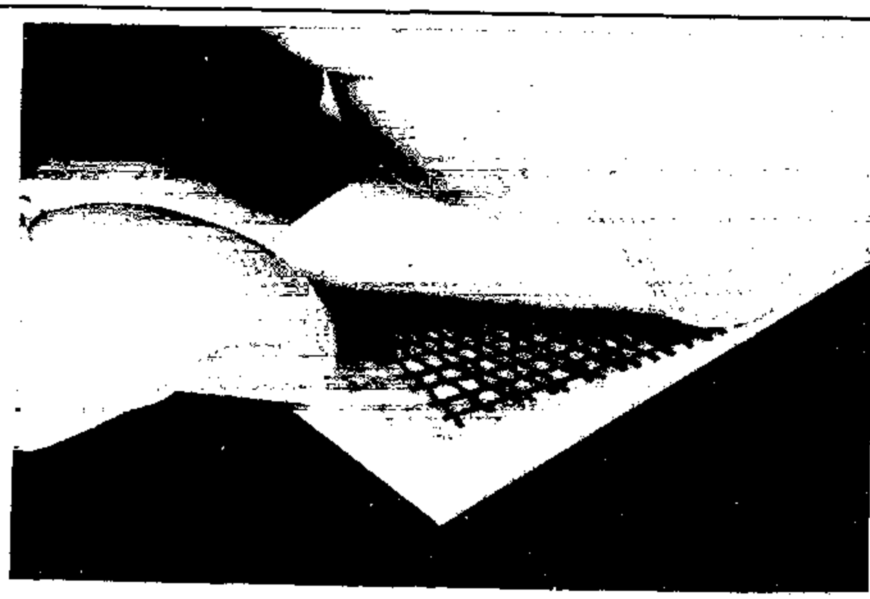


Figure 3.13 - Multiple-Ply Scrim Reinforced Geomembrane

Regarding the preparation of a specification or MQA document for multiple-ply scrim reinforced CSPE-R geomembranes the following should be considered.

1. The finished geomembrane should be free from surface blemishes, scratches and other defects (additive agglomerates, visually discernible rework, etc.).

2. The finished geomembrane sheet should be of a uniform color (which may be black, or by the addition of colorants, be white, tan, gray, blue, etc.), gloss and surface texture.

3. A uniform reinforcing scrim pattern should be reflected on both sides of the geomembrane and should be free from such anomalies as knots, gathering of yarns, delaminations or nonuniform and deformed scrim.

4. The sheet should not be embossed since the surface irregularities caused by the scrim are adequate to prohibit blocking.

5. The thickness of the sheet should be measured over the scrim and at a minimum should be the nominal thickness minus 10%.

6. The geomembrane sheet should have a salvage, i.e., geomembrane ply directly on geomembrane ply with no fabric scrim, on both edges. This salvage shall be approximately 6 mm (0.25 in.).

7. Various MQC tests such as strength, puncture, tear, ply adhesion, etc., should be part of a certification program which should be available and implemented.

8. The frequency of performing each of the preceding tests should be covered in the MQC plan and it should be implemented and followed.

9. The finished geomembrane sheet should be rolled onto stable wind-up cores of at least 75 mm (3.0 in.) in diameter.

3.2.7.2 Panel Fabrication

CSPE-R geomembranes as just described are typically 100 to 200 cm (40 to 80 in.) wide and are transported in rolls weighing up to 6.7 kN (1500 pounds) to a panel fabrication facility. When a specific job order is placed, the rolls are unwound and placed on top of one another for factory seaming into a panel, recall Fig. 3.12. A panel will typically consist of 5 to 10 rolls accordion seamed to one another. After seaming, the panel is accordion folded in its length direction and placed onto a wooden pallet. It is then appropriately covered and shipped to the job site for deployment. To be noted is that some fabricators use other procedures for panel preparation.

In preparing a specification or MQA document for CSPE-R geomembrane panels, the following items should be considered.

1. Factory seaming of CSPE-R rolls should use thermal, chemical or bodied chemical fusion methods, see ASTM D-4545. It should be noted that dielectric seaming is a factory seaming method for joining CSPE-R rolls. This is a thermal, or heat fusion, method that is acceptable and is currently unique to factory seaming of flexible thermoplastic geomembranes. It is not a field seaming method.

2. Factory seams should be subjected to the same type of nondestructive tests as field seams (to be described later). A start-up seam is made prior to making panel production seams from which destructive tests are taken (to be described later).

3. When factory seams are made by chemical fusion methods they are generally protected against sticking to the adjacent sheet (i.e., blocking) by covering them with 100 mm (4 in.) wide thin strip of polyethylene film. When the panels are unfolded in the field these strips are discarded. Other systems may not require this film.

4. The folded panels must be protected against accidental damage and excessive exposure during handling, transportation and storage. Usually they are protected by containing them in a heavy cardboard enclosure and placed on a wooden pallet for shipping.

5. The cardboard enclosures are labeled and coded according to the specific job specifications.

3.2.8 Spread Coated Geomembranes

As mentioned previously, an exception to the calendering method of producing flexible geomembranes, is the spread coating process. This process is currently unique to a geomembrane type called ethylene interpolymer alloy (EIA-R), but has been used to produce other specialty geomembranes in the past. The process utilizes a dense fabric substrate, commonly either a woven or nonwoven textile, and spreads the molten polymer on its surface. Due to the dense structure of the fabric, penetration of the viscous polymer to the opposite side is usually not complete. When cooled, the sheet must be turned over and the process repeated on the opposite side. Adherence of the polymer to the fabric is essential.

Geomembranes produced by the spread coating method are indeed multiple-ply reinforced materials, but produced by a method other than calendering. MQC and MQA plans and specifications should be framed in a similar manner as described previously for CSPE-R geomembranes.

3.3 Handling

While there should be great concern and care focused on the manufacturers and installers of geomembranes, it is also incumbent that they are packaged, handled, stored, transported, re-stored, re-handled and deployed in a manner so as not to cause any damage. This section is written with these many ancillary considerations in mind.

3.3.1 Packaging

Different types of geomembranes require different types of packaging after they are manufactured. Generally HDPE and VLDPE are packaged around a core in roll form, while PVC and CSPE-R are accordion folded in two directions and packaged onto pallets.

3.3.1.1 Rolls

Both HDPE and VLDPE geomembranes are manufactured and fed directly to a wind-up core in full-width rolls. No external wrapping or covering is generally needed, nor provided. These rolls, which weigh up to 22 kN (5000 pounds), are either moved by fork-lifts using a long rod inserted into the core (called a "stinger") or they are picked up by fabric slings with a crane or hoist. Note that the slings are often dedicated to each particular roll and follow along with it until its actual deployment. The rolls are usually stored in an outdoor area. They are stacked such that one roll is nested into the valley of the two underlying rolls, see Fig. 3.14.

Regarding a specification or MQA document for finished rolls of HDPE geomembranes the following applies.

1. The cores on which the rolls of geomembranes are wound should be at least 150 mm (6.0 in.) outside diameter.

2. The cores should have a sufficient inside diameter such that fork lift stingers can be used for lifting and movement.

3. The cores should be sufficiently strong that the roll can be lifted by a stinger or with slings without excessively deflecting, nor structurally buckling the roll.

4. The stacking of rolls at the manufacturing facility should not cause buckling of the cores nor flattening of the rolls. In general, the maximum stacking limit is 5 rolls high.

5. If storage at the manufacturer's facility is for longer than 6 months, the rolls should be covered by a sacrificial covering, or placed within a temporary or permanent enclosure.

6. The manufacturer should identify all rolls with the manufacturer's name, product identification, thickness, roller number, roll dimensions and date manufactured.

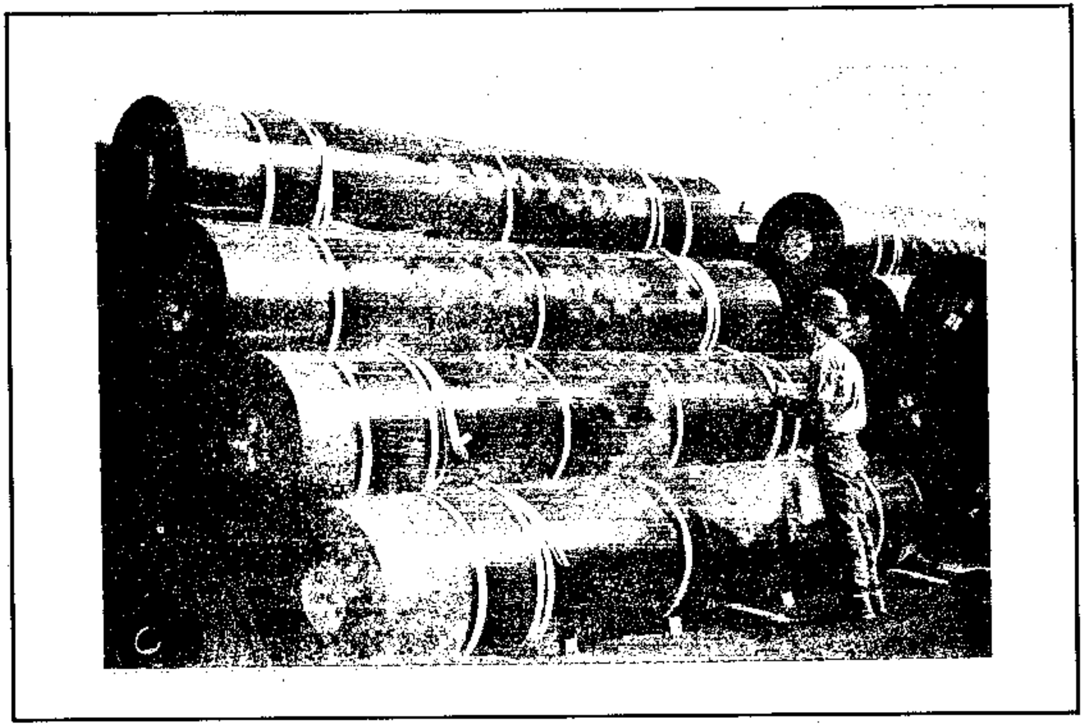


Figure 3.14 - Rolls of Polyethylene Awaiting Shipment to a Job Site

3.3.1.2 Accordion Folded

PVC and CSPE-R geomembranes are initially manufactured in rolls and are then sent to a fabricator for factory seaming into panels. At the fabrication facility they are unrolled directly on top of one another, factory seamed along alternate edges of the rolls and are then accordion folded both width-wise and length-wise and placed onto wooden pallets for packaging and shipment. PVC and CSPE-R geomembranes are generally not stored longer than a few weeks at the fabrication facility.

Regarding items for a specification or MQA document, the following applies.

1. The wooden pallets on which the accordion folded geomembranes are placed should be structurally sound and of good workmanship so that fork lifts or cranes can transport and maneuver them without structurally failing or causing damage to the geomembrane.

2. The wooden pallets should extend at least 75 mm (3 in.) beyond the edge of the folded geomembrane panel on all four sides.

3. The folded geomembrane panel should be packaged in treated cardboard or plastic wrapping for protection from precipitation and direct ultraviolet exposure.

4. Banding straps around the geomembrane and pallet should be properly cushioned so as not to cause damage to any part of the geomembrane panel.

5. Palleted geomembranes should be stored only on level surfaces since the folded material is susceptible to shifting and possible damage.

6. The stacking of palleted geomembrane panels on top of one another should not be permitted.

7. If storage at the fabricator's facility is for longer than 6 months, the palleted panels should be covered with a sacrificial covering, temporary shelter or placed within a permanent enclosure.

8. The fabricator should identify all panels with the manufacturers name, product information, thickness, panel number, panel dimensions and date manufactured.

3.3.2 Shipment, Handling and Site Storage

The geomembrane rolls or pallets are shipped to the job site, offloaded, and temporarily stored at a remote location on the job site, see Fig. 3.15.

Regarding items for a specification or CQA document*, the following applies:

1. Unloading of rolls or pallets at the job site's temporary storage location should be such that no damage to the geomembrane occurs.

2. Pushing, sliding or dragging of rolls or pallets of geomembranes should not be permitted.

3. Offloading at the job site should be performed with cranes or fork lifts in a workmanlike manner such that damage does not occur to any part of the geomembrane.

4. Temporary storage at the job site should be in an area where standing water cannot accumulate at any time.

5. The ground surface should be suitably prepared such that no stones or other rough objects which could damage the geomembranes are present.

6. Temporary storage of rolls of HDPE or VLDPE geomembranes in the field should not be so high that crushing of the core or flattening of the rolls occur. This limit is typically 5 rolls high.

7. Temporary storage of pallets of PVC or CSPE-R geomembranes by stacking should not be permitted.

8. Suitable means of securing the rolls or pallets should be used such that shifting, abrasion or other adverse movement does not occur.

9. If storage of rolls or pallets of geomembranes at the job site is longer than 6 months, a sacrificial covering or temporary shelter should be provided for protection against precipitation, ultraviolet exposure and accidental damage.

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* Note that the designations of MQC and MQA will now shift to CQC and CQA since field construction personnel are involved. These designations will carry forward throughout the remainder of this Chapter.

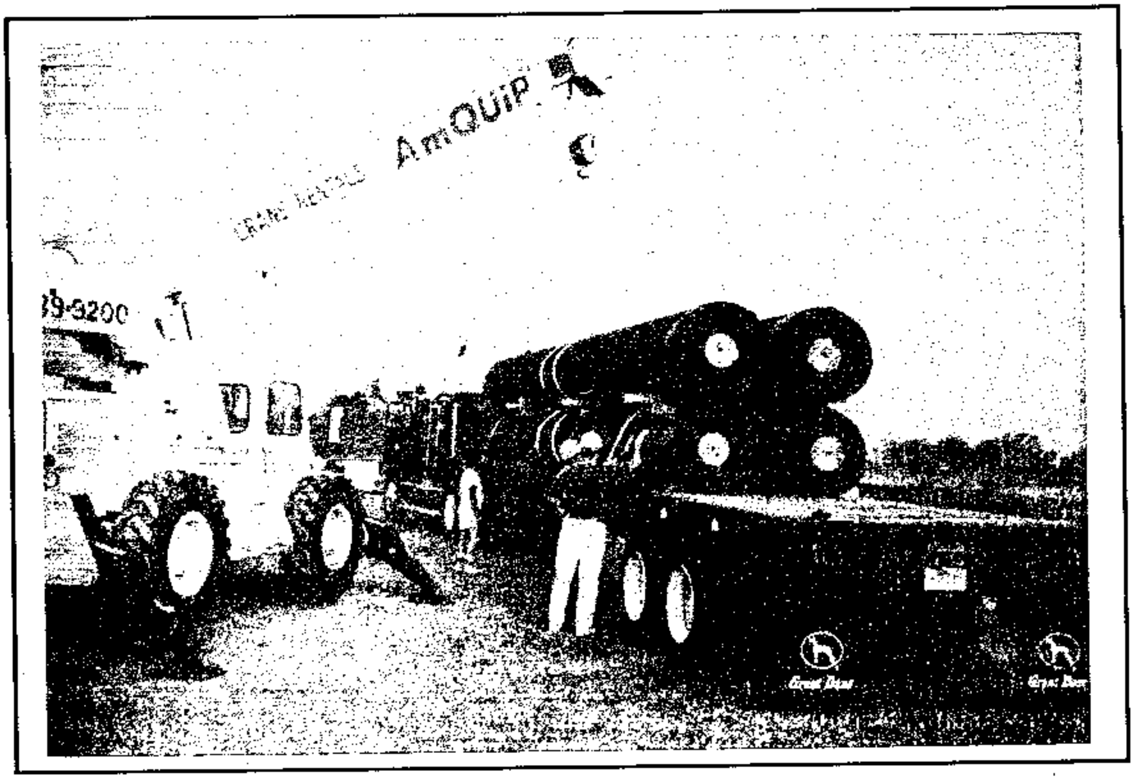


Figure 3.15 - Photograph of Truck Shipment of Geomembranes

3.3.3 Acceptance and Conformance Testing

It is the primary duty of the installation contractor, via the CQC personnel, to see that the geomembrane supplied to the job site is the proper material that was called for in the contract, as specified by the Plans and Specifications. It is also the duty of the CQA Engineer to verify this material to be appropriate. Clear marking should identify all rolls or pallets with the information described in Section 3.3.1. A complete list of roll numbers should be prepared for each material type.

Upon delivery of the rolls or pallets of geomembrane, the CQA Engineer should ensure that conformance test samples are obtained and sent to the proper laboratory for testing. This will generally be the laboratory of the CQA firm, but may be that of the CQC firm if so designated in the CQA documents. Alternatively, conformance testing could be performed at the manufacturers facility and when completed the particular lot should be marked for the particular site under investigation.

The following items should be considered for a specification or CQA document with regard to acceptance and conformance testing.

1. The particular tests selected for acceptance and conformance testing can be all of those listed previously, but this is rarely the case since MQC and MQA testing should have preceded the field operations. However, at a minimum, the following tests are recommended for field acceptance and conformance testing for the particular

geomembrane type.

(a) HDPE: thickness (ASTM D-5199), tensile strength and elongation (ASTM D-638) and possibly puncture (FTM Std 101C) and tear resistance (ASTM D-1004, Die C)

(b) VLDPE: thickness (ASTM D-5199), tensile strength and elongation (ASTM D-638), and possibly puncture (FTM Std 101C) and tear resistance (ASTM D-1004, Die C)

(c) PVC: thickness (ASTM D-5199), tensile strength and elongation (ASTM D-882), tear resistance (ASTM D-1004, Die C)

(d) CSPE-R: thickness (ASTM D-5199), tensile strength and elongation (ASTM D-751), ply adhesion (ASTM D-413, Machine Method, Type A)

2. The method of geomembrane sampling should be prescribed. For geomembranes on rolls, 1 m (3 ft.) from the entire width of the roll on the outermost wrap is usually cut and removed. For geomembranes folded on pallets, the protective covering must be removed, the uppermost accordion folded section opened and an appropriate size sample taken. Alternatively, factory seam retains can be shipped on top of fabricated panels for easy access and use in conformance testing.

3. The machine direction must be indicated with an arrow on all samples using a permanent marker.

4. Samples are usually taken on the basis of a stipulated area of geomembrane, e.g., one sample per 10,000 m^2 (100,000 ft^2). Alternatively, one could take samples at the rate of one per lot, however, a lot must be clearly defined. One possible definition could be that a lot is a group of consecutively numbered rolls or panels from the same manufacturing line.

5. All conformance test results should be reviewed, accepted and reported by the CQA Engineer before deployment of the geomembrane.

6. Any nonconformance of test results should be reported to the Owner/Operator. The method of a resolution of such differences should be clearly stated in the CQA document. One possible guidance document for failing conformance tests could be ASTM D-4759 titled "Determining the Specification Conformance of Geosynthetics".

3.3.4 Placement

When the subgrade or subbase (either soil or some other geosynthetic) is approved as being acceptable, the rolls or pallets of the temporarily stored geomembranes are brought to their intended location, unrolled or unfolded, and accurately spotted for field seaming, see Fig. 3.16.

3.3.4.1 Subgrade (Subbase) Conditions

Before beginning to move the geomembrane rolls or pallets from their temporary storage location at the job site, the soil subgrade (or other subbase material) should be checked for its preparedness.

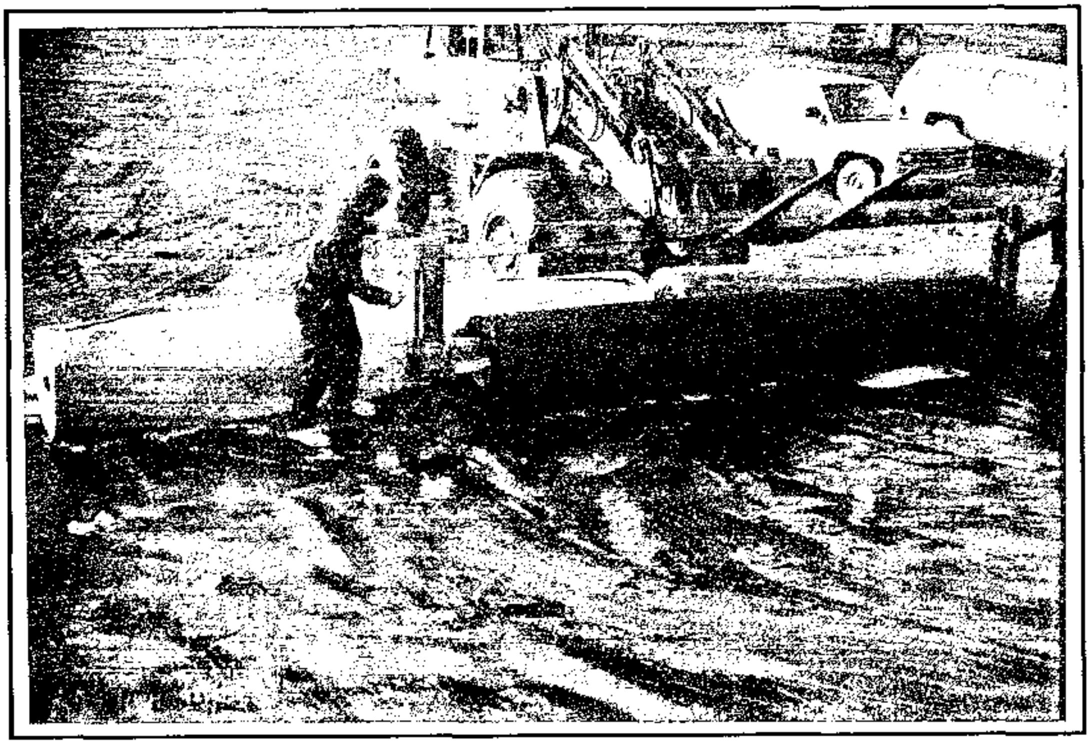


Figure 3.16 - Photographs Showing the Unrolling (Upper) and Unfolding (Lower) of Geomembranes

Some items recommended for a specification or CQA document include the following:

1. The soil subgrade shall be of the specified grading, moisture content and density as required by the installer and as approved by the CQA engineer for placement of the geomembrane. See Chapter 2 for these details for compacted clay liner subgrades.

2. Construction equipment deploying the rolls or pallets shall not deform or rut the soil subgrade excessively. Tire or track deformations beneath the geomembrane should not be greater than 25 mm (1.0 in.) in depth.

3. The geomembrane shall not be deployed on frozen subgrade where ruts are greater than 12 mm (0.5 in.) in depth.

4. When placing the geomembrane on another geosynthetic material (geotextile, geonet, etc.), construction equipment should not be permitted to ride directly on the lower geosynthetic material. In cases where rolls must be moved over previously placed geosynthetics it is necessary to move materials by hand or by using small pneumatic tired lifting units. Tire inflation pressures should be limited to a maximum value of 40 kPa (6 lb/in^2).

5. Underlying geosynthetic materials (such as geotextiles or geonets) should have all folds, wrinkles and other undulations removed before placement of the geomembrane.

6. Care, and planning, should be taken to unroll or unfold the geomembrane close to its intended, and final, position.

3.3.4.2 Temperature Effects - Sticking/Cracking

High temperatures can cause geomembrane surfaces on rolls, or accordion folded on pallets, to stick together, a process commonly called "blocking". At the other extreme, low temperatures can cause geomembrane sheets to crack when unrolled or unfolded. Comments on unrolling, or unfolding of geomembranes at each of these temperature extremes follow.

For example, a specification or CQA document should have included in it the following items.

1. Geomembranes when unrolled or unfolded should not stick together to the extent where tearing, or visually observed straining of the geomembrane, occurs. The upper temperature limit is very specific to the particular type of geomembrane. A sheet temperature of 50°C (122°F) is the upper limit that a geomembrane should be unrolled or unfolded unless it is shown otherwise to the satisfaction of the CQA engineer.

2. Geomembranes which have torn or have been excessively deformed should be rejected, or shall be repaired per the CQA Document.

3. Geomembranes when unrolled or unfolded in cold weather should not crack, craze, or distort in texture. A sheet temperature of 0°C (32°F) is the lower limit that a geomembrane should be unrolled or unfolded unless it is shown otherwise to the satisfaction of the CQA engineer.

3.3.4.3 Temperature Effects - Expansion/Contraction

Polyethylene geomembranes expand when they are heated and contract when they are cooled. Other types of geomembranes may slightly contract when heated. This expansion and contraction must be considered when placing, seaming and backfilling geomembranes in the field. Fig. 3.17 shows a wrinkled polyethylene liner which has expanded due to thermal warming from the sun.

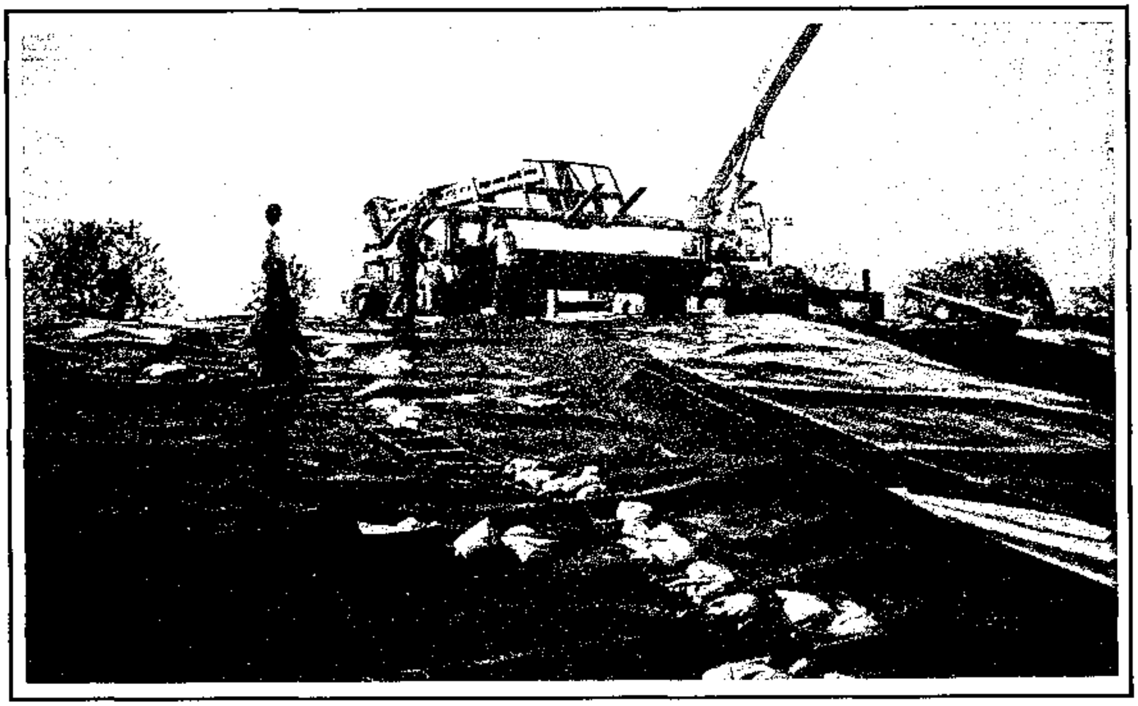


Figure 3.17 - HDPE Geomembrane Showing Sun Induced Wrinkles

Either the contract plans and specifications, or the CQA documents should cover the expansion/contraction situation on the basis of site specific and geomembrane specific conditions. Some items to consider include the following:

1. Sufficient slack shall be placed in the geomembrane to compensate for the coldest temperatures envisioned so that no tensile stresses are generated in the geomembrane or in its seams either during installation or subsequently after the geomembrane is covered.

2. The geomembrane shall have adequate slack such that it does not lift up off of the subgrade or substrate material at any location within the facility, i.e., no "trampolining" of the geomembrane shall be allowed to occur at any time.

3. The geomembrane shall not have excessive slack to the point where creases fold over upon themselves either during placement and seaming, or when the protective soil or drainage materials are placed on the geomembrane.

4. Permanent (fold-over type) creases in the covered geomembrane should not be permitted at any time.

5. The amount of slack to be added to the deployed and seamed geomembrane should be carefully considered and calculated, taking into account the type of geomembrane and the geomembrane's temperature during installation versus its final temperature in the completed facility.

3.3.4.4 Spotting

When a geomembrane roll or panel is deployed it is generally required that some shifting will be necessary before field seaming begins. This is called "spotting" by many installers.

Some items for a specification or CQA document should include the following:

1. Spotting of deployed geomembranes should be done with no disturbance to the soil subgrade or geosynthetic materials upon which they are placed.

2. Spotting should be done with a minimum amount of dragging of the geomembrane on soil subgrades.

3. Temporary tack welding (usually with a hand held hot air gun) of all types of thermoplastic geomembranes should be allowed at the installers discretion.

4. When temporary tack welds of geomembranes are utilized, the welds should not interfere with the primary seaming method, or with the ability to perform subsequent destructive seam tests.

3.3.4.5 Wind Considerations

Wind damage to geomembranes, unfortunately, is not an uncommon occurrence, see Fig. 3.18. Many deployed geomembranes have been uplifted by wind and have been damaged. In some cases the geomembranes have even been torn out of anchor trenches. This is sometimes referred to as "blow-out" by field personnel. Generally, but not always, the unseamed geomembrane rolls or panels acting individually are most vulnerable to wind uplift and damage.

The contract plans and specification, or at least the CQA documents, must be very specific as to resolutions regarding geomembranes that have been damaged due to shifting by wind. Some suggestions follow.

1. Geomembrane rolls or panels which have been displaced by wind should be inspected and approved by the CQA engineer before any further field operations commence.

2. Geomembrane rolls or panels which have been damaged (torn, punctured, or deformed excessively and permanently) shall be rejected and/or repaired as directed in the contract plans, specifications or CQA documents.

3. Permanent crease marks, or severely folded (crimped) locations, in geomembranes

should not be permitted unless it can be shown that such distortions have no adverse effect on the properties of the geomembrane. If this cannot be done, these areas should be cut out and properly patched as per the contract documents and approved by the CQA Engineer.

4. If patching of wind damaged geomembranes becomes excessive (to the limit set forth in the specifications or CQA plan), the entire roll or panel should be rejected.

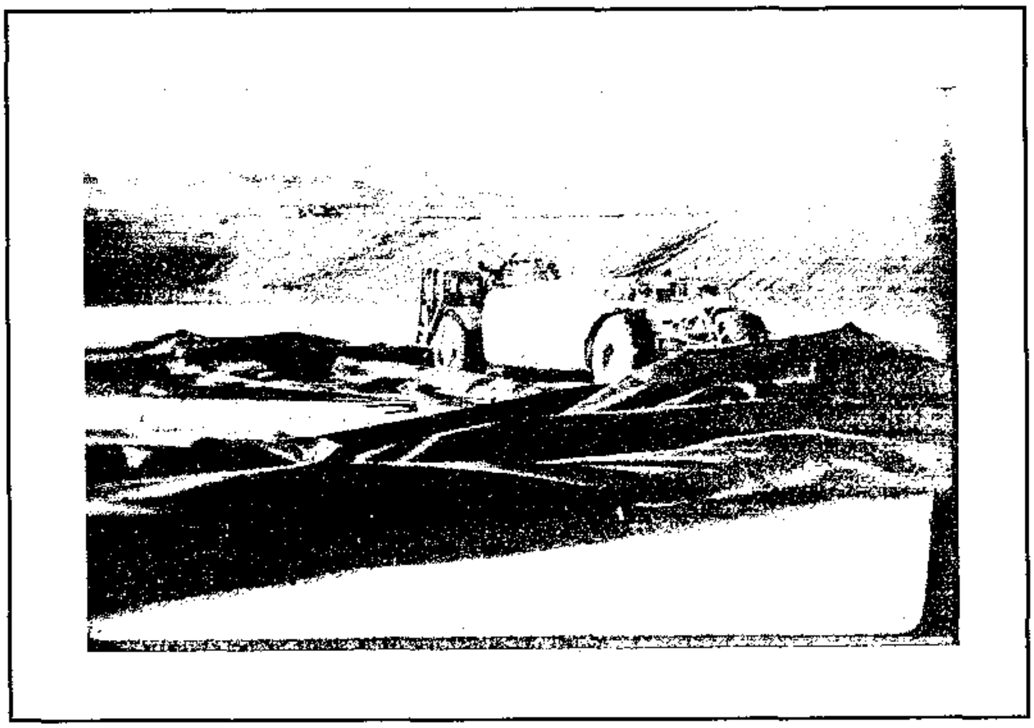


Figure 3.18 - Wind Damage to Deployed Geomembrane

3.4 Seaming and Joining

The field seaming of the deployed geomembrane rolls or panels is a critical aspect of their successful functioning as a barrier to liquid (and sometimes vapor) flow. This section describes the various seaming methods in current use, references a recently published EPA Technical Guidance Document on seam fabrication techniques (EPA, 1991), and describes the concept and importance of test strips (or trial seams).

3.4.1 Overview of Field Seaming Methods

The fundamental mechanism of seaming polymeric geomembrane sheets together is to temporarily reorganize, i.e., melt, the polymer structure of the two surfaces to be joined in a controlled manner that, after the application of pressure and after the passage of a certain amount of time, results in the two sheets being bonded together. This reorganization results from an input of energy that originates from either thermal or chemical processes. These processes may involve the addition of extra polymer in the bonded area.

Ideally, seaming two geomembrane sheets would result in no net loss of tensile strength across the two sheets and the joined sheets would perform as one single geomembrane sheet. However, due to stress concentrations resulting from the seam geometry, current seaming techniques may result in minor tensile strength loss relative to the parent geomembrane sheet. The characteristics of the seamed area are a function of the type of geomembrane and the seaming technique used. These characteristics, such as residual strength, geomembrane type, and seaming type, should be recognized by the designer when applying the appropriate design factors-of-safety for the overall geomembrane function and facility performance.

It should be noted that the seam can be the location of the lowest tensile strength in a geomembrane liner. Designers and inspectors should be aware of the importance of seeking only the highest quality geomembrane seams. The minimum seam tensile strengths (as determined by design) for various geomembranes must be predetermined by laboratory testing, knowledge of past field performance, manufacturers literature, various trade journals or other standards setting organizations that maintain current information on seaming techniques and technologies.

The methods of seaming at the time of the printing of this document and discussed herein are given in Table 3.2 and shown schematically in Fig. 3.19.

Table 3.2. Fundamental Methods Of Joining Polymeric Geomembranes

Thermal Processes	Chemical Processes
Extrusion:	Chemical:
• Fillet	• Chemical Fusion
• Flat	• Bodied Chemical Fusion
Fusion:	Adhesive:
• Hot Wedge	• Chemical Adhesive
• Hot Air	• Contact Adhesive

Within the entire group of thermoplastic geomembranes that will be discussed in this manual, there are four general categories of seaming methods extrusion welding, thermal fusion or melt bonding, chemical fusion and adhesive seaming. Each will be explained along with their specific variations so as to give an overview of field seaming technology.

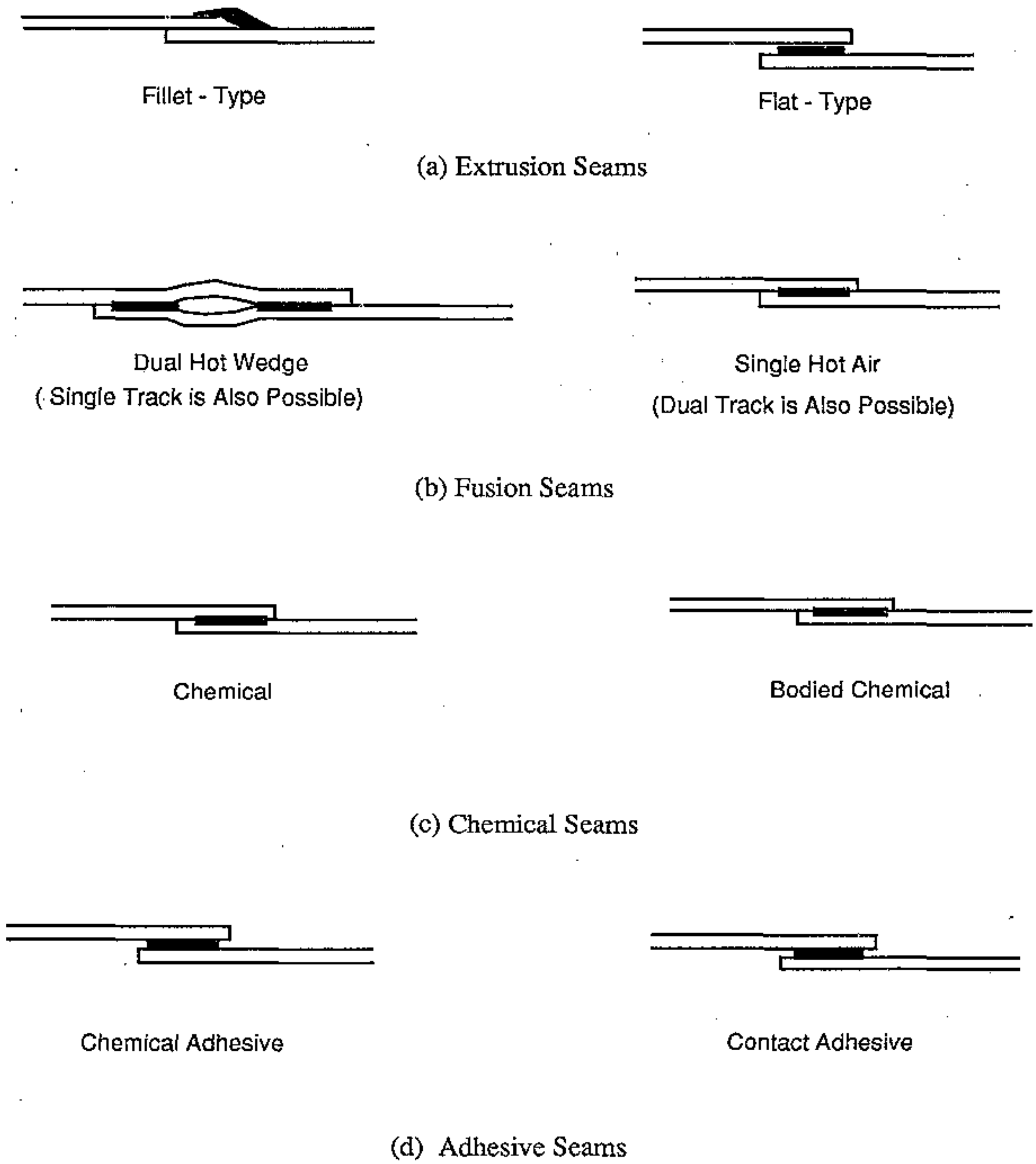


Figure 3.19 - Various Methods Available to Fabricate Geomembrane Seams

Extrusion welding is presently used exclusively on geomembranes made from polyethylene. A ribbon of molten polymer is extruded over the edge of, or in between, the two surfaces to be joined. The molten extrudate causes the surfaces of the sheets to become hot and melt, after which the entire mass cools and bonds together. The technique is called extrusion fillet seaming when the extrudate is placed over the leading edge of the seam, and is called extrusion flat seaming when the extrudate is placed between the two sheets to be joined. It should be noted that extrusion fillet seaming is essentially the only practical method for seaming polyethylene geomembrane patches, for seaming in poorly accessible areas such as sump bottoms and around pipes and for seaming of extremely short seam lengths. Temperature and seaming rate both play important roles in obtaining an acceptable bond; excessive melting weakens the geomembrane and inadequate melting results in poor extrudate flow across the seam interface and low seam strength. The polymer used for the extrudate is also very important and should generally be the same polyethylene compound used to make the geomembrane. The designer should specify acceptable extrusion compounds and how to evaluate them in the specifications and CQA documents.

There are two thermal fusion or melt-bonding methods that can be used on all thermoplastic geomembranes. In both of them, portions of the opposing surfaces are truly melted. This being the case, temperature, pressure, and seaming rate all play important roles in that excessive melting weakens the geomembrane and inadequate melting results in low seam strength. The hot wedge, or hot shoe, method consists of an electrically heated resistance element in the shape of a wedge that travels between the two sheets to be seamed. As it melts the surface of the two sheets being seamed, a shear flow occurs across the upper and lower surfaces of the wedge. Roller pressure is applied as the two sheets converge at the tip of the wedge to form the final seam. Hot wedge units are controllable as far as temperature, amount of pressure applied and travel rate. A standard hot wedge creates a single uniform width seam, while a dual hot wedge (or "split" wedge) forms two parallel seams with a uniform unbonded space between them. This space can be used to evaluate seam quality and continuity of the seam by pressurizing the unbonded space with air and monitoring any drop in pressure that may signify a leak in the seam.

The hot air method makes use of a device consisting of a resistance heater, a blower, and temperature controls to force hot air between two sheets to melt the opposing surfaces. Immediately following the melting of the surfaces, pressure is applied to the seamed area to bond the two sheets. As with the hot wedge method, both single and dual seams can be produced. In selected situations, this technique may also be used to temporarily "tack" weld two sheets together until the final seam or weld is made and accepted.

Regarding the chemical fusion seam types; chemical fusion seams make use of a liquid chemical applied between the two geomembrane sheets to be joined. After a few seconds, required to soften the surface, pressure is applied to make complete contact and bond the sheets together. As with any of the chemical seaming processes to be described, the two adjacent materials to be bonded are transformed into a viscous phase. Care must be used to see that the proper amount of chemical is applied in order to achieve the desired results. Bodied chemical fusion seams are similar to chemical fusion seams except that 1% to 20% of the parent lining resin or compound is dissolved in the chemical and then is used to make the seam. The purpose of adding the resin or compound is to increase the viscosity of the liquid for slope work and/or adjust the evaporation rate of the chemical. This viscous liquid is applied between the two opposing surfaces to be bonded. After a few seconds, pressure is applied to make complete contact. Chemical adhesive seams make use of a dissolved bonding agent (an adherent) in the chemical or bodied chemical which is left after the seam has been completed and cured. The adherent thus becomes an additional element in the system. Contact adhesives are applied to both mating surfaces. After reaching the proper degree of tackiness, the two sheets are placed on top of one another, followed by application of roller pressure. The adhesive forms the bond and is an additional element in the system.

Other emerging seaming methods use ultrasonic, electrical conduction and magnetic induction energy sources. Since these methods are in the developmental stage, they will not be described further in this document. See EPA (1991) for further details.

In order to gain an overview as to which seaming methods are used for the various thermoplastic geomembranes described in this document, Table 3.3 is offered. It is generalized, but it is used to introduce the primary seaming methods versus the type of geomembrane that is customarily seamed by that method.

Table 3.3 Possible Field Seaming Methods for Various Geomembranes Listed in this Manual

Type of Seaming Method	Type of Geomembrane					
	HDPE	VLDPE	Other PE	PVC	CSPE-R	Other Flexible
extrusion (fillet and flat)	A	A	A	n/a	n/a	A
thermal fusion (hot wedge and hot air)	A	A	A	A	A	A
chemical (chemical and bodied chemical)	n/a	n/a	n/a	A	A	A
adhesive (chemical and contact)	n/a	n/a	n/a	A	A	A

Note: A = method is applicable
n/a = method is "not applicable"

3.4.2 Details of Field Seaming Methods

Full details of field seaming methods for the edges and ends of geomembrane rolls or panels has recently been described in EPA Technical Guidance Document, EPA/530/SW-91/051, entitled: "Inspection Techniques for the Fabrication of Geomembrane Seams". In this document (EPA, 1991) are separate chapters devoted to the following field seaming methods.

- extrusion fillet seams

- extrusion flat seams
- hot wedge seams
- hot air seams
- chemical and bodied chemical fused seams
- chemical adhesive seams

There is also a section on emerging technologies for geomembrane seaming. The interested reader should consult this document for details regarding all of these seaming methods.

Whenever the plans and specifications are not written around a particular seaming method the actual method which is used becomes a matter of choice for the installation contractor. As seen in Table 3.3, there are a number of available choices for each geomembrane type. Furthermore, even when the installation contractor selects the particular seaming method to be used, its specific details are rarely stipulated even in the specification or CQA documents. This is to give the installation contractor complete latitude in selecting seaming temperatures, travel rates, mechanical roller pressures, chemical type, tack time, hand rolling pressure, etc. The role of the plans, specifications and CQA documents is to adequately provide for destructive tests (on test strips and on production seams) and nondestructive tests (on production seams) to assure that the seams are fabricated to the highest quality and uniformity and are in compliance with the project's documents.

This is not to say that the specification never influences the type of seaming method. For example, if the specifications call for a nondestructive constant air pressure test to be conducted, the installation contractor must use a thermal fusion technique like the dual hot wedge or dual hot air methods since they are the only methods that can produce such a seam.

3.4.3 Test Strips and Trial Seams

Test strips and trial seams, also called qualifying seams, are considered to be an important aspect of CQC/CQA procedures. They are meant to serve as a prequalifying experience for personnel, equipment and procedures for making seams on the identical geomembrane material under the same climatic conditions as the actual field production seams will be made. The test strips are usually made on two narrow pieces of excess geomembrane varying in length between 1.0 to 3.0 m (3 to 10 ft.), see Fig. 3.20. The test strips should be made in sufficient lengths, preferably as a single continuous seam, for all required testing purposes.

The goal of these test strips is to reproduce all aspects of the actual production field seaming activities intended to be performed in the immediately upcoming work session so as to determine equipment and operator proficiency. Ideally, test strips can be used to estimate the quality of the production seams while minimizing damage to the installed geomembrane through destructive mechanical testing. Test strips are typically made every 4 hours (for example, at the beginning of the work shift and after the lunch break). They are also made whenever personnel or equipment are changed and when climatic conditions reflect wide changes in geomembrane temperature or when other conditions occur that could affect seam quality. These details should be stipulated in the contract specifications or CQA documents.

The destructive testing of the test strips should be done as soon as the installation contractor feels that the strength requirements of the contract specification or CQA documents can be met. Thus it behooves the contractor to have all aspects of the test strip seam fabrication in complete working order just as would be done in the case of fabricating production field seams. For extrusion and thermal fusion seams, destructive testing can be done as soon as the seam cools. For chemical fusion and adhesive seams this could take several days and the use of a field oven to accelerate the curing of the seam is advisable.

Figure 3.20 - Fabrication of a Geomembrane Test Strip

From two to six test specimens are cut from the test strip using a 25 mm (1.0 in. wide die). They are selected at random by the CQA inspector. The specimens are then tested in both peel and shear using a field tensiometer, see Fig. 3.21. (Generally peel tests are more informative in assessing the quality of the seam). If any of the test specimens fail, a new test strip is fabricated. If additional specimens fail, the seaming apparatus and seamer should not be accepted and should not be used for seaming until the deficiencies are corrected and successful trial welds are achieved. The CQA inspector should observe all trial seam procedures and tests. If the specimens pass, seaming operations can move directly to production seams in the field. Pass/fail criteria for destructive seam tests will be described in Section 3.5.

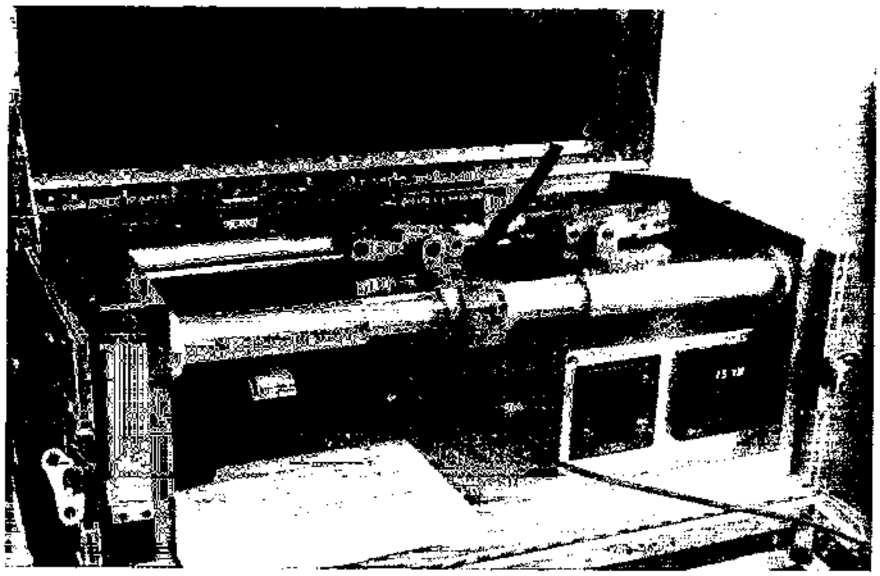


Figure 3.21 - Photograph of a Field Tensiometer Performing a Geomembrane Seam Test

The flow chart illustrated in Fig. 3.22 gives an idea of the various decisions that can be reached depending upon the outcome of destructive tests on test strip specimens. Here it is seen that failed test strips are linked to an increased frequency of destructive tests to be taken on production field seams made during the time interval between making the test strip and its testing. Furthermore, it is seen that there are only two chances at making adequate test strips before production field seaming is stopped and repairs are initiated. These details should be covered in either the project specification or the CQA documents.

Some specification or CQA document items regarding the fabrication of geomembrane seam test strips include the following:

1. The frequency of making test strips should be clearly stated. Typically this is at the beginning of the day, after the noon break and whenever changed conditions are encountered, e.g., changes in weather, equipment, personnel.

2. The CQA Engineer should have the option of requesting test strips of any field seaming crew or device at any time.

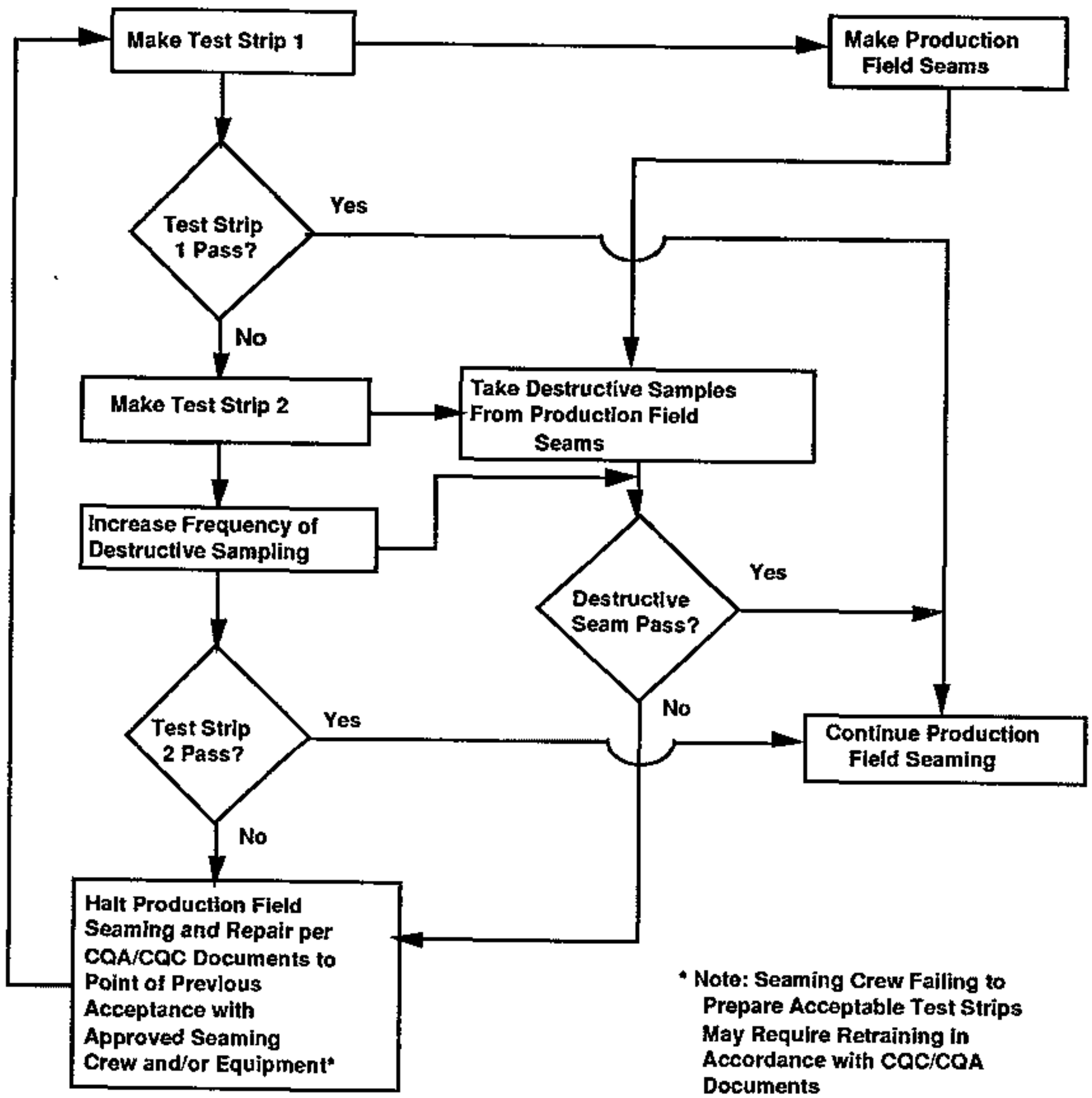


Figure 3.22 - Test Strip Process Flow Chart

3. The procedure for sampling and evaluating the field test strip samples should be clearly outlined, i.e., the number of peel and shear test specimens to be cut and tested from the test strip sample, the rate of testing and what the required strength values are in these two different modes of testing.

4. The fabrication of the field test strip and testing of test specimens should be observed by the CQA personnel.

5. The time for testing after the test strip is fabricated varies between seam types. For extrusion and fusion fabricated seams, the testing can commence immediately after the polymer cools to ambient temperature. For chemical fusion and adhesive fabricated seams, the testing must wait until adequate curing of the seam occurs. This can take as long as 1 to 7 days. During this time all production seaming must be tracked and documented.

6. Accelerated oven curing of chemical and adhesive fabricated seams is acceptable so as to hasten the curing process and obtain test results as soon as possible. GRI Test Method GM-7 can be used for this purpose.

7. The required inspection protocol and implications of failed test specimens from the test strips must be clearly stated. The protocol outlined in Fig. 3.22 is suggested.

8. Field test strips are usually discarded after the destructive test specimens are removed and tested. If this is not the case, it should be clearly indicated who receives the test strip samples and what should be the utilization (if any) of these samples.

3.5 Destructive Test Methods for Seams

The major reason that plans and specifications do not have to be specific about the type of seaming methods and their particular details is that geomembrane seams can be readily evaluated for their quality by taking samples and destructively testing them either at the job site or in a timely manner at a testing laboratory thereafter.

3.5.1 Overview

By destructively testing geomembrane seams it is meant to actually cut out (i.e., to sample) and remove a portion of the completed production seam, and then to further cut the sample into appropriately sized test specimens. These specimens are then tested according to a specified procedure to failure or to yield depending upon the type of geomembrane.

A possible procedure is to select the sampling location and cut two closely spaced 25 mm (1.0 in.) wide test specimens from the seam. The distance between these two test specimens is defined later. The individual specimens are then tested in a peel mode using a field tensiometer (recall Fig. 3.21). If the results are acceptable, the complete seam between the two field test specimens is removed and properly identified and distributed. If either test specimen fails, two new locations on either side of the failed specimen(s) are selected until acceptable seams are located. The seam distance between acceptable seams is usually repaired by cap-stripping but other techniques are also possible. The exact procedure must be stipulated in the specifications or CQA document.

The length dimension of the field seam sample between the two test specimens just described varies according to whatever is stipulated in the plans and specifications, or in accordance with the CQA documents. Some common options are to sample the seam for a distance of either 36 cm (14 in.), 71 cm (28 in.) or 106 cm (42 in.) along its length. Since the usual destructive seam tests are either shear or peel tests and both types are 25 mm (1.0 in.) wide test specimens, this allows for approximately 10, 20 or 30 tests (half shear and half peel) to be conducted on the respective lengths cited above. The sample width perpendicular to the seam is usually 30 cm (12 in.) with the seam being centrally located within this dimension.

The options of seam sample length between the two peel test specimens mentioned above that are seen in various plans, specifications, and CQA documents, are as follows:

- A 36 cm (14 in.) sample is taken from the seam and cut into 5 shear and 5 peel specimens. The tests are conducted in the field or at a remote laboratory by, or under the direction of, the responsible CQA organization.
- A 71 cm (28 in.) long sample is taken from the seam and cut in half. One half is further cut into 5 shear and 5 peel test specimens which are tested in the field or at a remote laboratory by the CQC organization (usually the installation contractor). The other half is sent to a remote laboratory for testing by the CQA organization who also does 5 shear and 5 peel tests. Alternatively, sometimes only the CQA organization does the testing and the second half of the sample is left intact and archived by the owner/operator.
- A 106 cm (42 in.) long sample is taken from the seam and cut into three individual 36 cm (14 in.) samples. Individual samples go to the CQC organization, the CQA organization and the owner/operator. The CQC and CQA organizations each cut their respective samples into 5 shear and 5 peel test specimens and conduct the appropriate tests immediately. The remaining sample is archived by the owner/operator.

Whatever is the strategy for taking samples from the production seams for destructive testing it must be clearly outlined in the contract plans and specifications and further defined and/or corroborated in the CQA documents.

Obviously, the hole created in the production seam from which the test sample was originally taken must be patched in an appropriate manner. See Fig. 3.23 for such a patched sampling location. Recognize that the seams of such patches are themselves candidates for field sampling and testing. If this is done, one would have the end result of patch on a patch, which is a rather unsightly and undesirable condition.

3.5.2 Sampling Strategies

The sampling of production seams of installed geomembranes represents a dilemma of major proportions. Too few samples results in a poor statistical representation of the strength of the seam, and too many samples requires an additional cost and a risk of having the necessary repair patches being problems in themselves. Unfortunately, there is no clear strategy for all cases, but the following are some of the choices that one has in formulating a specification or CQA plan.

Note also that in selecting a sampling strategy the sampling frequency is tied directly into the performance of the test strips described in Section 3.4.3. If the test strips fail during the time that production seaming is ongoing, the frequency of destructive sampling and testing must be increased. The following strategies, however, are for situations where geomembrane seam test strips are being made in an acceptable manner.

3.5.2.1 Fixed Increment Sampling

By far the most commonly used sampling strategy is the "fixed increment sampling" method. In this method, a seam sample is taken at fixed increments along the total length of the seams. Increments usually range from 75 to 225 m (250 to 750 ft) with a commonly specified value being one destructive test sample every 150 m (500 ft). Note that this value can be applied either directly to the record drawings during layout of the seams, to each seaming crew as they progress during the work period, or to each individual seaming device. Once the increment is decided upon, it should be held regardless of the location upon which it falls, e.g., along side slopes, in sumps, etc. Of course, if the CQA documents allow otherwise, exceptions such as avoiding sumps, connections, protrusions, etc. can be made.

Figure 3.23 - Completed Patch on a Geomembrane Seam Which had Previously Been Sampled for Destructive Tests

3.5.2.2 Randomly Selected Sampling

In random selection of destructive seam sample locations it is first necessary to preselect a preliminary estimate of the total number of samples to be taken. This is done by taking the total seam length of the facility and dividing it by an arbitrary interval, e.g., 150 m (500 ft), to obtain the total number of samples that are required. Two choices to define the actual sampling locations are now available: "stratified" random sampling, or "strict" random sampling. The stratified method takes each pre-selected interval (e.g., a 150 m (500 ft) length) and randomly selects a single sample location within this interval. Thus with stratified random sampling one has location variability within a fixed increment (unlike fixed frequency sampling which is always at the exact end of the increment). The strict method uses the total seam length of the facility (or cell) and randomly selects sample locations throughout the facility up to the desired number of samples. Thus with strict random sampling a group of samples may be taken in close proximity to one another, which necessarily leaves other areas with sparse sampling.

There are various ways of randomly selecting the specific location within an interval, e.g., in a specific region of great concern, or within the total project seam length. These are as follows:

- Use a random number generator from statistical tables to predetermine the sampling locations within each interval or for the entire project.
- Use a programmable pocket calculator with a random number generator program to select the sampling location in the field for each interval or for the entire project.
- Use a random number obtained by simply multiplying two large numbers together to form an 8-digit result. A pocket calculator with an adequate register will be necessary. The center two digits in such a procedure are quite randomly distributed and can be used to obtain the sampling location. For example, multiplication of the following two numbers "4567" by 4567" gives 20857489 where the central two digits, i.e., the "57", are used to select the location within the designated sampling interval. If this interval were 500 ft., the sampling location within it would be at 0.57 x 500 = 285 ft. from the beginning of the interval. The next location of the sample would require a new calculation resulting in a different central two-digit number somewhere within the next 500 ft. sampling interval and would be located in a similar fashion.

3.5.2.3 Other Sampling Strategies

There are two other sampling strategies which might be selected in determining how many destructive seam samples should be taken. Both are variable strategies in that repeated acceptable seam tests are rewarded by requiring fewer samples and repeated failures are penalized by requiring more frequent samples. These two strategies are called the "method of attributes" and the use of "control charts". Both set upper and lower bounds which require either fewer or more frequent testing than the initially prescribed sampling frequency. Each of these methods are described fully in Richardson (1992).

Whatever the sampling strategy used, it should never limit or prohibit the ability to select a destructive seam sample from a suspect area. This should ultimately be an option left to the CQA engineer.

3.5.3 Shear Testing of Geomembrane Seams

Shear testing of specimens taken from field fabricated geomembrane seams represents a reasonably simulated performance test. The possible exception is that a normal stress is not applied to the surfaces of the test specimen thus it is an "unconfined" tension test. A slight rotation may be induced during tensioning of the specimen, making the actual test results tend toward conservative values. The configuration of a shear test in a tension testing machine is shown in Fig. 3.24.

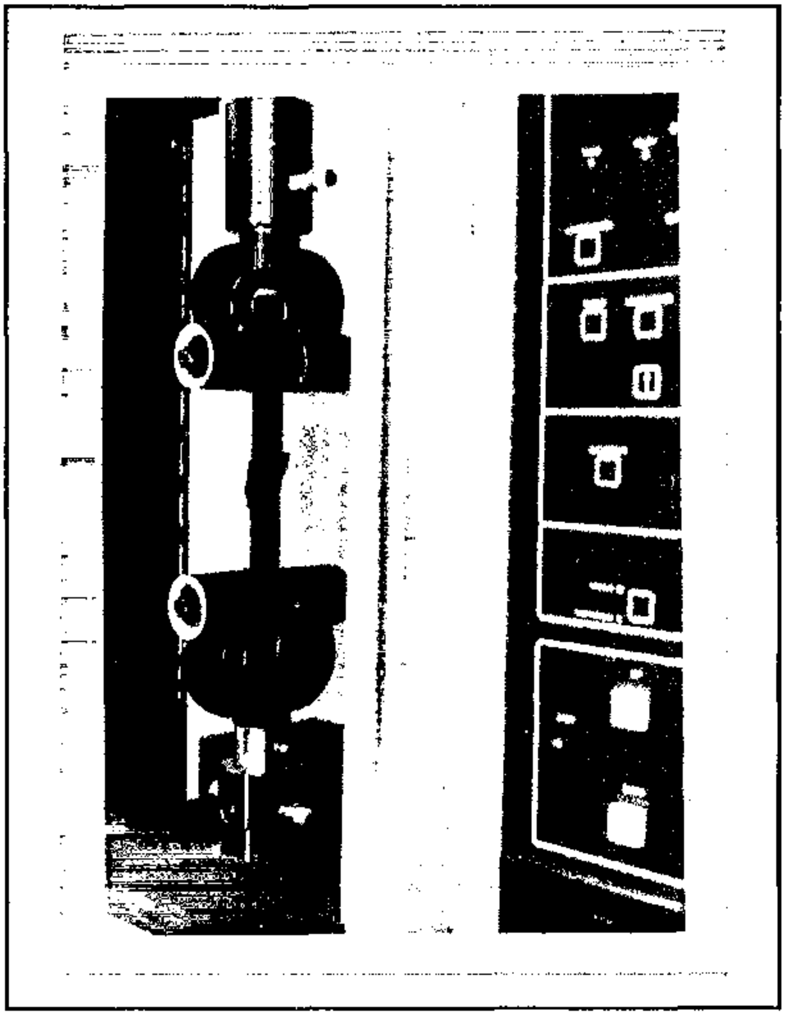


Figure 3.24 - Shear Test of a Geomembrane Seam Evaluated in a CQC/CQA Laboratory Environment

Commonly recommended shear tests for HDPE, PVC, CSPE-R and EIA-R seams, along with the methods of testing the unseamed sheet material in tension, are given in Table 3.4. The VLDPE data presented was included in a way so as to parallel the HDPE testing protocol except for the strain rate values which are faster since breaking values, rather than yield values are required. There is no pronounced yield value when tensile testing VLDPE geomembranes.

Table 3.4 Recommended Test Method Details for Geomembrane Seams in Shear and in Peel and for Unseamed Sheet

Type of Test	HDPE	VLDPE	PVC	CSPE-R
Shear Test on Seams				
ASTM Test Method	D4437	D4437	D3083	D751
Specimen Shape	Strip	Strip	Strip	Grab
Specimen Width (in.)	1.00	1.00	1.00	4.00 (1.00 grab)
Specimen Length (in.)	6.00 + seam	6.00 + seam	6.00 + seam	9.00 + seam
Gage Length (in.)	4.00 + seam	4.00 + seam	4.00 + seam	6.00 + seam
Strain Rate (ipm)	2.0	20	20	12
Strength (psi) or (ppi)	Force/(1.00×t)	Force/(1.00×t)	Force/(1.00×t)	Force
Peel Test on Seams				
ASTM Test Method	D4437	D4437	D413	D413
Specimen Shape	Strip	Strip	Strip	Strip
Specimen Width (in.)	1.00	1.00	1.00	1.00
Specimen Length (in.)	4.00	4.00	4.00	4.00
Gage Length (in.)	n/a	n/a	n/a	n/a
Strain Rate (ipm)	2.0	20	2.0	2.0
Strength (psi) or (ppi)	Force/(1.00×t)	Force/(1.00×t)	Force/1.00	Force/1.00
Tensile Test on Sheet				
ASTM Test Method	D638	D638	D882	D751
Specimen Shape	Dumbbell	Dumbbell	Strip	Grab
Specimen Width (in.)	0.25	0.25	1.00	4.00 (1.00 Grab)
Specimen Length (in.)	4.50	4.50	6.00	6.00
Gage Length (in.)	1.30	1.30	2.00	3.00
Strain Rate (ipm)	2.0	20	20	12
Strength (psi) or (lb)	Force/(0.25×t)	Force/(0.25×t)	Force/(1.00×t)	Force
Strain (in./in.)	Elong./1.30	Elong./1.30	Elong./2.00	Elong./3.00
Modulus (psi)	From Graph	From Graph	From Graph	n/a

where n/a = not applicable
t = geomembrane thickness
psi = pounds/square inch of specimen cross section
ppi = pounds/linear inch width of specimen
ipm = inches/minute
Force = maximum force attained at specimen failure (yield or break)

Insofar as the shear testing of nonreinforced geomembrane seams (HDPE, VLDPE and PVC), all use a 25 mm (1.0 in.) wide test specimen with the seam being centrally located within the testing grips. For the reinforced geomembranes (CSPE-R and EIA-R) a "grab" test specimen is used. In a grab tension test the specimen is 200 mm (4.0 in.) wide but is only gripped in the central 25 mm (1.0 in.). The test specimen is tensioned, at its appropriate strain rate, until failure occurs. If the seam delaminates (i.e., pulls apart in a seam separation mode), the seam fails in what is called a "non-film tear bond", or non-FTB. In this case, it is rejected as a failed seam. Details on various types of seam failures and on the interpretation of FTB are found in Haxo (1988). Conversely, if the seam does not delaminate, but fails in the adjacent sheet material on either side of the seam, it is an acceptable failure mode, i.e., called a "film tear bond", or FTB, and the seam strength is then calculated.

The seam strength (for HDPE, VLDPE and PVC) is the maximum force attained divided by either the original specimen width (resulting in units of force per unit width), or the original specimen cross sectional area (resulting in units of stress). It is general procedure to use force per unit width as it is an absolute strength value which can be readily compared to other test results. If stress units are desired, one can use the nominal thickness of the geomembrane, or continuously measure the actual thickness of each test specimen. This latter alternative requires considerable time and effort and is generally not recommended. The procedure is slightly different for the reinforced geomembranes (CSPE-R and EIA-R) which use a grab test method. Here the strength is based on the maximum tensile force that can be mobilized and a stress value is not calculated.

The resulting value of seam shear strength is then compared to the required seam strength (which is the usual case) or to the strength of the unseamed geomembrane sheet. If the latter, the procedures for obtaining this value are listed in Table 3.4. In each case the test protocol for seam and sheet are the same, except for HDPE and VLDPE. The sheet strength value for these polyethylene geomembranes are based on a ASTM D-638 "dumbbell-shaped" specimens, although the strength is calculated on the reduced section width. With all of these sheet tension tests, the nominal thickness of the unseamed geomembrane sheet is used for the comparison value. If actual thickness of the sheet is considered, the results will be reflected accordingly. Note, however, that this will require a large amount of additional testing (to get average strength values) and is not a recommended approach.

Knowing the seam shear strength and the unseamed sheet strength (ether by a specified value or by testing), allows for a seam shear efficiency calculation to be made as follows:

$$E_{shear} = \frac{T_{seam\ in\ shear}}{T_{unseamed\ sheet}} (100) \qquad (3.1)$$

where

E_{shear} = seam efficiency in shear (%)

T_{seam} = seam shear strength (force or stress units)

T_{sheet} = sheet tensile strength (force or stress units)

The contract plans, specifications or CQA documents should give the minimum allowable seam shear strength efficiency. As a minimum, the guidance listed below can be used whereby percentages of seam shear efficiencies (or values) are listed:

HDPE = 95% of specified minimum yield strength
VLDPE = typically 1200 lb/in^2
PVC = 80%
CSPE-R = 80% (for 3-ply reinforced)
EIA-R = 80%

Generally an additional requirement of a film tear bond, or FTB, will also be required in addition to a minimum strength value. This means that the failure must be located in the sheet material on either side of the seam and not within the seam itself. Thus the seam cannot delaminate.

Lastly, the number of failures allowed per number of tests conducted should be addressed. If sets of 5 test specimens are performed for each field sample, many specifications allow for one failure out of the five tested. If the failure number is larger, then the plans, specifications or CQA documents must be clear on the implications.

When a destructive seam test sample fails, many specifications and CQA documents require two additional samples to be taken, one on each side of the original sample each spaced 3 m (10 ft) from it. If either one of these samples fail, the iterative process of sampling every 3 m (10 ft) is repeated until passing test results are observed. In this case the entire seam between the two successful test samples must be questioned. For example, remedies for polyethylene geomembranes are to cap strip the entire seam or if the seam is made with a thermal fusion method (hot air or hot wedge) to extrude a fillet weld over the outer seam edge. When such repairs are concluded the seams on the cap strip or extrusion fillet weld should be sampled and tested as just described.

Note that elongation of the specimens during shear testing is usually not monitored (although current testing trends are in this direction), the only value under consideration is the maximum force that the seam can sustain. It should also be mentioned that the test is difficult to perform on the inside of the tracks facing the air channel of a dual channel thermal fusion seam. For small air channels the tab available for gripping will be considerably less than that required in test methods as given in Table 3.4. Regarding the testing of the inside or outside tracks (away from the air channel) of a dual channel thermal fusion seam, or even both tracks, the specification or CQA document should be very specific.

3.5.4 Peel Testing of Geomembrane Seams

Peel testing of specimens taken from field fabricated geomembrane seams represent a quality control type of index test. Such tests are not meant to simulate in-situ performance but are very important indicators of the overall quality of the seam. The configuration of a peel test in a tension testing machine is shown in Fig. 3.25.

The recommended peel tests for HDPE, PVC, CSPE-R and EIA-R seams, along with the unseamed sheet material in tension are given in Table 3.4. The VLDPE data was included in a way so as to parallel the HDPE testing protocol.

Insofar as the peel testing of geomembrane seams is concerned, it is seen that all of the geomembranes listed have a 25 mm (1.0 in.) width test specimen. Furthermore, the specimen lengths and strain rate are also equal for all geomembrane types. The only difference is that HDPE and VLDPE use the thickness of the geomembrane to calculate a tensile strength value in stress units, whereas PVC, CSPE-R and EIA-R calculate the tensile strength value in units of force per unit width, i.e., in units of pounds per linear inch of seam.

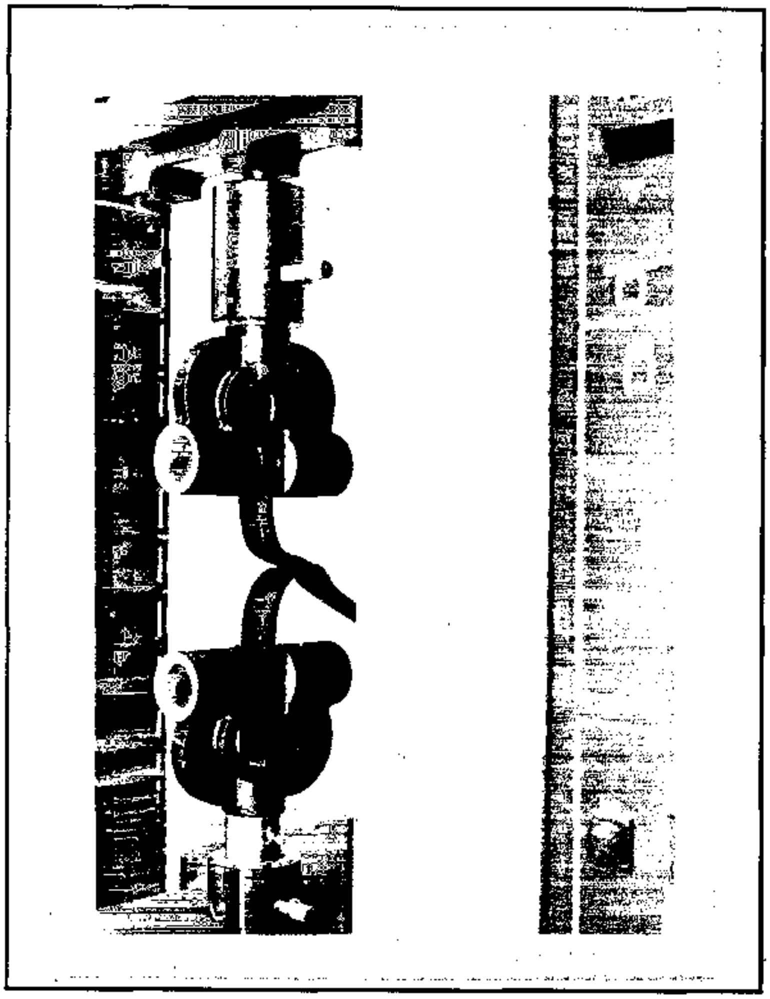


Fig. 3.25 - Peel Test of a Geomembrane Seam Evaluated in a CQC/CQA Laboratory Environment

In a peel test the test specimen is tensioned, at its appropriate strain rate, until failure occurs. If the seam delaminates (i.e., pulls apart in a seam separation mode), it is called a "non-film tear bond or non-FTB", and is recorded accordingly. Conversely, if the seam does not delaminate, but fails in the adjacent sheet material on either side of the seam it is called a "film tear bond or FTB" and the seam strength is calculated. Details on various types of seam failures and on the interpretation of FTB are found in Haxo (1988). The seam strength is the maximum force attained divided by the specimen width (resulting in units of force per unit width), or by the specimen cross sectional area (resulting in units of stress). The former procedure is the most common, i.e., peel strengths are measured in force per unit width units. If stress units are desired the thickness of the geomembrane sheet must be included. The nominal sheet thickness is usually used. If the actual sheet thickness is used, a large amount of thickness measurements will be required to obtain a statistically reliable value. It is not a recommended procedure.

The resulting value of seam peel strength is then compared to a specified value (the usual case) or to the strength of the unseamed geomembrane sheet. The testing procedures for obtaining these values are listed in Table 3.4. It can be seen, however, that only with PVC is the same width test specimen used for peel and sheet testing. For HDPE and VLDPE one is comparing a 1.0 in. uniform width peel test with a dumbbell shaped specimen, while for CSPE-R and EIA-R one is comparing a uniform width peel test with the strength from a grab shaped test specimen. If, however, one does have a specified sheet strength value or a measured value, a seam peel strength efficiency calculation can be made as follows:

$$E_{peel} = \frac{T_{\text{seam in peel}}}{T_{\text{unseamed sheet}}} (100) \tag{3.2}$$

where

E_{peel} = seam efficiency in peel (%)
T_{seam} = seam peel strength (force or stress units)
T_{sheet} = sheet tensile strength (force or stress units)

The contract plans, specifications or CQA documents should give the minimum allowable seam peel strength efficiency. As a minimum, the guidance listed below can be used whereby percentage peel efficiencies (or values) are listed as follows:

HDPE = 62% of specified minimum yield strength and FTB
VLDPE = typically 1000 lb/in^2
PVC = 10 lb/in.
CSPE-R = 10 lb/in. or FTB
EIA-R = 10 lb/in.

Lastly, the number of failures allowed per number of tests conducted should be addressed. If sets of 5 test specimens are performed for each field sample, many specifications allow for one failure out of the five tested. If the failure number is larger, then the plans, specifications or CQA documents must be clear on the implications.

When a destructive seam test sample fails, many specifications require an additional two samples to be taken, one on each side of the original spaced 3 m (10 ft) from it. If either one of these samples fail the iterative process of sampling every 3 m (10 ft) is repeated until successful samples result. In this case, the entire seam between the last successful test samples must be questioned. Remedies are to cap strip the entire seam or if the seam is HDPE or VLDPE made with a thermal fusion method (hot air or hot wedge) to extrude a fillet weld over the outer seam edge. When this is done the seams on the cap strip or extrusion fillet weld may be sampled and tested as just described.

Note that neither elongation of the specimen nor peel separation, during the test is usually monitored (although current testing trends are in this direction), the only value under consideration is the maximum tensile force that the seam can sustain. It should also be mentioned that both frontward and backward peel tests can be performed thereby challenging both sides of a seam. For dual channel seams, both insides of the tracks facing the air channel can be tested, but due to the narrow width of most air channels the tab available for gripping will be considerably less than that given in Table 3.4. Regarding the testing of the inside or outside tracks (away from the air channel) of a dual channel seam, or even both tracks, the specification or CQA document should be very specific.

3.5.5 General Specification Items

Regarding field sampling of geomembrane seams and their subsequent destructive testing, a specification or CQA document should consider the following items.

1. CQA personnel should observe all production seam sample cutting.
2. All samples should be adequately numbered and marked with permanent identification.
3. All sample locations should be indicated on the geomembrane layout (and record) drawings.
4. The reason for taking the sample should be indicated, e.g., statistical routine, suspicious feature, change in sheet temperature, etc.
5. The sample dimensions should be given insofar as the length of sample and its width. The seam will generally be located along the center of the length of the sample.
6. The distribution of various portions of the sample (if more than one) should be specified.
7. The number of shear and peel tests to be conducted on each sample (field tests and laboratory tests) should be specified.
8. The specifics of conducting the shear and peel tests should be specified, e.g., use of actual sheet thickness, or of nominal sheet thickness. The following are suggested ASTM test methods for each geomembrane type:

Geomembrane	Seam Shear Test	Seam Peel Test	Sheet Test
HDPE	D-4437	D-4437	D-638
VLDPE	D-4437	D-4437	D-638
PVC	D-3083	D-413	D-882
CSPE-R	D-751	D-413	D-751
EIA-R	D-751	D-751	D-751

9. The CQA personnel should witness all field tests and see that proper identification and details accompany the test results. Details should be provided in the CQA documents. Such details as follows are often required.

- date and time
- ambient temperature
- identification of seaming unit, group or machine
- name of master seamer
- welding apparatus temperature and pressure, or chemical type and mixture
- pass or fail description
- a copy of the report should be attached to the remaining portion of the sample

10. The CQA personnel should verify that samples sent to the testing laboratory are properly marked, packaged and shipped so as not to cause damage.

11. Results of the laboratory tests should come to the CQA Engineer in a stipulated time. For extrusion and thermally bonded seams, verbal test results are sometimes required with 24 to 72 hours after the laboratory receives the samples. For chemically bonded seams, the time frame is longer and depends on whether or not accelerated heat curing of the seams is required. In all cases, the CQA Engineer must inform the Owner's representative of the results and make appropriate recommendations.

12. The procedures for seam remediation in the event of failed destructive tests should be clear and unequivocal. Options usually are (a) to repair the entire seam between acceptable sampling locations, or (b) to retest the seam on both sides in the vicinity of the failed sample. If they are acceptable only this section of the seam is repaired. If they are not, a wider spaced set of samples are taken and tested.

13. Repairs to locations where destructive samples were removed should be stipulated. These repairs are specific to the type of geomembrane and to the seaming method. Guidance in this regard is available in EPA (1991).

14. Each repair of a patched seam where a test sample had been removed should be verified. This is usually done by an appropriate nondestructive test. If, however, the sampling strategy selected calls for a destructive test to be made at the exact location of a patch it should be accommodated. Thus the final situation will require a patch to be placed on an earlier patch. If this (unsightly) detail is to be avoided, it should be stated outright in the specifications or CQA document.

15. The time required to retain and store destructive test samples on the part of the CQC and CQA organizations should be stipulated.

3.6 Nondestructive Test Methods for Seams

3.6.1 Overview

Although it is obviously important to conduct destructive tests on the fabricated seams, such tests do not give adequate information on the continuity and completeness of the entire seam between sampling locations. It does little good if one section of a seam meets the specification requirements, only to have the section next to it missed completely by the field-seaming crew.

Thus continuous methods of a nondestructive testing (NDT) nature will be discussed here. In each of these methods the goal is to validate 100% of the seams or, at minimum, a major percentage of them.

3.6.2 Currently Available Methods

The currently available NDT methods for evaluating the adequacy of geomembrane field seams are listed in Table 3.5 in the order that they will be discussed.

The *air lance* method uses a jet of air at approximately 350 kPa (50 lb/in.^{2}) pressure coming through an orifice of 5 mm (3/16 in.) diameter. It is directed beneath the upper edge of the overlapped seam and is held within 100 mm (4.0 in.) from the edge of the seamed area in order to detect unbonded areas. When such an area is located, the air passes through the opening in the seam causing an inflation and fluttering in the localized area. A distinct change in sound emitted can generally be heard. The method works best on relatively thin, less than 1.1 mm (45 mils), flexible geomembranes, but works only if the defect is open at the front edge of the seam, where the air jet is directed. It is essentially a geomembrane installer's method to be used in a construction quality control (CQC) manner.

The *mechanical point stress or "pick" test* uses a dull tool, such as a blunt screw-driver, under the top edge of a seam. With care, an individual can detect an unbonded area, which would be easier to separate than a properly bonded area. It is a rapid test that obviously depends completely on the care and sensitivity of the person doing it. Detectability is similar to that of using the air lance, but both are very operator-dependent. This test is to be performed only by the geomembrane installer as a CQC method. Design or inspection engineers should not use the pick test but rather one or more of the techniques to be discussed later.

The *pressurized dual seam* method was mentioned earlier in connection with the dual hot wedge or dual hot air thermal seaming methods. The air channel that results between the dual bonded tracks is inflated using a hypodermic needle and pressurized to approximately 200 kPa (30 lb/in.^{2}). There is no limit as to the length of the seam that is tested. If the pressure drop is within an allowable amount in the designated time period (usually 5 minutes), the seam is acceptable; if a unacceptable drop occurs, a number of actions can be taken:

- The distance can be systematically halved until the leak is located.
- The section can be tested by some other leak detection method.
- An extrusion fillet weld can be placed over the entire edge.
- A cap strip can be seamed over the entire edge.

Details of the test can be found in GRI Test Method GM6. The test is an excellent one for long, straight-seam lengths. It is generally performed by the installation contractor, but usually with CQA personnel viewing the procedure and documenting the results.

Table 3.5 - Nondestructive Geomembrane Seam Testing Methods, Modified from Richardson and Koerner (1988)

Nondestructive Test Method	Primary User		General Comments					
	CQC	CQA	Cost of Equipment	Speed of Tests	Cost of Tests	Type of Result	Recording Method	Operator Dependency
1. air lance	yes	---	$200	fast	low	yes-no	manual	high
2. mechanical point (pick) stress	yes	---	nil	fast	nil	yes-no	manual	very high
3. dual seam (positive pressure)	yes	---	$200	fast	moderate	yes-no	manual	low
4. vacuum chamber (negative pressure)	yes	yes	$1000	slow	very high	yes-no	manual	moderate
5. electric wire	yes	yes	$500	fast	nil	yes-no	manual	high
6. electric field	yes	yes	$20,000	slow	high	yes-no	manual and automatic	low
7. ultrasonic pulse echo	---	yes	$5000	moderate	high	yes-no	automatic	moderate
8. ultrasonic impedance	---	yes	$7000	moderate	high	qualitative	automatic	unknown
9. ultrasonic shadow	---	yes	$5000	moderate	high	qualitative	automatic	moderate

The *vacuum chamber (box)* method uses a box up to 1.0 m (3 ft) long with a transparent top that is placed over the seam; a vacuum of approximately 20 kPa (3 lb/in.^{2}) is applied. When a leak is encountered the soapy solution originally placed over the seam shows bubbles thereby reducing the vacuum. This is due to air entering from beneath the geomembrane and passing through the unbonded zone. The test is slow to perform (a 10 sec dwell time is currently recommended) and is often difficult to make a vacuum-tight joint at the bottom of the box where it passes over the seam edges. Due to upward deformations of the liner into the vacuum box, only geomembrane thickness greater than 1.0 mm (40 mils) should be tested in this manner. For thinner, more flexible geomembranes an open grid wire mesh can be used along the bottom of the box to prevent uplift. It should also be noted that vacuum boxes are the most common form of nondestructive test currently used by design engineers and CQA inspectors for polyethylene geomembranes. It should be recognized that 100% of the field seams cannot be inspected by this method. The test cannot cover portions of sumps, anchor trenches, and pipe penetrations with any degree of assurance. The method is also very awkward to use on side slopes. The adequate downward pressure required to make a good seal is difficult to mobilize since it is usually done by standing on top of the box.

Electric sparking (not mentioned in Table 3.5) is a technique used to detect pinholes in thermoplastic liners. The method uses a high-voltage (15 to 30 kV) current, and any leakage to ground (through an opening or hole) results in sparking. The method is being investigated for possible field use. The *electric wire* method places a copper or stainless steel wire between the overlapped geomembrane region and actually embeds it into the completed seam. After seaming, a charged probe of about 20,000 volts is connected to one end of the wire and slowly moved over the length of the seam. A seam defect between the probe and the embedded wire results in an audible alarm from the unit.

The *electric field* test utilizes a potential which is applied across the geomembrane by placing a positive electrode in water within the geomembrane and a ground electrode in the subgrade or in the sump of the leak detection system. A current will only flow between the electrodes through a hole (leak) in the geomembrane. The potential gradients in the ponded water are measured by "walking" the area with a previously calibrated probe. The operator walks along a calibration grid layout and identifies where anomalies exist. Holes less than 1 mm diameter can be identified. These locations can be rechecked after the survey is completed by other methods, such as the vacuum box. In deep water, or for hazardous liquids, a remote probe can be dragged from one side of the impoundment to the other across the surface of the geomembrane. On side slopes that are not covered by water, a positively charged stream of water can be directed onto the surface of the geomembrane. When the water stream encounters and penetrates a hole, contact with the subgrade is made. At this point current flow is indicated, thus locating the hole. Pipe penetrations through the geomembrane and soil cover that goes up the side slope and contacts the subgrade reduce the sensitivity of the method.

The last group of nondestructive test methods noted in Table 3.5 can collectively be called *ultrasonic methods*. A number of ultrasonic methods are available for seam testing and evaluation. The *ultrasonic pulse echo* technique is basically a thickness measurement technique and is only for use with nonreinforced geomembranes. Here a high-frequency pulse is sent into the upper geomembrane and (in the case of good acoustic coupling and good contact between the upper and lower sheets) reflects off of the bottom of the lower one. If, however, an unbonded area is present, the reflection will occur at the unbonded interface. The use of two transducers, a pulse generator, and a CRT monitor are required. It cannot be used for extrusion fillet seams, because of their nonuniform thickness. The *ultrasonic impedance plane* method works on the principle of acoustic impedance. A continuous wave of 160 to 185 kHz is sent through the seamed geomembrane, and a characteristic dot pattern is displayed on a CRT screen. Calibration of the dot pattern is required to signify a good seam; otherwise, it is not. The method has potential for all types of geomembranes but still needs additional developmental work. The *ultrasonic shadow method* uses two roller transducers: one sends a signal into the upper geomembrane and the other receives the signal from the lower geomembrane on the other side of the seam (Richardson and Koerner, 1988). The technique can be used for all types of seams, even those in difficult locations, such as around manholes, sumps, appurtenances, etc. It is best suited for semicrystalline geomembranes, including HDPE, and will not work for scrim-reinforced liners.

3.6.3 Recommendations for Various Seam Types

The various NDT methods listed in Table 3.5 have certain uniqueness and applicability to specific seam and geomembrane types. Thus a specification should only be framed around the particular seam type and geomembrane type for which it has been developed. Table 3.6 gives guidance in this regard. Even within Table 3.6, there are certain historical developments. For example, the air lance method is used routinely on the flexible geomembranes seamed by chemical methods, whereas the vacuum chamber method is used routinely on the relatively stiff HDPE geomembranes. Also to be noted is that the dual seam can technically be used on all geomembranes, but only when they are seamed by a dual track thermal fusion method, i.e., by hot wedge or hot air seaming methods. Thus by requiring such a dual seam pressure test method one mandates the type of seam which is to be used by the installation contractor.

Lastly, it should be mentioned that only three of the nine methods listed in Table 3.5 are used routinely at this point in time. They are the air lance, dual seam and vacuum chamber methods. The others are either uniquely used by the installation contractor (pick test and electric wire), or are in the research and development stage (electric current and the various ultrasonic test methods).

3.6.4 General Specification Items

Regarding field evaluation of geomembrane seams and their nondestructive testing, a specification or CQA document should consider the following items:

1. The purpose of nondestructive testing should be clearly stated. For example, nondestructive testing is meant to verify the continuity of field seams and not to quantify seam strength.

2. Generally nondestructive testing is conducted as the seaming work progresses or as soon as a suitable length of seam is available.

3. Generally nondestructive testing of some type is required for 100% of the field seams. For geomembranes supplied in factory fabricated panels, the factory seams may, or may not, be specified to be nondestructively tested in the field. This decision depends on the degree of MQC (and MQA) required on factory fabricated seams.

4. The specification should recognize that the same type of nondestructive test cannot be used in every location. For example, in sumps and at pipe penetrations the dual air channel and vacuum box methods may not be usable.

5. It must be recognized that there are no current ASTM Standards on any of the NDT methods presented in Table 3.5 although many are in progress. Thus referencing to such consensus documents is not possible. For temporary guidance, there is a GRI Standard available for dual seam air pressure test method, GRI GM-6.

6. CQA personnel should observe all nondestructive testing procedures.
7. The location, data, test number, name of test person and outcome of tests must be recorded.
8. The Owner's representative should be informed of any deficiencies.
9. The method of repair of deficiencies found by nondestructive testing should be clearly outlined in the specifications or CQA documents, as should the retesting procedure.

Table 3.6 Applicability Of Various Nondestructive Test Methods To Different Seam Types And Geomembrane Types

NDT Method	Seam Types*	Geomembrane Types
1. air lance	C, BC, Chem A, Cont. A	all except HDPE
2. mechanical point stress	all	all
3. dual seam	HW, HA	all
4. vacuum chamber	all	all
5. electric wire	all	all
6. electric current	all	all
7. ultrasonic pulse echo	HW, HA C, BC, Chem. A, Cont. A	HDPE, VLDPE, PVC
8. ultrasonic impedance	HW, HA C, BC, Chem. A, Cont. A	HDPE, VLDPE, PVC
9. ultrasonic shadow	E Fil., E Flt., HW, HA	HDPE, VLDPE

*E Fil. = extrusion fillet
E Flt. = extrusion flat
HW = hot wedge
HA = hot air
C = chemical
BC = bodied chemical
Chem. A = chemical adhesive
Cont. A = contact adhesive

3.7 Protection and Backfilling

The field deployed and seamed geomembrane must be backfilled with soil or covered with a subsequent layer of geosynthetics in a timely manner after its acceptance by the CQA personnel. If the covering layer is soil, it will generally be a drainage material like sand or gravel depending upon the required permeability of the overlying layer. Depending upon the particle size, hardness and angularity of this soil, a geotextile or other type of protection layer may be necessary. If the covering layer is a geosynthetic, it will generally be a geonet or geocomposite drain, which is usually placed directly upon the geomembrane. This is obviously a critical step since geomembranes are relatively thin materials with puncture and tear strengths of finite proportions. Specifications should be very clear and unequivocal regarding this final step in the installation survivability of geomembranes.

3.7.1 Soil Backfilling of Geomembranes

There are at least three important considerations concerning soil backfilling of geomembranes: type of soil backfill material, type of placement equipment and considerations of slack in the geomembrane.

Concerning the type of soil backfilling material; its particle size characteristics, hardness and angularity are important with regard to the puncture and tear resistance of the geomembrane. In general, the maximum soil particle size is very important, with additional concerns over poorly graded soils, increased angularity and increased hardness being of significance. Past research on puncture resistance of geomembranes has shown that HDPE and CSPE-R geomembranes are more sensitive to puncture than are VLDPE and PVC geomembranes for conventional thicknesses of the respective types of geomembranes. Using truncated cones in laboratory tests to simulate the puncturing phenomenon (Hullings and Koerner, 1991), the critical cone height values which were obtained are listed in Table 3.7. It should be cautioned, however, that these values are not based on actual soil subgrades, nor on geostatic type stresses. The values are meant to give relative performance between the different geomembrane types.

Table 3.7. Critical Cone Heights For Selected Geomembranes In Simulated Laboratory Puncture Studies (Richardson and Koerner, 1988)

Geomembrane Type	Geomembrane Thickness		Critical Cone Height	
	mm	mil	mm	inch
HDPE	1.5	60	12	0.50
VLDPE	1.0	40	89	3.50
PVC	0.5	20	70	2.75
CSPE-R	0.9	36	15	0.60

Although the truncated cone hydrostatic test is an extremely challenging index-type test, the data of Table 3.7 does not reflect creep and/or stress relaxation of the geomembrane. In reviewing numerous CQA documents it appears that the maximum backfill particle size for use with HDPE and CSPE-R geomembranes should not exceed 12-25 mm (0.5-1.0 in.). VLDPE and PVC geomembranes appear to be able to accommodate larger soil backfill particle sizes. If the soil particle size must exceed the approximate limits given (e.g., for reasons of providing high permeability in a drainage layer), then a protection material must be placed on top of the geomembrane and beneath the soil. Geotextiles, as well as other protection materials, have been used in this regard. New materials, e.g., recycled fiber geotextiles and rubber matting, are being evaluated.

Concerning the type of placement equipment, the initial lift height of the backfill soil is very important. (Note that construction equipment should never be allowed to move directly on any deployed geomembrane. This includes rubber tired vehicles such as automobiles and pickup trucks but does not include light weight equipment like all-terrain vehicles (ATV's). The minimum initial lift height should be determined for the type of placement equipment and soil under consideration, however, 150 mm (6 in.) is usually considered to be a minimum. Between this value and approximately 300 mm (12.0 in.), low ground pressure placement equipment should be specified. Ground contact pressure equipment of less than 35 kPa (5.0 lb/in^2) is recommended. For lift heights of greater than 300 mm (12.0 in.), proportionately heavier placement equipment can be used.

Placement of soil backfilling should proceed from a stable working area adjacent to the deployed geomembrane and gradually progress outward. Soil is never to be dropped from dump trucks or front end loaders directly onto the geomembrane. The soil should be pushed forward in an upward tumbling action so as not to impact directly on the geomembrane. It should be placed by a bulldozer or front end loader, never by a motor grader which would necessarily have its front wheels riding directly on the geomembrane. Sometimes "fingers" of backfill are pushed out over the geomembrane with controlled amounts of slack between them. Figure 3.26 shows a sketch and photograph of this type of soil covering placement. Backfill is then widened so as to connect the "fingers", with the controlled slack being induced into the geomembrane. This procedure is at the discretion of the design engineer and depends on site specific materials and conditions.

If a predetermined amount of slack is to be placed in the geomembrane, the temperature of the geomembrane itself during backfilling is important and should be contrasted against the minimum service temperature that the geomembrane will eventually experience. This difference in temperature, assuming the geomembrane temperature at the time of backfilling is higher than the minimum service temperature, is multiplied by the distance between backfilling "fingers" and by the coefficient of thermal expansion/ contraction of the particular geomembrane. Coefficients of thermal expansion/contraction found in the literature are given in Table 3.8. Note, however, that the coefficient of expansion/contraction of the site specific geomembrane should be available for such calculations.

While many geomembrane polymers fall in the same general range of coefficient of thermal expansion/contraction (as seen in Table 3.8), it is the stiff and relatively thick geomembranes, which are troublesome during backfilling. Here the slack accumulates in a wave which should not be allowed to crest over on itself, lest a fold is trapped beneath the backfill. In such cases, the "fingers" of backfilling must be relatively close together. If the situation becomes unwieldy due to very high geomembrane temperature, the backfilling should temporarily cease until the ambient temperature decreases. This will have the effect of requiring less slack to be placed in the geomembrane.

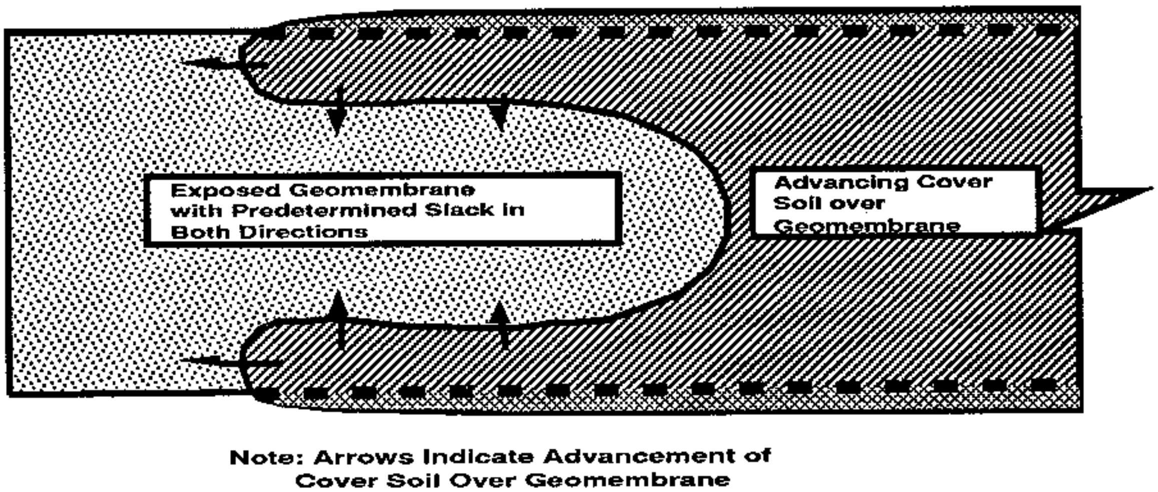


Figure 3.26 - Advancing Primary Leachate Collection Gravel in "Fingers" Over the Deployed Geomembrane

Table 3.8 - Coefficients Of Thermal Expansion/Contraction Of Various Nonreinforced Geomembrane Polymers (Various References)*

Polymer Type	Thermal linear expansivity x 10^{-5} per 1°F	per 1°C
Polyethylene		
high density	7-12	12-22
medium density	6-8	11-15
low density	5-7	9-13
very low density	11-16	20-30
Polypropylene	3-5	5-9
Polyvinyl chloride		
unplasticized	3-10	5-18
plasticized	4-14	7-25

*Values are approximate and change somewhat with the particular formulation and with the actual temperature range over which the values are measured.

3.7.2 Geosynthetic Covering of Geomembranes

Various geosynthetic materials may be called upon to cover the deployed and seamed geomembrane. Often a geotextile or a geonet will be the covering material. Sometimes, however, it will be a geogrid (for cover soil reinforcement on slopes) or even a drainage geocomposite (again on slopes to avoid instability of natural drainage soils). As with the previous discussion on soil covering, no construction vehicles of any type should be allowed to move directly on the geomembrane (or any other geosynthetic for that matter). Generators, low tire inflation ATV's, and other seaming related equipment are allowed as long as they do not damage the geomembrane. As a result, the movement of large rolls of geotextile or geonet becomes very labor intensive. Proper planning and sequencing of the operations is important for logistical control. The geosynthetic materials are laid directly on the geomembrane with no bonding of any type to the geomembrane being allowed. For example, thermally fusing of a geonet to a geomembrane should not be permitted. Temperature compensation (as described earlier) should be added based on material characteristics.

The geosynthetics placed above the geomembrane will either be overlapped (as with some geotextiles), sewn (as with other geotextiles), connected with plastic ties (as with geonets), mechanically joined with rods or bars (as with geogrids), or male/female joined (as with drainage composites). These details will be described in Chapter 6 on geosynthetic materials other than geomembranes.

3.7.3 General Specification Items

The specification or CQA document for backfilling should be written around the concept that the geomembrane must be protected against damage by the overlying material. Since soil, usually sand or gravel, is the most common backfilling material, the items that follow should be considered.

1. The temperature during soil backfilling should be considered. Expansion, contraction, puncture, tear and other properties vary in accordance with the geomembrane temperature.

2. In general, backfilling in warm climates or during summer months should be performed at the coolest part of the day.

3. In extreme cases of excessively high temperatures, backfilling may be required during non-typical work hours, e.g., sunrise to 10:00 AM or 5:00 PM to sunset.

4. If soil backfilling is to be done between sunset and sunrise, i.e., at night, the work area should be suitably lit for safety, constructability and inspection considerations.

5. If soil backfilling is to be done at night, excessive equipment noise may not be tolerated by people in the local neighborhood. This is an important and obviously site specific condition which should be properly addressed.

6. When a geotextile or other protection layer is to be placed above the geomembrane it should be done so according to the plans and specifications.

7. Soil placement equipment should never move, or drive, directly on the geomembrane.

8. Personnel or materials vehicles (automobiles, pickup trucks, etc.) should never drive directly on the geomembrane.

9. The soil particle size characteristics should be stipulated as part of the design requirements.

10. The minimum soil lift thickness should be stipulated in the design requirements. Furthermore, the thickness should be clear as to whether it is loose or compacted thickness.

11. The maximum ground contact pressure of the placement equipment should be stipulated in the design requirements.

12. For areas regularly traversed by heavy equipment, e.g., the access route for loaded dump trucks, a larger than usual fill height should be required.

13. The CQA personnel should be available at all times during backfilling of the geomembrane. It is the last time when anyone will see the completely installed material.

14. Documentation should include the soil type, lift thickness, total thickness, density and moisture conditions (as appropriate).

3.8 References

ASTM D-413, "Rubber Property-Adhesion to Flexible Substrate"

ASTM D-638, "Tensile Properties of Plastics"

ASTM D-751, "Test Methods for Coated Fabrics"

ASTM D-792, "Specific Gravity and Density of Plastics by Displacement"

ASTM D-882, "Test Methods for Tensile Properties of Thin Plastic Sheeting"

ASTM D-1004, "Initial Tear Resistance of Plastic Film and Sheeting"

ASTM D-1238, "Flow Rates of Thermoplastics by Extrusion Plastometer"

ASTM D-1248, "Polyethylene Plastics and Extrusion Materials"

ASTM D-1505, "Density of Plastics by the Density-Gradient Technique"

ASTM D-1603, "Carbon Black in Olefin Plastics"

ASTM D-1765, "Classification System for Carbon Black Used in Rubber Products"

ASTM D-2663, "Rubber Compounds - Dispersion of Carbon Black"

ASTM D-3015, "Recommended Practice for Microscopical Examination of Pigment Dispersion in Plastic Compounds"

ASTM D-3083, "Specification for Flexible Poly (Vinyl Chloride) Plastic Sheeting for Pond, Canal, and Reservoir Lining"

ASTM D-4437, "Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes"

ASTM D-4545, "Practice for Determining the Integrity of Factory Seams Used in Joining Manufactured Flexible Sheet Geomembranes"

ASTM D-4759, "Determining the Specification Conformance of Geosynthetics"

ASTM D-5046, "Specification for Fully Crosslinked Elastomeric Alloys"

ASTM D-5199, "Measuring Nominal Thickness of Geotextiles and Geomembranes"

ASTM D-5321 "Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method"

ASTM D-5397, "Notched Constant Tensile Load Test for Polyolefin Geomembranes"

FTM Std. 101C, "Puncture Resistance and Elongation Test," Federal Test Method 2065," March 13, 1980.

GRI GM-6, "Pressurized Air Channel Test for Dual Seamed Geomembranes"

GRI GM-7, "Accelerated Curing of Geomembrane Test Strips Made by Chemical Fusion Methods"

GRI GS-7, "Determining the Index Friction Properties of Geosynthetics"

Haxo, H. E., (1988), "Lining of Waste Containment and Other Impoundment Facilities," EPA/600/2-88/052, Washington, DC.

Hsuan, Y. and Koerner, R. M. (1992), "Stress Cracking Potential and Behavior of HDPE Geomembranes," Final Report to U.S. EPA, Contract No. CR-815692.

Hullings, D. E. and Koerner, R. M. (1991), "Puncture Resistance of Geomembranes Using a Truncated Cone Test," *Proceedings*, Geosynthetics '91, IFAI, pp. 273-286.

Richardson, G. N. and Koerner, R. M. (1988), "Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments," EPA/600/S2-87/097.

Richardson, G. N. (1992), "Construction Quality Management for Remedial Action and Remedial Design Waste Containment Systems," U.S. EPA, EPA/540/R-92/073, Washington, DC.

U. S. Environmental Protection Agency (1991) "Inspection Techniques for the Fabrication of Geomembrane Field Seams," EPA Technical Guidance Document, EPA/530/SW-91/051.

Chapter 4

Geosynthetic Clay Liners

4.1 Types and Composition of Geosynthetic Clay Liners

As with most types of manufactured products within a given category, there are sufficient differences such that no two products are truly equal to one another. Geosynthetic clay liners (GCLs) are no exception. Yet, there are a sufficient number of common characteristics such that the current commercially available products deserve a separate category and a separate treatment in this manual. GCLs can be defined as follows:

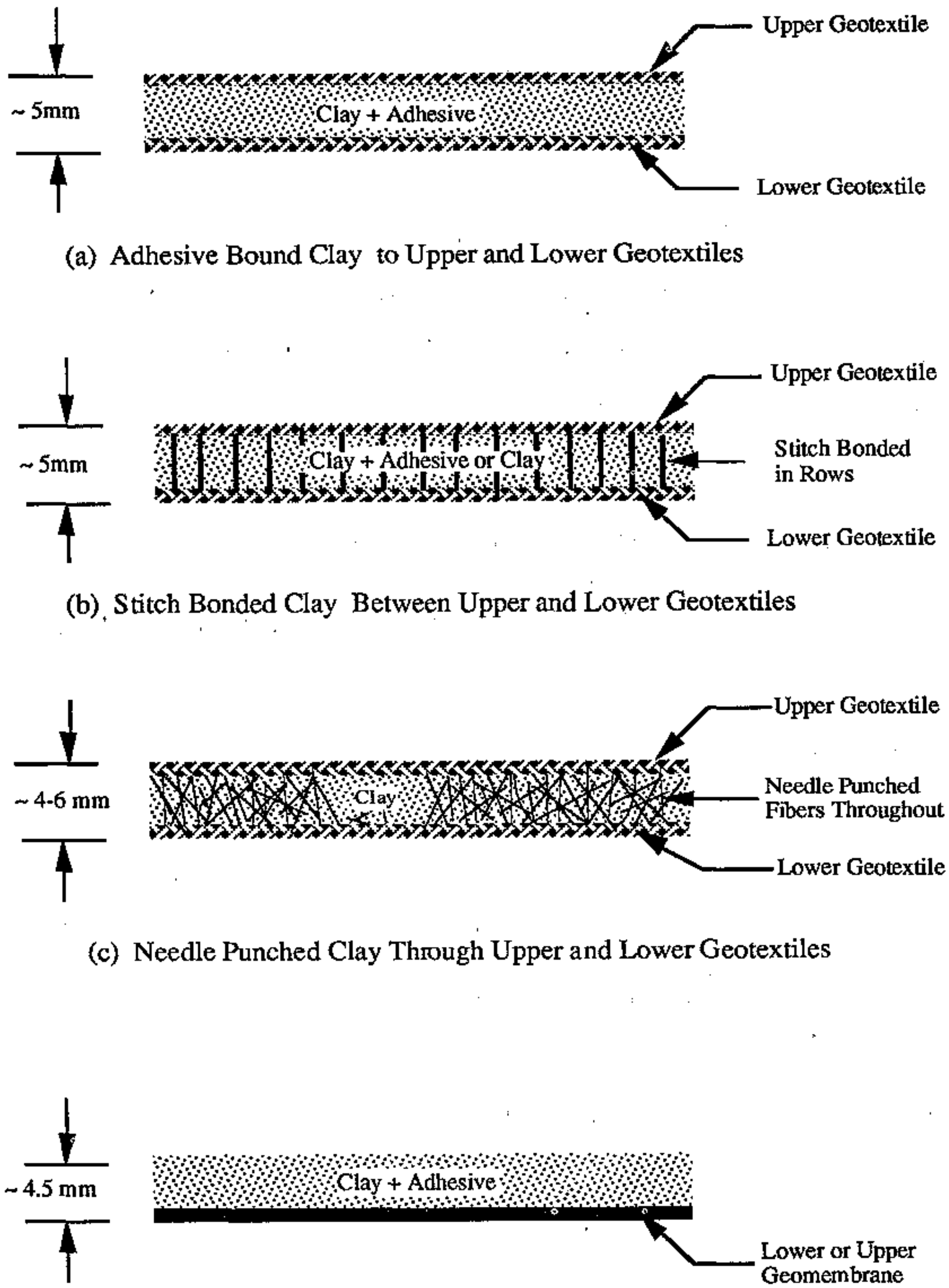
> "Geosynthetic clay liners (GCLs) are factory manufactured, hydraulic barriers typically consisting of bentonite clay or other very low permeability clay materials, supported by geotextiles and/or geomembranes which are held together by needling, stitching and/or chemical adhesives"

Other names that GCLs have been listed under, are "clay blankets", "clay mats", "bentonite blankets", "bentonite mats", "prefabricated bentonite clay blankets", etc. GCLs are hydraulic barriers to water, leachate or other liquids. As such, they are used to augment or replace compacted clay liners or geomembranes, or they are used in a composite manner to augment the more traditional clay liner or geomembrane materials.

Cross section sketches of the currently available GCLs at the time of writing are shown in Fig. 4.1. General comments regarding each type follow:

- Figure 4.1(a) illustrates a bentonite clay mixed with a water soluble adhesive which is supported by individual geotextiles on both its upper and lower surfaces.
- Figure 4.1(b) illustrates a stitchbonded variation of the above type of product whereby the upper and lower geotextiles are joined by continuous sewing in discrete rows throughout the machine direction of the product as well as a recent product which consists of bentonite powder alone with no admixed adhesive.
- Figure 4.1(c) illustrates a bentonite clay powder or granules, containing no adhesive, which is supported by individual geotextiles on its upper and lower surfaces and is needle punched throughout to provide for its stability. Several variations of this type of GCL are available including styles with clay infilled in the voids of the upper geotextile.
- Figure 4.1(d) illustrates a bentonite clay which is admixed with an adhesive and is supported by a geomembrane on its lower surface, as shown, or it can be used in an inverted manner with the geomembrane side facing upward. Variations of this product are also available with textured or raised geomembrane surfaces.

All of the GCL products available in North America use sodium bentonite clay (predominately smectite) powder or granules at as-manufactured mass per unit areas in the range of 3.2 to 6.0 kg/m^2 (0.66 to 1.2 lb/ft^2). The clay thickness in the various products vary between the range of 4.0 to 6.0 mm (160 to 320 mils). GCLs are delivered to the job site at moisture contents which



(a) Adhesive Bound Clay to Upper and Lower Geotextiles

(b) Stitch Bonded Clay Between Upper and Lower Geotextiles

(c) Needle Punched Clay Through Upper and Lower Geotextiles

(d) Adhesive Bound Clay to a Geomembrane

Figure 4.1 - Cross Section Sketches of Currently Available Geosynthetic Clay Liners (GCLs)

vary from 5 to 23%, depending upon the local humidity. Note that this is sometimes referred to in the technical literature as the "dry" state. The types of geotextiles used with the different products vary widely in their manufacturing style (e.g., woven slit film, needle punched nonwoven, spunlaced, heat bonded nonwovens, etc.) and in their mass per unit area [e.g., varying from 85 g/m^2 (2.5 oz/yd^2) to 1000 g/m^2 (30 oz/yd^2). The particular product with a geomembrane backing can also vary in its type, thickness and surface texture.

GCLs are factory made in widths of 2.2 to 5.2 m (7 to 17 ft) and lengths of 30 to 61 m (100 to 200 ft). Upon manufacturing GCLs are rolled onto a core and are covered with a plastic film to prevent additional moisture gain during storage, transportation ,and placement prior to their final covering with an overlying layer.

4.2 Manufacturing

This section on manufacturing of GCLs will discuss the various raw materials, manufacturing of the rolls, and covering of the rolls.

4.2.1 Raw Materials

The bentonite clay materials currently used in the manufacture of GCLs are all of the sodium montmorillonite variety which is a naturally occurring mineral in the Wyoming and North Dakota regions of the USA. After the clay is mined, it is dried, pulverized, sieved and stored in silos until it is transported to a GCL manufacturing facility.

The other raw material ingredient used in the manufacture of certain GCLs (recall Section 4.1) is an adhesive which is a proprietary product among the two manufacturers that produce this type of GCL. Additionally, geotextiles and/or geomembranes are used as substrate (below the clay) or superstrate (above the clay) layers which are product specific as was mentioned in the previous section.

Regarding a specification or MQA document for the various raw materials used in the manufacture of GCLs, the following items should be considered.

1. The clay should meet the GCL manufacturer's specification for quality control purposes. This is often 70% to 90% sodium montmorillonite clay from the Wyoming/North Dakota "Black Hills" region of bentonite deposits. A certificate of analysis should be submitted by the vendor for each lot of clay supplied. While the situation is far from established, the certificate may include the various compounds of the clay, per X-Ray diffraction or methylene-blue absorption, particle size per ASTM D-422 or C-136, moisture content per ASTM D-2216 or D-4643, bulk density per ASTM B-417, and free swell.

2. The GCL manufacturer should have a MQC plan which describes the procedures for accomplishing quality in the final product, various tests to be conducted and their frequency. This MQC document should be fully implemented and followed.

3. The MQC test methods that the GCL manufacturer performs on the clay component may include the following; free swell per USP-NF-XVIII or ASTM draft standard, "Determination of Volumetric Free Swell of Powdered Bentonite Clay," plate water absorption per ASTM E-946, moisture content per ASTM D-2216 or D-4643 and (sometimes) particle size per ASTM D-422, fluid loss per API 13B, pH per ASTM D-4972, and liquid/plastic limit per ASTM D-4318.

4. For those products which use adhesives, the composition of the proprietary adhesive is rarely specified. If a statement is required, it should signify that the adhesive selected has been successfully used in the past and to what extent.

5. The geotextiles used as the substrate or the superstrate, or the geomembrane vary according to the particular style of product. Manufacturers current literature should be used in this regard. If a statement is required it should signify that the products selected have been successfully used in the past and to what extent.

6. If further detail is needed as to a specification for the geotextiles, see Chapter 6. Similarly, specifications for geomembranes are found in Chapter 3.

7. The type of sewing thread (or yarn) which is used in joining the products is rarely specified. If a statement is required it should signify that the materials selected have been successfully used in the past and to what extent.

4.2.2 Manufacturing

The raw materials just described are used to make the final GCL product. The production facilities are all relatively large operations where the products are made in a continuous manner. Process quality control is obviously necessary and is practiced by all GCL manufacturers. Figure 4.2 illustrates, in schematic form, the various processing methods used for those GCLs which have adhesives mixed with the clay and those which are stitch bonded and needle punched. Figure 4.2(a) illustrates an adhesively bonded clay product which has an adhesive sprayed in a number of layers with intermittent additions of bentonite. The clay is placed either between geotextiles or on a geomembrane. Figure 4.2(b) illustrates the needle punching or stitch bonding of a bentonite clay powder after it is placed between the covering geotextiles. Windup around a core and placement of the protective covering is common among all GCLs.

There are numerous items which should be included in a specification or MQA document focused on the manufactured GCL product.

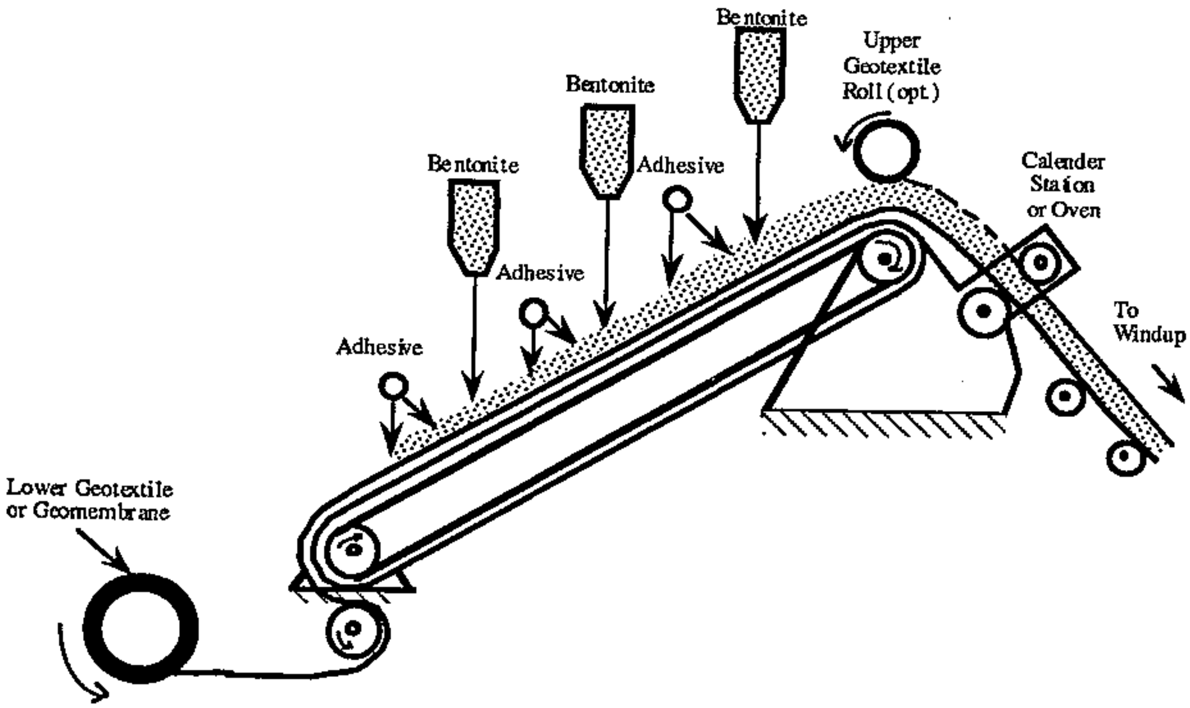
1. There should be verification that the actual geotextiles or geomembrane used meet the manufacturer's specification for that particular type and style.

2. A statement should be included that the geotextile property values are based on the minimum average roll value (MARV) concept. The geomembrane's properties are generally based on average values.

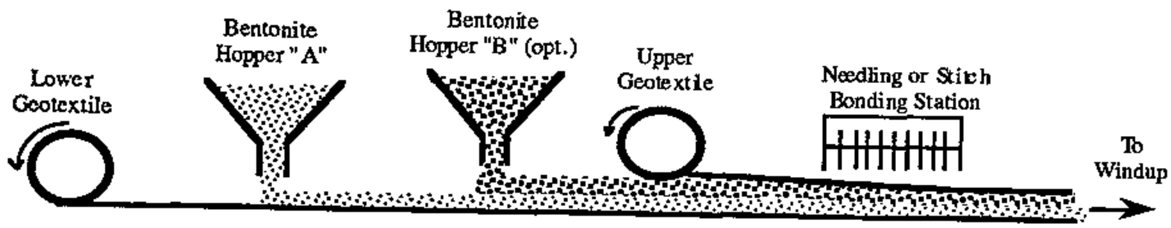
3. Verification that needle punched nonwoven geotextiles have been inspected continuously for the presence of broken needles using an in-line metal detector. There should also be a magnet, or other device, for removal of broken needles.

4. Verification that the proper mass per unit area of bentonite clay has been added to the product should be provided. At a minimum, this should consist of providing a calculated value based on the net weight of the final roll divided by its area (with deduction for the mass per unit area of the geosynthetics and the adhesive, if any).

5. Thickness measurements are product dependent, i.e., some GCLs can be quality controlled via thickness while others cannot.



(a) Adhesive Mixed with Clay



(b) Needle Punched or Stitch Bonded Through Clay

Figure 4.2 - Schematic Diagrams of the Manufacture of Different Types of Geosynthetic Clay Liners (GCLs)

6. It is recommended that the overlap distance on both sides of the GCL be marked with two continuous waterproof lines guiding the minimum overlap distances.

7. The product should be wrapped around a core which is structurally sound such that it can support the weight of the roll without excessive bending or buckling under normal handling conditions as recommended by the manufacturer.

8. The GCL manufacturer should have a MQC plan for the finished product, which includes sampling frequency, and it should be implemented and followed.

9. The manufacturer's quality control tests on the finished product should be stipulated and followed. Typical tests include thickness per ASTM D-1777 or ASTM D-5199, total product mass per unit area per ASTM D-5261, clay content mass per unit area per ASTM D-5261, hydraulic conductivity (permeability) per ASTM D-5084 or GRI GCL2 and sometimes shear strength at various locations such as top, mid-plane and bottom per ASTM D-5321. Other tests as recommended by the manufacturer are also acceptable.

4.2.3 Covering of the Rolls

The final step in the manufacturing of GCLs is their covering with a waterproof, tightly-fit, plastic covering. This covering is sometimes a spirally wound polyethylene film approximately 0.05 to 0.08 mm (2 to 5 mils) thick and is the final step in production. The covering can also be a plastic bag, or sheet, pulled over the product as a secondary operation. Figure 4.3 shows the factory storage of GCLs, with their protective covering, before shipment to the field.

Some items for a specification or MQA document with regard to the covering of GCLs are the following:

1. The manufacturer should clearly stipulate the type of protective covering and the manner of cover placement. The covering should be verified as to its capability for safe storage and proper transportation of the product.

2. The covering should be placed around the GCL in a workmanlike manner so as to effectively protect the product on all of its exposed surfaces and edges.

3. The central core should be accessible for handling by fork lift vehicles fitted with a long pole (i.e., a "stinger") attached. For wide GCLs, e.g., wider than approximately 3.5 m (11.5 ft), handling should be by overhead cranes utilizing two dedicated slings provided on each roll at approximately the one-third points.

4. Clearly visible labels should identify the name and address of the manufacturer, trademark, date of manufacture, location of manufacture, style, roll number, lot number, serial number, dimensions, weight and other important items for proper identification. Refer to ASTM D-4873 for proper labeling in this regard. In some cases, the roll number itself is adequate to trace the entire MQC record and documentation.

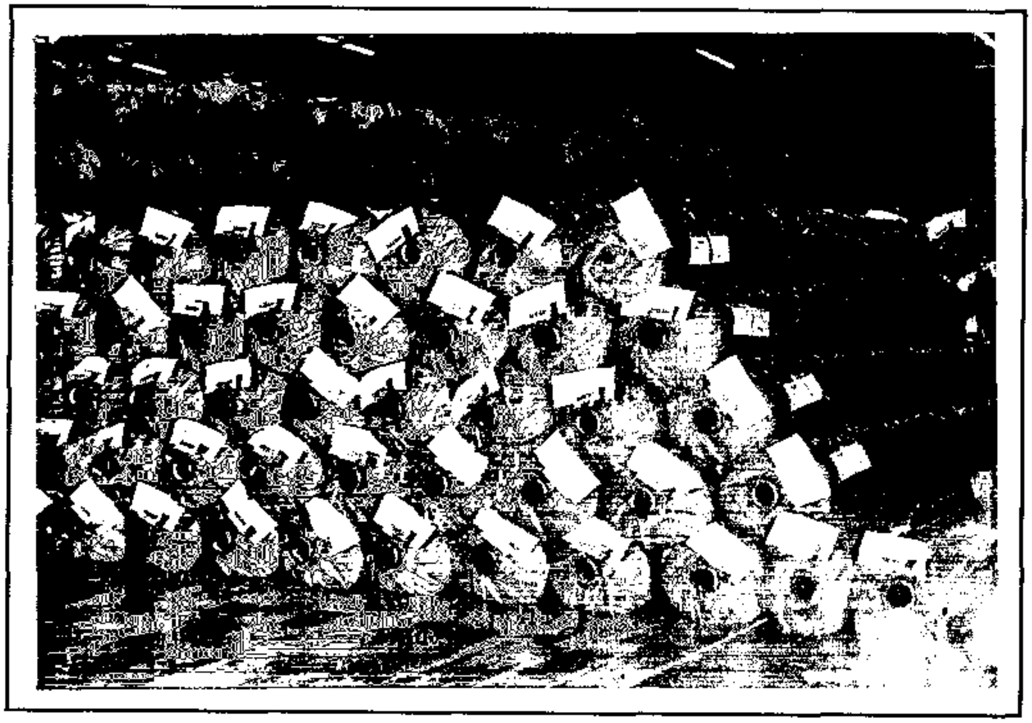


Figure 4.3 - Indoor Factory Storage of Geosynthetic Clay Liners (GCLs) Waiting for Shipment to a Job Site

4.3 Handling

A number of activities occur between the manufacture of a GCL, its final positioning in the field and subsequent backfilling. Topics such as storage at the factory, transportation, storage at the site and acceptance/conformance testing will be described in this section.

4.3.1 Storage at the Manufacturing Facility

Storage of GCLs at the manufacturers facility is common. Storage times typically range from days to six months. Figure 4.3 illustrated typical GCL storage at a fabrication facility.

Some specifications or MQA items to consider for storage and handling of GCLs are the following:

1. GCLs should always be stored indoors until they are ready to be transported to the field site.

2. Handling of the GCLs should be such that the protective wrapping is not damaged. If it is, it must be immediately rewrapped by machine or by hand. In the case of minor tears it may be taped.

3. Placement and stacking of rolls should be done in a manner so as to prevent thinning of the product at the points of contact with the storage frame or with one another. Storage in individually supported racks is common so as to more efficiently use floor space.

4.3.2 Shipment

Rolls of GCLs are shipped from the manufacturers storage facility to the job site via common carrier. Ships, railroads and trucks have all been used depending upon the locations of the origin and final destination. The usual carrier within the USA is truck, which should be with the GCLs contained in an enclosed trailer as shown in Fig. 4.4(a), or on an open flat-bed trailer which is tarpaulin covered as shown in Fig. 4.4(b). Some manufacturers have their own dedicated fleet of trucks. The rolls are sometimes handled by fork lift with a stinger attached. The "stinger" is a long tapered rod which fits inside the core upon which the GCL is wrapped, see Fig. 4.4(a). Alternatively, rolls can be handled using the two captive slings provided on each roll.

Insofar as a specification or MQA document is concerned, a few items should be considered.

1. The GCLs should be shipped by themselves with no other cargo which could damage them in transit, during stops, or while offloading other materials.

2. The method of loading the GCL rolls, transporting them and offloading them at the job site should not cause any damage to the GCL, its core, nor its protective wrapping.

3. Any protective wrapping that is damaged or stripped off of the rolls should be repaired immediately or the roll should be moved to a enclosed facility until its repair can be made to the approval of the quality assurance personnel.

4. If any of the clay has been lost during transportation or from damage of any type, the outer layers of GCL should be discarded until undamaged product is evidenced. The remaining roll must be rewrapped in accordance with the manufacturer's original method to prevent hydration or further damage to the remaining roll.

4.3.3 Storage at the Site

Storage of GCLs at the field site is cautioned due to the potential for moisture pickup (even through the plastic covering) or accidental damage. The concept of "just-in-time-delivery" can be used for GCLs transported from the factory to the field. When storage is required for a short period of time i.e., days or a few weeks, and the product is delivered in trailers, the trailers can be unhitched from their tractors and used as temporary storage. See the photograph of Fig. 4.5(a). Alternatively, storage at the job site can also be acceptable if the GCLs are properly positioned, protected and maintained, see Fig. 4.5(b).

If storage of GCLs is permitted on the job site, offloading of the rolls should be done in an acceptable manner. Some specification or CQA* document items to consider are the following.

1. Handling of rolls of GCLs should be done in a competent manner such that damage does not occur to the product nor to its protective wrapping. In this regard ASTM D-4873, "Identification, Storage and Handling of Geotextiles", should be referenced and followed.

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* Note that the designations of MQC and MQA will now shift to CQC and CQA since field construction personnel are involved.

Figure 4.4(a) - Fork Lift Equipped with a "Stinger"

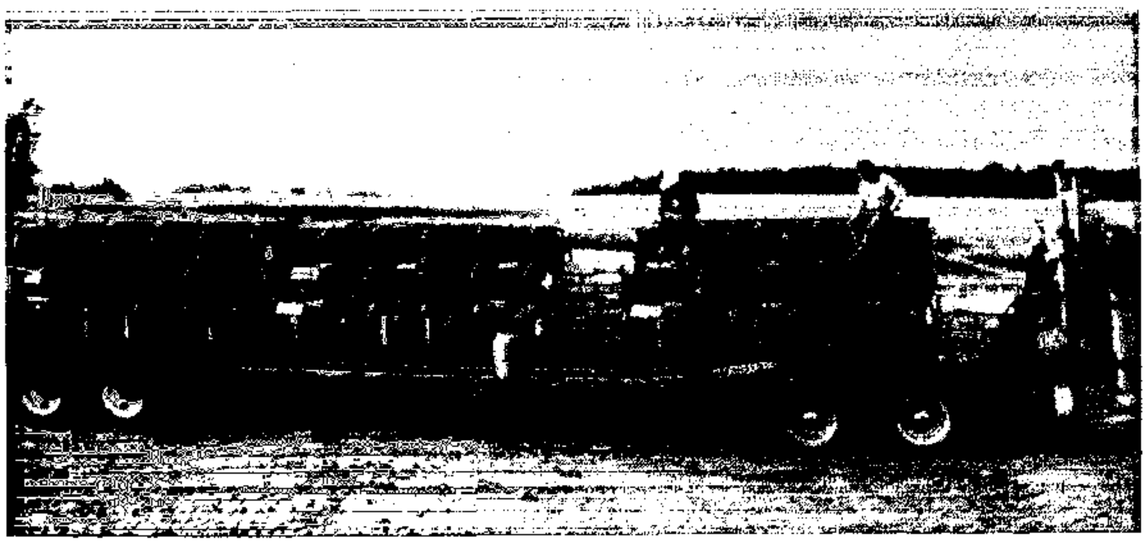


Figure 4.4(b) - GCL Rolls on a Flat-Bed Trailer

Figure 4.5(a) - Photograph of Temporary Storage of GCLs in their Shipping Trailers

Figure 4.5(b) - Photograph of Temporary Storage of GCLs at Project Site

2. The location of temporary field storage should not be in areas where water can accumulate. The rolls should be stored on high flat ground or elevated off of the ground so as not to form a dam creating the ponding of water. It is recommended to construct a platform so that GCL rolls are continuously supported along their length.

3. The rolls should not be stacked so high as to cause thinning of the product at points of contact. Furthermore, they should be stacked in such a way that access for conformance testing is possible.

4. If outdoor storage of rolls is to be longer than a few weeks particular care, e.g., using tarpaulins, should be taken to minimize moisture pickup or accidental damage. For storage periods longer than one season a temporary enclosure should be placed over the rolls, or they should be moved within an enclosed facility.

4.3.4 Acceptance and Conformance Testing

Upon delivery of the GCLs to the field site, the CQA officer should see that conformance test samples are obtained. These samples are then sent to the CQA Laboratory for testing to ensure that the GCL conforms to the project plans and specifications. The samples are taken from selected rolls by removing the protective wrapping and cutting full-width, 1 m (3 ft.) long samples from the outer wrap of the selected roll(s). Sometimes one complete outer revolution of GCL is discarded before the test sample is taken. The rolls are immediately re-wrapped and replaced in the shipping trailers or in the temporary field storage area. Alternatively, conformance testing could be performed at the manufacturer's facility and when completed the particular lot should be identified for the particular project under investigation..

Items to consider for a specification or CQA document in this regard are the following:

1. The samples should be identified by type, style, lot and roll numbers. The machine direction should be noted on the sample(s) with a waterproof marker.

2. A lot is usually defined as a group of consecutively numbered rolls from the same manufacturing line. Other definitions are also possible and should be clearly stated in the CQA documents.

3. Sampling should be done according to the project specification and/or CQA documents. Unless otherwise stated, sampling should be based on a lot basis. Different interpretations of sampling frequency within a lot are based on total area or on number of rolls. For example, sampling could be based on 10,000 m^2 (100,000 ft^2) of area or on use of ASTM D-4354 which is based on rolls.

4. Testing at the CQA laboratory may include mass per unit area per ASTM D-5261, and free swell of the clay component per GRI-GCL1. The sampling frequency for these index tests should be based on ASTM D-4354. Other conformance tests, which are more performance oriented, could be required by the project specifications but at a reduced frequency compared to the above mentioned index tests. Examples are hydraulic conductivity (permeability) ASTM D-5084 (mod.) or GRI GCL2 and direct shear testing per ASTM D-5321. The sampling frequency for these performance tests might be based on area, e.g., one test per 10,000 m^2 (100,000 ft^2).

5. If testing of the geotextiles, or geomembrane, covering the GCLs is desired it should be done on the original rolls of the geotextiles, or geomembrane, before they are fabricated into the GCL product. Once fabricated their properties will change considerably due to the needling, stitching and/or gluing during manufacturing.

6. Peel testing of needle punched or stitch bonded GCLs should be done in accordance with ASTM D-413 (mod.). The sampling frequency is recommended to be one test per 2000 m^2 (20,000 ft^2).

7. Conformance test results should be sent to the CQA engineer prior to installation of any GCL from the lot under review.

8. The CQA engineer should review the results and should report any nonconformance to the Owner/Operator's Project Manager.

9. The resolution of failing conformance tests must be clearly stipulated in the specifications or CQA documents. Statements should be based upon ASTM D-4759 entitled "Determining the Specification Conformance of Geosynthetics."

4.4 Installation

This section will cover the placement, joining, repairing and covering of GCLs.

4.4.1 Placement

The installation contractor should remove the protective wrapping from the rolls to be deployed only after the substrate layer (soil or other geosynthetic) in the field has been approved by CQA personnel. The specification and CQA documents should be written in such a manner as to ensure that the GCLs are not damaged in any way. A CQA inspector should be present at all times during the handling, placement and covering of GCLs. Figure 4.6(a) shows the typical placement of a GCL in the field on soil subgrade and Fig. 4.6(b) shows placement (without heavy equipment) on an underlying geosynthetic.

The following items should be considered for inclusion in a specification or CQA document.

1. The installer should take the necessary precautions to protect materials underlying the GCL. If the substrate is soil, construction equipment can be used to deploy the GCL providing excessive rutting is not created. Excessive rutting should be clearly defined and quantified. In some cases 25 mm (1.0 in.) is the maximum rut depth allowed. If the ground freezes, the depth of ruts should be further reduced to a specified value. If the substrate is a geosynthetic material, GCL deployment should be by hand, or by use of small jack lifts or light weight equipment on pneumatic tires having low ground contact pressure.

2. The minimum overlap distance which is specified should be verified. This is typically 150 to 300 mm (6 to 12 in.) depending upon the particular product and site conditions.

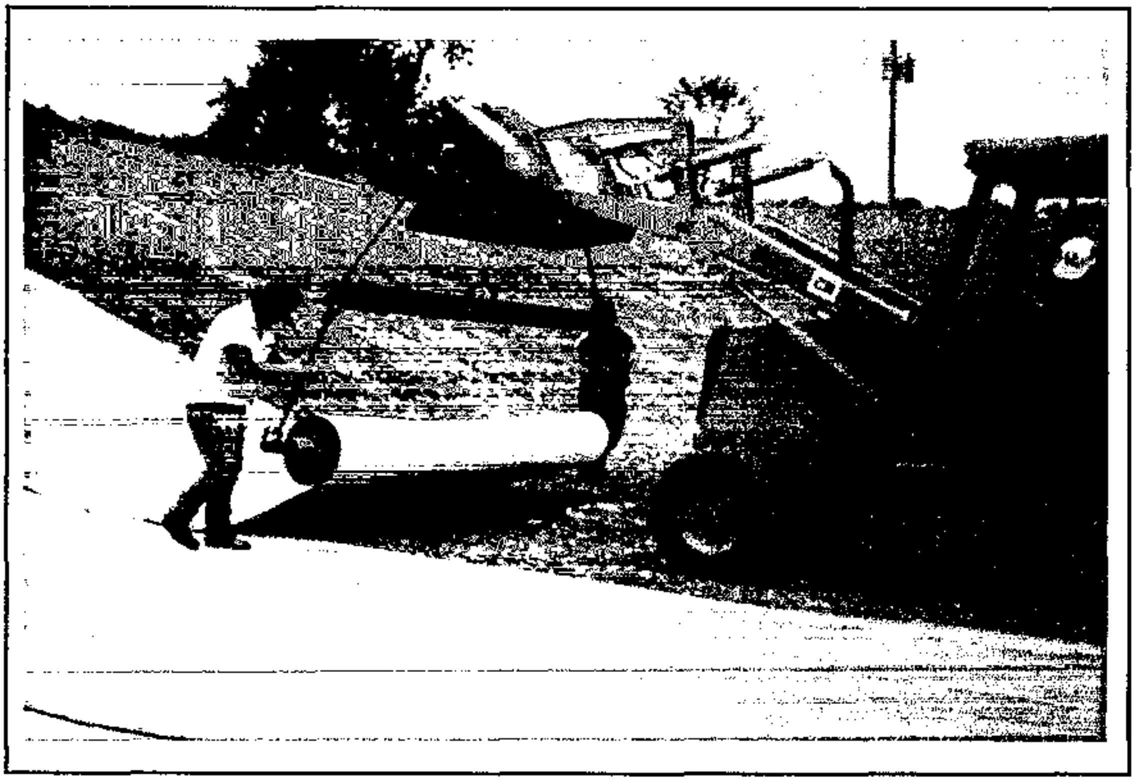


Figure 4.6(a) - Field Deployment of a GCL on a Soil Subgrade

Figure 4.6(b) - Field Deployment of a GCL on an Underlying Geosynthetic

3. Additional bentonite clay should be introduced into the overlap region with certain types of GCLs. There are typically those with needle punched nonwoven geotextiles on their surfaces. The clay is usually added by using a line spreader or line chalker with the bentonite clay in a dry state. Alternatively, a bentonite clay paste, in the mixture range of 4 to 6 parts water to 1 part of clay, can be extruded in the overlap region. Manufacturer's recommendations on type and quantity of clay to be added should be followed.

4. During placement, care must be taken not to entrap in or beneath the GCL, fugitive clay, stones, or sand that could damage a geomembrane, cause clogging of drains or filters, or hamper subsequent seaming of materials either beneath or above the GCL.

5. On side slopes, the GCL should be anchored at the top and then unrolled so as to keep the material free of wrinkles and folds.

6. Trimming of the GCL should be done with great care so that fugitive clay particles do not come in contact with drainage materials such as geonets, geocomposites or natural drainage materials.

7. The deployed GCL should be visually inspected to ensure that no potentially harmful objects are present, e.g., stones, cutting blades, small tools, sandbags, etc.

4.4.2 <u>Joining</u>

Joining of GCLs is generally accomplished by overlapping without sewing or other mechanical connections. The overlap distance requirements should be clearly stated. For all GCLs the required overlap distance should be marked on the underlying layer by a pair of continuous guidelines. The overlap distance is typically 150 to 300 mm (6 to 12 in.). For those GCLs, with needle punched nonwoven geotextiles on their surfaces, dry bentonite is generally placed in the overlapped region. If this is the case, utmost care should be given to avoid fugitive bentonite particles from coming into contact with leachate collection systems. Another variation, however, has been to extrude a moistened tube of bentonite into the overlapped region.

Items to consider for a specification or CQA document follow:

1. The amount of overlap for adjacent GCLs should be stated and adhered to in field placement of the materials.

2. The overlap distance is sometimes different for the roll ends versus the roll edges. The values should be stated and followed.

3. If dry or moistened bentonite clay (or other material) is to be placed in the overlapped region, the type and amount should be stated in accordance with the manufacturer's recommendations and/or design considerations. Index testing requirements for proper verification of the clay should be specified accordingly. Furthermore, the placement procedure should be clearly outlined so as to have enough material to make an adequately tight joint and yet not an excessive amount which could result in fugitive clay particles.

4.4.3 <u>Repairs</u>

For the geotextile-related GCLs, holes, tears or rips in the covering geotextiles made during transportation, handling, placement or anytime before backfilling should be repaired by patching using a geotextile. If the bentonite component of the GCL is disturbed either by loss of material or by shifting, it should be covered using a full GCL patch of the same type of product.

Some relevant specification or CQA document items follow.

1. Any patch, used for repair of a tear or rip in the geotextile, should be done using the same type as the damaged geotextile or other approved geotextile by the CQA engineer.

2. The size of the geotextile patch must extend at least 30 cm (12 in.) beyond any portion of the damaged geotextile and be adhesive or heat bonded to the product to avoid shifting during backfilling with soil or covering with another geosynthetic.

3. If bentonite particles are lost from within the GCL or if the clay has shifted, the patch should consist of the full GCL product. It should extend at least 30 cm (12 in.) beyond the extent of the damage at all locations. For those GCLs requiring additional bentonite clay in overlap seaming, the similar procedure should be use for patching.

4. Particular care should be exercised in using a GCL patch since fugitive clay can be lost which can find its way into drainage materials or onto geomembranes in areas which eventually are to be seamed together.

4.5 Backfilling or Covering

The layer of material placed above the deployed GCL will be either soil or another geosynthetic. Soils will vary from compacted clay layers to coarse aggregate drainage layers. Geosynthetics will generally be geomembranes although other geosynthetics may also be used depending on the site specific design. The GCL should generally be covered before a rainfall or snow event occurs. The reason for covering with the adhesive bonded GCLs is that hydration before covering can cause changes in thickness as a result of uneven swelling or whenever compressive or shear loads are encountered. Hydration before covering may be less of a concern for the needled and stitch bonded types of GCLs, but migration of the fully hydrated clay in these products might also be possible under sustained compressive or shear loading. Figure 4.7 shows the premature hydration of a GCL being gathered up by hand to be discarded in the adjacent landfill.

Some recommended specifications or CQA document items are as follows:

1. The GCL should be covered with its subsequent layer before a rainfall or snowfall occurs.

2. The GCL should not be covered before observation and approval by the CQA personnel. This requires close coordination between the installation crew and the CQA personnel.

3. If soil is to cover the GCL it should be done such that the GCL or underlying materials are not damaged. Unless otherwise specified, the direction of backfilling should proceed in the direction of downgradient shingling of the GCL overlaps. Continuous observation of the soil placement is recommended.

4. If a geosynthetic is to cover a GCL, both underlying and the newly deployed material should not be damaged.

5. The overlying material should not be deployed such that excess tensile stress is mobilized in the GCL. On side slopes, this requires soil backfill to proceed from the bottom of the slope upward. Other conditions are site specific and material specific.

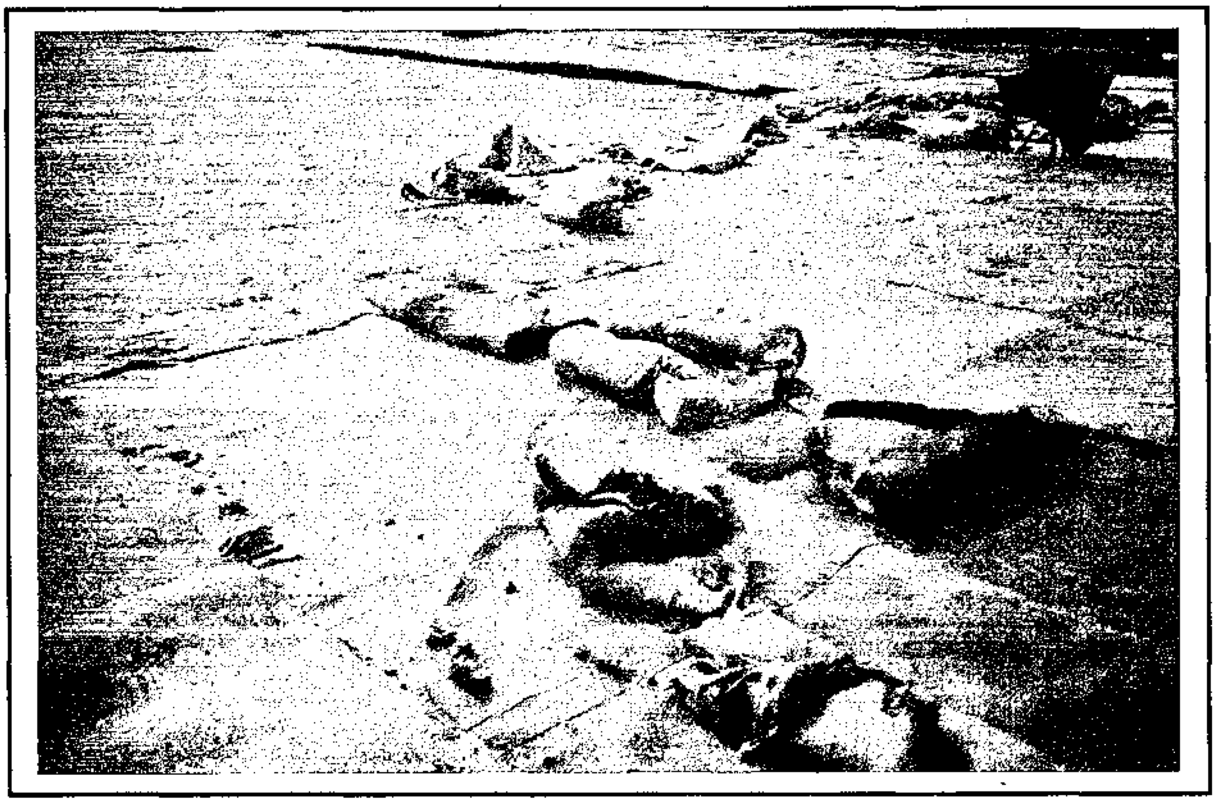


Figure 4.7 - Premature Hydration of a Geosynthetic Clay Liner Being Gathered and Discarded due to its Exposure to Rainfall Before Covering

4.6 References

API 13B, "Fluid Loss of Bentonite Clays"

ASTM B-417, "Apparent Density of Non Free-Flowing Metal Powders"

ASTM C-136, "Sieve Analysis of Fine and Coarse Aggregates"

ASTM D-413, "Rubber Property - Adhesion to Flexible Substrate"

ASTM D-422, "Particle Size Analysis of Soils"

ASTM D-1777, "Measuring Thickness of Textile Materials"

ASTM D-2216, "Laboratory Determination of Water (Moisture) Content of Soil and Rock"

ASTM D-4318, "Liquid Limit, Plastic Limit, and Plasticity Index of Soils"

ASTM D-4354, "Sampling of Geosynthetics for Testing"

ASTM D-4643, "Determination of Water (Moisture Content) of Soil by Microwave Oven Method"

ASTM D-4759, "Determining the Specification Conformance of Geosynthetics"

ASTM D-4873, "Identification, Storage and Handling of Geotextiles"

ASTM D-4972, "Method for pH of Soils"

ASTM D-5084, "Hydraulic Conductivity of Saturated Porous Material Using A Flexible Wall Permeameter"

ASTM D-5199, "Nominal Thickness of Geotextiles and Geomembranes"

ASTM D-5261, "Measuring Mass per Unit Area of Geotextiles"

ASTM D-5321, "Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method"

ASTM E-946, "Water Absorption of Bentonite of Porous Plate Method"

GRI GCL1, "Free Swell Conformance Test of Clay Component of a GCL"

GRI GCL2, "Permeability of Geosynthetic Clay Liners (GCLs)"

USP-NF-XVII, "Swell Index Test"

Chapter 5

Soil Drainage Systems

5.1 Introduction and Background

Natural soil drainage materials are used extensively in waste containment units. The most common uses are:

1. Drainage layer in final cover system to reduce the hydraulic head on the underlying barrier layer and to enhance slope stability by reducing seepage forces in the cover system.

2. Gas collection layer in final cover systems to channel gas to vents for controlled removal of potentially dangerous gases.

3. Leachate collection layer in liner systems to remove leachate for treatment and to remove precipitation from the disposal unit in areas where waste has not yet been placed.

4. Leak detection layer in double liner systems to monitor performance of the primary liner and, if necessary, to serve as a secondary leachate collection layer.

5. Drainage trenches to collect horizontally-flowing fluids, e.g., ground water and gas.

Drainage layers are also used in miscellaneous ways, such as to drain liquids from backfill behind retaining walls or to relieve excess water pressure in critical areas such as the toe of slopes.

5.2 Materials

Soil drainage systems are constructed of materials that have high hydraulic conductivity. High hydraulic conductivity is not only required initially, but the drainage material must also maintain a high hydraulic conductivity over time and resist plugging or clogging. The hydraulic conductivity of drainage materials depends primarily on the grain size of the finest particles present in the soil. An equation that is occasionally used to estimate hydraulic conductivity of granular materials is Hazen's formula:

$$k = (D_{10})^2 \qquad (5.1)$$

where k is the hydraulic conductivity (cm/s) and D_{10} is the equivalent grain diameter (mm) at which 10% of the soil is finer by weight. To determine the value of D_{10}, a plot is made of the grain-size distribution of the soil (measured following ASTM D-422) as shown in Fig. 5.1. The equivalent grain diameter (D_{10}) is determined from the grain size distribution curve as shown in Fig. 5.1.

Experimental data verify that the percentage of fine material in the soil dominates hydraulic conductivity. For example, the data in Table 5.1 illustrate the influence of a small amount of fines upon the hydraulic conductivity of a filter sand. The addition of just a few percent of fine material to a drainage material can reduce the hydraulic conductivity of the drainage material by 100 fold or more.

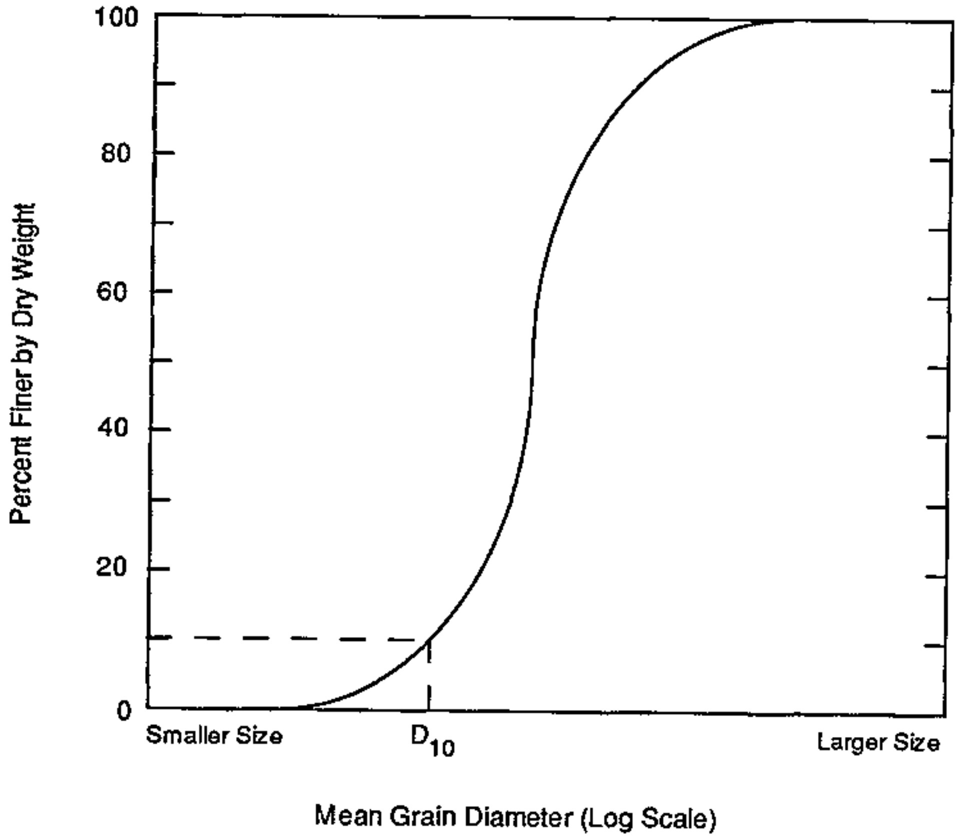


Figure 5.1 - Grain Size Distribution Curve

Construction specifications usually stipulate a minimum hydraulic conductivity for the drainage layer. The value specified varies considerably from project to project but is typically in the range of 0.01 to 1 cm/s. The method used to determine hydraulic conductivity in the laboratory is ASTM D-2434.

Table 5.1 Effect of Fines on Hydraulic Conductivity of a Washed Filter Aggregate (from Cedergren, 1989)

Percent Passing No. 100* Sieve	Hydraulic Conductivity (cm/s)
0	0.03 to 0.11
2	0.004 to 0.04
4	0.0007 to 0.02
6	0.0002 to 0.007
7	0.00007 to 0.001

*Opening size is 0.15 mm.

Drainage materials may also be required to serve as filters. For instance, as shown in Fig. 5.2, a filter layer may be needed to protect a drainage layer from plugging. The filter layer must serve three functions:

1. The filter must prevent passage of significant amounts of soil through the filter, i.e., the filter must retain soil.
2. The filter must have a relatively high hydraulic conductivity, e.g., the filter should be more permeable than the adjacent soil layer.
3. The soil particles within the filter must not migrate significantly into the adjacent drainage layer.

Filter specifications vary somewhat, but the design procedures are similar. The determination of requirements for a filter material proceeds as follows:

1. The grain size distribution curve of the soil to be retained (protected) is determined following procedures outlined in ASTM D-422. The size of the protected soil at which 15% is finer ($D_{15, soil}$) and 85% is finer ($D_{85, soil}$) is determined.
2. Experience shows that the particles of the protected soil will not significantly penetrate into the filter if the size of the filter at which 15% is finer ($D_{15, filter}$) is less than 4 to 5 times D_{85} of the protected soil:

$$D_{15, filter} \leq (4 \text{ to } 5)\, D_{85, soil} \tag{5.2}$$

3. Experience shows that the hydraulic conductivity of the filter will be significantly greater than that of the protected soil if the following criterion is satisfied:

$$D_{15,\ \text{filter}} \geq 4\ D_{15,\ \text{soil}} \qquad (5.3)$$

4. To ensure that the particles within the filter do not tend to migrate excessively into the drainage layer, the following criterion may be applied:

$$D_{15,\ \text{drain}} \leq\ (4 \text{ to } 5)\ D_{15,\ \text{filter}} \qquad (5.4)$$

5. Experience shows that the hydraulic conductivity of the drain will be significantly greater than that of the filter if the following criterion is satisfied:

$$D_{15,\ \text{drain}} \geq 4\ D_{15,\ \text{filter}} \qquad (5.5)$$

Filter design is complicated significantly by the presence of biodegradable waste materials, e.g., municipal solid waste, directly on top of the filter. In such circumstances, the usual filter criteria may be modified to satisfy site-specific requirements. Some degree of reduction in hydraulic conductivity of the filter layer may be acceptable, so long as the reduction does not impair the ability of the drainage system to serve its intended function. A laboratory test method to quantify the hydraulic properties of both soil and geotextile filters that are exposed to leachate is ASTM D-1987. However, regardless of specific design criteria, the gradational characteristics of the filter material control the behavior of the filter. CQC/CQA personnel should focus their attention on ensuring that the drainage material and filter material meet the grain-size-distribution requirements set forth in the construction specifications, as well as other specified requirements such as mineralogy of the materials.

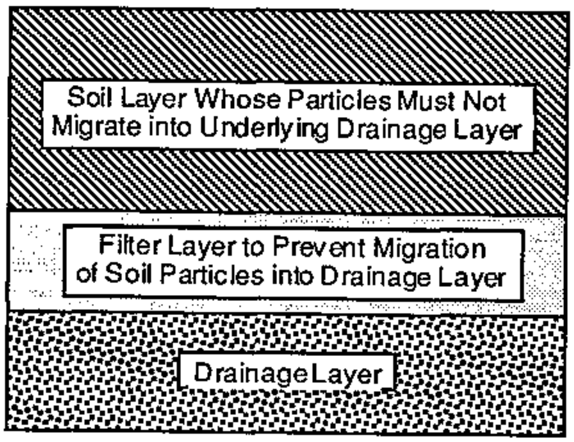


Figure 5.2 - Filter Layer Used to Protect Drainage Layer from Plugging

5.3 Control of Materials

The recommended procedure for verifying the hydraulic conductivity for a proposed drainage material is as follows. Samples of the proposed material should be obtained and shipped to a laboratory for testing. Samples should be compacted in the laboratory to a density that will be representative of the density to be used in the field. Hydraulic conductivity should be measured following procedures in ASTM D-2434 and compared with the required minimum values stated in the construction specifications. If the hydraulic conductivity exceeds the minimum value, the material is tentatively considered to be acceptable. However, it should be realized that the process of excavating and placing the drainage material will cause some degree of crushing of the drainage material and will produce additional fines. Thus, the construction process itself tends to increase the amount of fines in the drainage material and to decrease the hydraulic conductivity of the material. If the drainage material just barely meets the hydraulic conductivity requirements stated in the construction specifications from initial tests, there is a good possibility that the material will fail to meet the required hydraulic conductivity standard after the material has been placed. As a rule of thumb, approximately one-half to one percent of additional fines by weight will be generated every time a drainage material is handled, e.g., one-half to one percent additional fines would be generated when the drainage layer material is excavated and an additional one-half to one percent of fines would be generated when the material is placed. Also, the reproducibility of hydraulic conductivity tests is not well established; a material may just barely meet the hydraulic conductivity standard in one test but fail to meet minimum requirements in another test. Finally, if the drainage materials are found to be suitable prior to placement but unsuitable after placement, an extremely difficult situation arises -- it is virtually impossible to remove and replace the drainage material without risking damage to underlying geosynthetic components, e.g., a geomembrane. Therefore, some margin of safety should be factored into the selection of drainage material.

Because it is extremely difficult to remove and replace a drainage material without damaging an underlying geosynthetic component, testing of the drainage material should occur prior to placement of the material. The CQC personnel should have a high degree of confidence that the drainage material is suitable prior to placement of the material. Because the construction process may alter the characteristics of the drainage material, it is important that CQA tests also be performed on the material after it has been placed and compacted (if it is compacted).

The usual tests involve determination of the grain size distribution of the soil (ASTM D-422) and hydraulic conductivity of the soil (ASTM D-2434). Hydraulic conductivity tests tend to be time consuming and relatively difficult to reproduce precisely; the test apparatus that is employed, the compaction conditions for the drainage material, and other details of testing may significantly influence test results. Grain-size distribution analyses are simpler. Therefore, it is recommended that the CQA testing program emphasize grain-size distribution analyses, with particular attention paid to the amount of fines present in the drainage material, rather than hydraulic conductivity testing. The percent of fines is normally defined as the percent on a dry weight basis passing through a No. 200 sieve (openings of 0.075 mm). Again, it is emphasized that close testing and inspection of the borrow source or the supplier prior to placement of the material is critical, particularly if the drainage material is underlain by a geosynthetic material.

The recommended tests and frequency of testing are shown in Table 5.2. The same principles for sampling strategies discussed in Chapter 2 may be applied to location of tests or location of samples for drainage layer materials. Also, occasional failing tests may be allowed, but it is recommended that no more than 5% of the CQA tests be allowed to deviate from specifications, and the deviations should be relatively minor, i.e., no more than about 2% fines beyond the maximum value allowed and no less than about one-fifth the minimum allowable hydraulic conductivity.

Table 5.2 - Recommended Tests and Testing Frequencies for Drainage Material

Location of Sample	Type of Test	Minimum Frequency
Potential Borrow Source	Grain Size (ASTM D-422)	1 per 2,000 m^3
	Hydraulic Conductivity (ASTM D-2434)	1 per 2,000 m^3
	Carbonate Content* (ASTM D-4373)	1 per 2,000 m^3
On Site; After Placement and Compaction	Grain Size (ASTM D-422)	1 per Hectare for Drainage Layers; 1 per 500 m^3 for Other Uses
	Hydraulic Conductivity (ASTM D-2434)	1 per 3 Hectares for Drainage Layers; 1 per 1,500 m^3 for Other Uses
	Carbonate Content* (ASTM D-4373)	1 per 2,000 m^3

*The frequency of carbonate content testing should be greatly reduced to 1 per 20,000 m^3 for those drainage materials that obviously do not and cannot contain significant carbonates (e.g., crushed basalt).

5.4 Location of Borrow Sources

The construction specifications usually establish criteria that must be met by the drainage material. Earthwork contractors are normally given latitude in locating a suitable source of material that meets construction specifications. On occasion the materials may be available on site or from a nearby piece of property, but most frequently the materials are supplied by a commercial materials company. If the materials are supplied by an existing materials processor, stockpiles of materials are usually readily available for testing and no geotechnical investigations are required, other than to test the proposed borrowed material.

5.5 Processing of Materials

Materials may be processed in several ways. Oversized stones or rocks are typically removed by sieving. Fine material may also be removed by sieving. Washing the fines out of a sand or gravel can be particularly effective in removing silt and clay sized particles from granular material. For drainage layer materials that are supplied from a commercial processing facility, the facility owner is usually experienced in processing the material to remove fines.

For the CQA inspector the main processing issues are removal of oversized material, removal of angular material (if required to minimize potential to puncture a geomembrane), and assurance that excessive fines will not be present in the material.

On occasion the amount of limestone, dolostone, dolomite, calcite, or other carbonates in the drainage material may be an issue. Carbonate materials are slightly soluble in water. If the drainage material contains excessive carbonate, the carbonate may dissolve at one location and precipitate at another, plugging the material. CQA inspectors should also be cognizant of the need to make sure that carbonate components are not present in excessive amounts. If the specifications place a limit on carbonate content, tests should be performed to confirm compliance (Table 5.2).

5.6 Placement

Drainage materials may be placed in layers (e.g., as leachate collection layers) or they may be placed in drainage trenches (e.g., to provide drainage near the toe of a slope). Placement considerations differ depending on the application.

5.6.1 Drainage Layers

Granular drainage materials are usually hauled to the placement area in dump trucks, loosely dumped from the truck, and spread with bulldozers. The contractor should dump and spread the drainage material in a manner that minimizes generation of fine material. For instance, light-contact-pressure dozers can be used to spread the drainage material and minimize the stress on the granular material. Granular materials placed on top of geosynthetic components on side slopes should be placed from the bottom of the slope up.

When granular drainage material is placed on a previously-placed geomembrane or geotextile and spread with a dozer, the sand or gravel should be lifted and tumbled forward so as to minimize shear forces on the underlying geosynthetic. The dozer should not be allowed to "crowd" the blade into the granular material and drag it over the surface of the underlying geosynthetic material.

Granular materials are often placed with a backhoe in small, isolated areas such as sumps. Some drainage materials may even be placed by hand, e.g., in sumps and around drainage pipes.

CQA personnel should position themselves in front of the working face of the placement operation to be able to observe the materials as they are spread and to ensure that there is no puncture of underlying materials. CQA personnel should observe placement of drainage layers to ensure that fine-grained soil is not accidentally mixed with drainage material.

5.6.2 Drainage Trenches

Drainage materials are often placed in trenches to provide for subsurface drainage of water. A typical trench configuration is shown in Fig. 5.3. Often, a perforated pipe will be placed in the bottom of the trench. Geotextile filters are often required along the side walls to prevent migration of fine particles into the drainage material. CQA personnel should carefully review the plans and specifications to ensure that the drainage and filter components have been properly located in the trench prior to backfill.

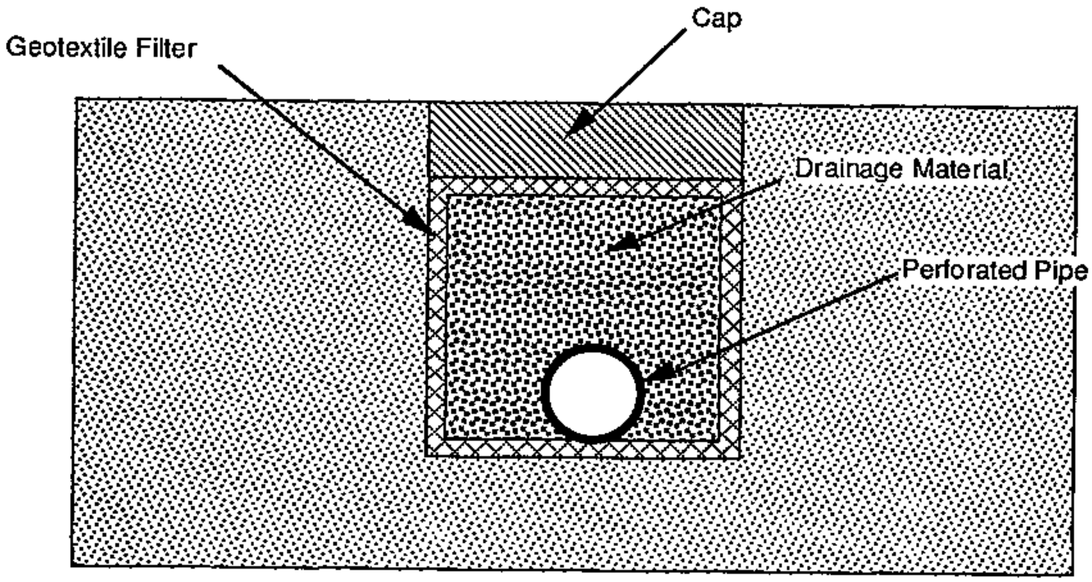


Figure 5.3 - Typical Design of a Drainage Trench

CQC/CQA personnel should be aware of all applicable safety requirements for inspection of trenches. Unsupported trenches can pose a hazard to personnel working in the trench or inspecting the trench. For trenches that are supported by shoring, CQA personnel should review with the contractor the plan for pulling the shoring in terms of the timing for placement of materials and ensure that the procedures are in accord with the specifications for the project.

Granular backfill is usually placed in a trench by a backhoe. For narrow trenches, a "tremie" is commonly used to direct the material into the trench without allowing the material to come into contact with soil on the sidewalls of the trench. Sometimes drainage materials are placed by hand for very small trenches.

A special type of trench involves support of the trench wall with a biodegradable ("biopolymer") slurry. The trench is excavated into soil using a biodegradable, viscous fluid to maintain the stability of the trench. The backfill is placed into the fluid-filled trench. An agent is introduced to promote degradation of the viscous drilling fluid, which quickly loses much of its viscosity and allows the granular backfill to attain a high hydraulic conductivity without any plugging effect from the slurry. This technology allows construction of deep, continuous drainage trenches but is used much more often for remediation of contaminated sites than in new waste containment facilities. Further details are given by Day (1990).

5.7 Compaction

Many construction specifications stipulate a minimum percentage compaction for granular drainage layers. There is rarely a need to compact drainage materials. However, on occasion, there may be a need to compact a drainage material for one of the following reasons:

1. If a settlement-sensitive structure is to be placed on top of the drainage layer, the drainage layer may need to be compacted to minimize settlement.

2. If dynamic loads might cause loose drainage material to liquefy or settle excessively, the material may need to be compacted.

3. If the drainage material must have exceptionally high strength, the material may need to be compacted.

Only in rare instances will the problems listed above be significant. Settlement-sensitive structures are rarely built on top of liner or cover systems. Liquefaction is rarely an issue because the hydraulic conductivity of the drainage material is normally sufficiently large to preclude the possibility of liquefaction. Strength is rarely a problem with granular materials. Reasons not to compact the drainage layer are as follows:

1. Compacting the drainage material increases the amount of fines in the drainage material, which decreases hydraulic conductivity.

2. Compacting the drainage layer reduces the porosity of the material, which decreases hydraulic conductivity.

3. Dynamic compaction stresses may damage underlying geosynthetics.

Unless there is a sound reason why the drainage material should be compacted, it is recommended that the drainage material not be compacted. The main goal of the drainage layer is to remove liquids, and this can only be accomplished if the drainage layer has high hydraulic conductivity. The uncompacted drainage layer may be slightly compressible, but the amount of compression is expected to be small.

There is a potential problem with drainage layer materials placed on side slopes. In some situations the friction between the drainage layer and underlying geosynthetic component may not be adequate to maintain stability of the side slope. CQA personnel should assume that the designer has analyzed slope stability and designed stable slide slopes for assumed materials and conditions. However, CQA personnel should be vigilant for evidence of slippage at the interface between the drainage layer and an underlying geosynthetic component. If problems are noted, the design engineer should be notified immediately.

5.8 <u>Protection</u>

The main protection required for the drainage layer is to ensure that large pieces of waste material do not penetrate excessively into the layer and that fines do not contaminate the layer. Many designs call for placement of protective soil or select waste on top of the leachate collection layer. As shown in Fig. 5.4, CQA personnel should stand near the working face of the first lift of solid waste placed on top of a leachate collection layer in a solid waste landfill to observe placement of select material.

Wind-borne fines may contaminate drainage materials. Soil erosion from adjacent slopes may also lead to accumulation of fines in the drainage material. The CQA personnel cannot complete their job until the drainage material is fully covered and protected.

Residual fines may be washed by rain from other soils, or the drainage material itself, during rain storms and accumulate in low areas. The accumulation of fines in sumps or other low points can reduce the effectiveness of the drainage system. CQC/CQA personnel should be aware of this potential problem and watch for (1) areas where fines may be washed into the drainage material; and (2) evidence of lack of free drainage in low-lying areas (e.g., development of ponds of water in the drainage material in low-lying areas). If excessive fines are washed into a portion of the drainage material, the design engineer should be contacted for further evaluation prior to covering the drainage material by the next successive layer in the system.

Figure 5.4 -- CQC and CQA Personnel Observing Placement of Select Waste on Drainage Layer.

5.9 References

ASTM D-422, "Particle Size Analysis of Soils"

ASTM D-1987, "Biological Clogging of Geotextile or Soil/Geotextile Filters"

ASTM D-2434, "Permeability of Granular Soils"

ASTM D-4373, "Calcium Carbonate Content of Soils"

Cedergren, H.R. (1989), *Seepage, Drainage, and Flow Nets*, Third Edition, John Wiley & Sons, New York, 465 p.

Day, S. R. (1990), "Excavation/Interception Trenches by the Bio-Polymer Slurry Drainage Trench Technique," *Superfund '90*, Hazardous Materials Control Research Institute, Silver Spring, Maryland, pp. 382-385.

Chapter 6

Geosynthetic Drainage Systems

6.1 Overview

The collection of liquids in waste containment systems, their drainage and eventual removal represents an important element in the successful functioning of these facilities. Focus in this chapter is on the primary and secondary leachate collection systems beneath solid waste and on surface water and gas removal systems in the cover above the waste. This chapter parallels Chapter 5 on natural soil drainage materials but now using geosynthetics. Combined systems such as geocomposites and geospacers are often used; however we will generally focus on the individual geosynthetic components. The individual materials to be described are the following:

- geotextiles used as filters over various drainage systems (geonets, geocomposites, sands and gravels)
- geotextiles used for gas collection
- geonets used as primary and/or secondary leachate collection systems, and gas collection
- other geosynthetic drainage systems used as surface water collection systems and possibly as primary and/or secondary leachate collection systems

The locations of the various geosynthetic materials listed above are illustrated in the sketch of Fig. 6.1.

6.2 Geotextiles

Geotextiles, which some refer to as filter fabrics or construction fabrics, consist of polymeric yarns (fibers) made into woven or nonwoven textile sheets and supplied to the job site in large rolls. When ready for placement, the rolls are removed from their protective covering, properly positioned and unrolled over the substrate material. The substrate upon which the geotextile is placed is usually a geonet, geocomposite, drainage soil or other soil material. The roll edges and ends are either overlapped for a specified distance, or are sewn together. After approval by the CQA personnel, the geotextile is covered with the overlying material. Depending on site specific conditions, this overlying material can be a geomembrane, geosynthetic clay liner, compacted clay liner, geonet, or drainage soil.

This section presents the MQA aspects of geotextiles insofar as their manufacturing is concerned and the CQA aspects as far as handling, seaming and backfilling is concerned.

6.2.1 Manufacturing of Geotextiles

The manufacturing of geotextiles made from polymeric fibers follows traditional textile manufacturing methods and uses similar equipment. It should be recognized at the outset that most manufacturing facilities have developed their respective geotextile products to the point where product quality control procedures and programs are routine and fully developed.

Three discrete stages in the manufacture of geotextiles should be recognized from an MQA perspective: (1) the polymeric materials; (2) yarn or fiber type; and (3) fabric type (IFAI, 1990).

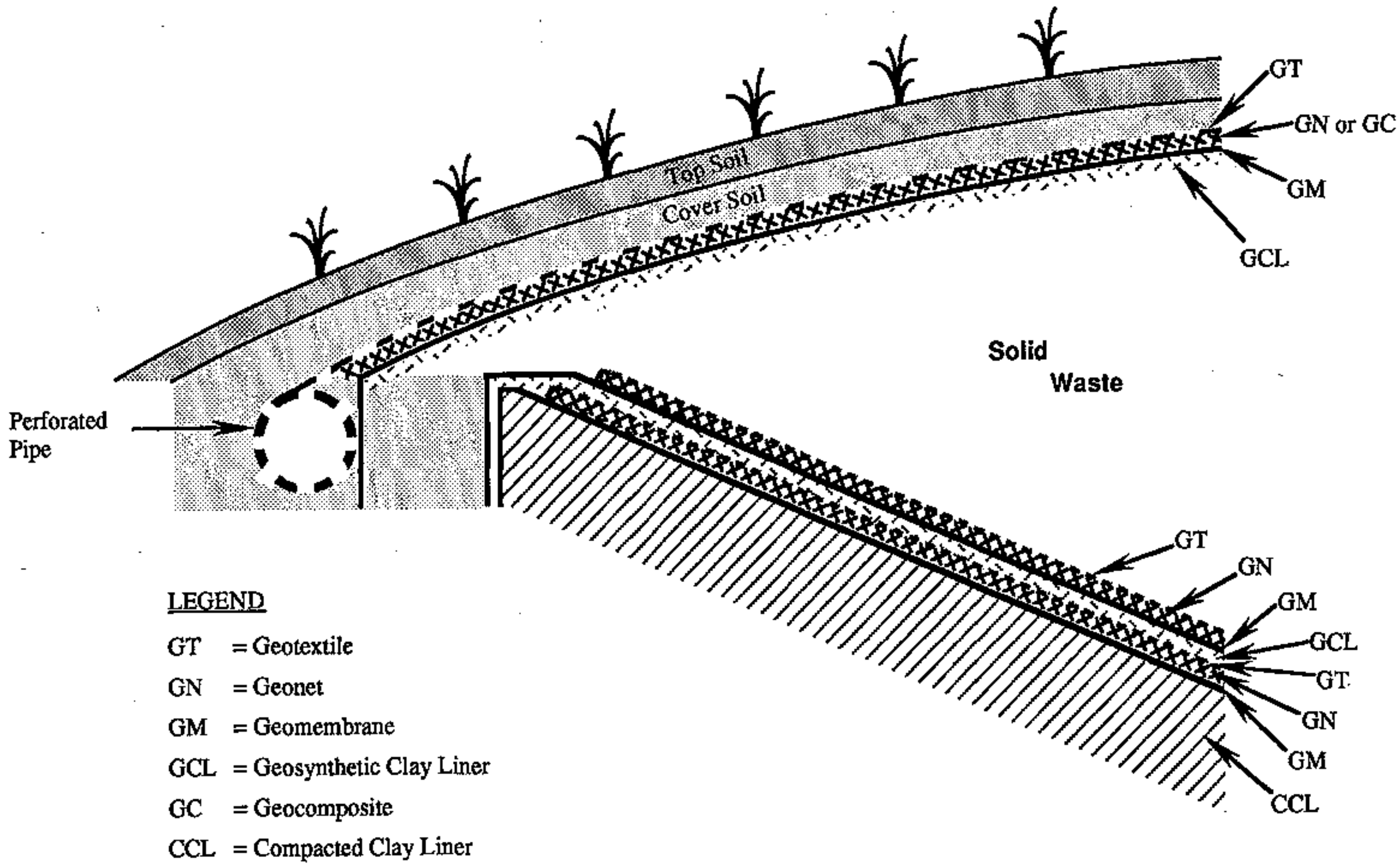


Figure 6.1 - Cross Section of a Landfill Illustrating the Use of Different Geosynthetics Involved in Waste Containment Drainage Systems

6.2.1.1 Resins and Their Additives

Approximately 75% of geotextiles used today are based on polypropylene resin. An additional 20% are polyester and the remaining 5% is a range of polymers including polyethylene, nylon and others used for specialty purposes. As with all geosynthetics, however, the base resin has various additives formulated with it resulting in the final compound. Additives for ultraviolet light protection and as processing aids are common, see Table 6.1.

Table 6.1 - Compounds Used in The Manufacture of Geotextiles (Values Are Percentages Based on Weight)

Generic Name	Resin	Carbon Black	Other Additives
Polypropylene	95 - 98	0 - 3	0 - 2
Polyester	97 - 98	0 - 1	0 - 2
Others	95 - 98	1 - 3	1 - 2

The resin is usually supplied in the form of pellets which is then blended with carbon black, either in the form of concentrate pellets or chips, or as a powder, and the additive package. The additive package is usually a powder and is proprietary with each particular manufacturer. For some manufacturers, the pellets are precompounded with carbon black and/or the entire additive package. Figure 6.2 shows polyester chips and carbon black concentrate pellets used in the manufacturer of polyester geotextiles. Polypropylene pellets and carbon black are similar to those shown in the manufacture of polyethylene geomembranes. Refer to Chapter 3 for details and in particular to Section 3.2.2 for use of recycled and/or reclaimed material.

The following items should be considered for a specification or MQA document for resins and additives used in the manufacture of geotextiles for waste containment applications.

1. The resin should meet MQC requirements. This usually requires a certificate of analysis to be submitted by the resin vendor for each lot supplied. Included will be various properties, their specification limits and the appropriate test methods. For polypropylene resin, the usual requirements are melt flow index, and other properties felt to be relevant by the manufacturer. For polyester resin, the usual requirements are intrinsic viscosity, solution viscosity, color, moisture content and other properties felt to be relevant by the manufacturer.

2. The internal quality control of the manufacturer should be reported to verify that the geotextile manufactured for the project meets the proper specifications.

3. The frequency of performing each of the preceding tests should be covered in the MQC plan and should be implemented and followed.

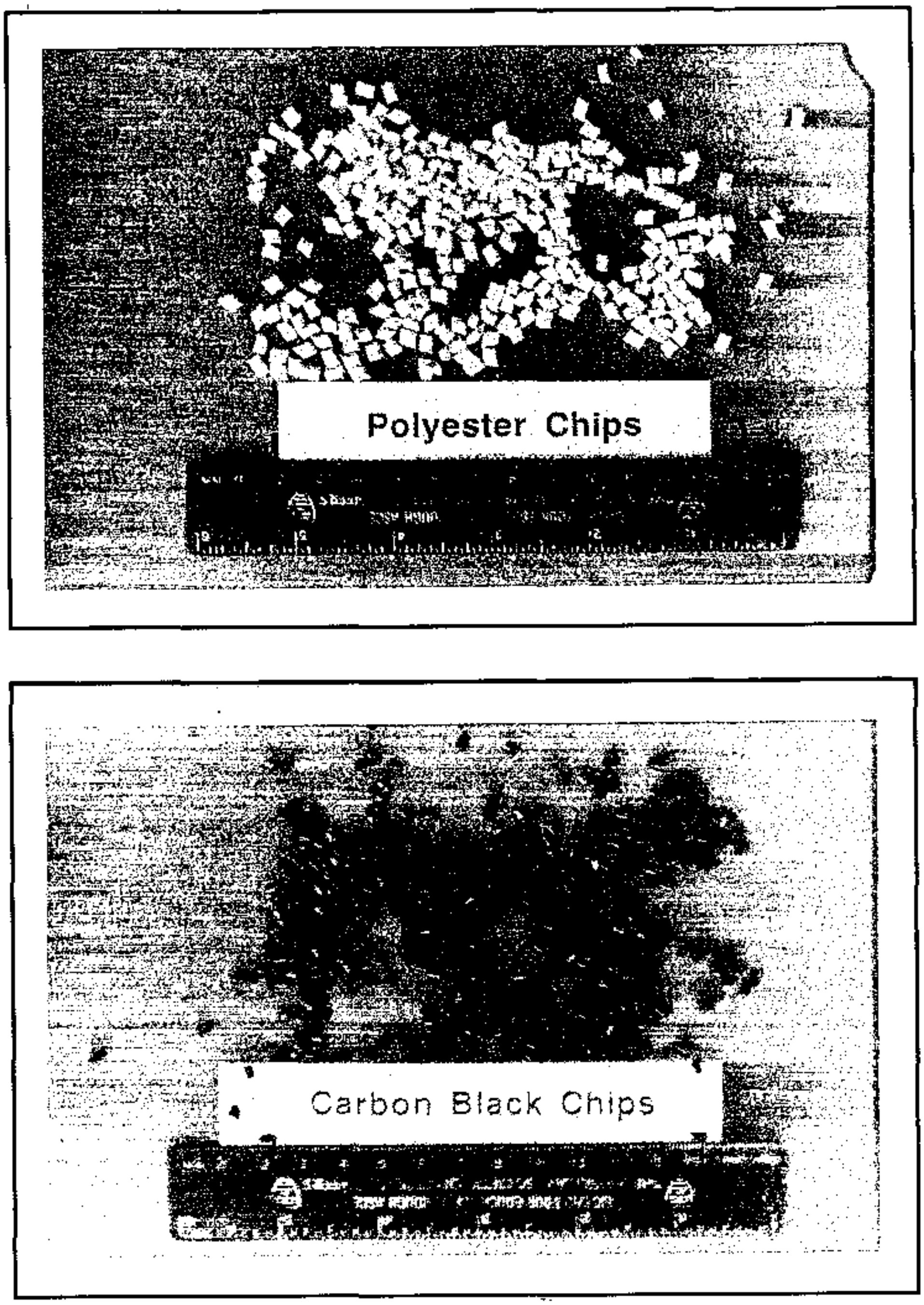


Figure 6.2 - Polyester Resin Chips (Upper) and Carbon Black Concentrate Pellets (Lower) Used for Geotextile Fiber Manufacturing

4. The percentage, according to ASTM D-1603, and type of carbon black should be specified for the particular formulation being used, although it is low in comparison to geomembranes.

5. The type and amount of stabilizers are rarely specified. If a statement is required it should signify that the stabilizer package has been successfully used in the past and to what extent.

6.2.1.2 Fiber Types

The resin, carbon black and stabilizers are introduced to an extruder which supplies heat, mixing action and filtering. It then forces the molten material to exit through a die containing many small orifices called a "spinnerette". Here the fibers, called "yarns", are usually drawn (work hardened) by mechanical tension, or impinged by air, as they are stretched and cooled. The resulting yarns, called "filaments", can be wound onto a bobbin, or can be used directly to form the finished product. Other yarn manufacturing variations include those made from staple fibers and flat, tape-like, yarns called "slit-film". Each type (filament, staple or slit-film) can be twisted together with others as shown in Fig. 6.3. Note that "yarn" is a generic term for any continuous strand (fiber, filament or tape) used to form a textile fabric. Thus all of the examples in Fig. 6.3 are yarns, except for staple, and can be used to manufacture geotextiles.

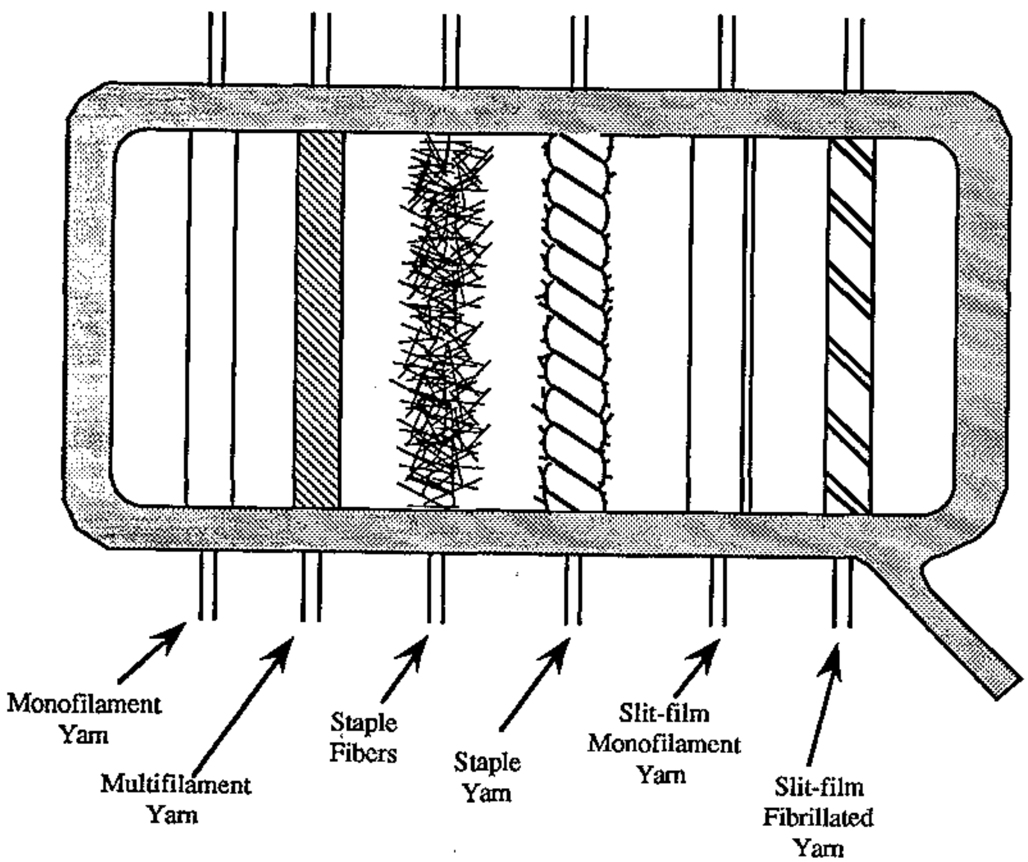


Figure 6.3 - Types of Polymeric Fibers Used in the Construction of Different Types of Geotextiles

6.2.1.3 Geotextile Types

The yarns just described are joined together to make a fabric, or geotextile. Generic classifications are woven, nonwoven and knit. Knit geotextiles, however, are rarely used in waste containment systems and will not be described further in this document.

The manufacturer of a woven geotextile uses the desired type of yarn from a bobbin and constructs the fabric on a weaving loom. Fabric weaving technology is well established over literally centuries of development. Most woven fabrics used for geotextiles are "simple", or "basket-type" weaves consisting of each yarn going over and under an intersecting yarn on an alternate basis. Figure 6.4(a) shows a micrograph of a typical woven geotextile pattern.

In contrast to this type of uniformly woven pattern are nonwoven fabrics as shown in Figs. 6.4(b) and (c). Here the yarns are utilized directly from the extruding spinnerette and laid down on a moving belt in a random fashion. The speed of the moving belt dictates the mass per unit area of the final product. While positioned on the belt the material is "lofty", and the yarns are not structurally bound in any way. Two variations of structural bonding can be used, which gives rise to two unique types of nonwoven geotextiles.

- Nonwoven, needlepunched geotextiles go through a needling process wherein barbed needles penetrate the fabric and entangle numerous fibers transverse to the plane of the fabric. Note the fiber entanglement pattern in Fig. 6.4(b). As a post-processing step, the fabric can be passed over a heated roller resulting in a singed or burnished surface of the yarns on one or both sides of the fabric.

- Nonwoven, heat bonded geotextiles are formed by passing the unbonded fiber mat through a source of heat, usually steam or hot air, thereby melting some of the fibers at various points. Note the fiber bonding pattern in Fig. 6.4(c). This compresses the mat and simultaneously joins the fibers at their intersections by melt bonding.

6.2.1.4 General Specification Items

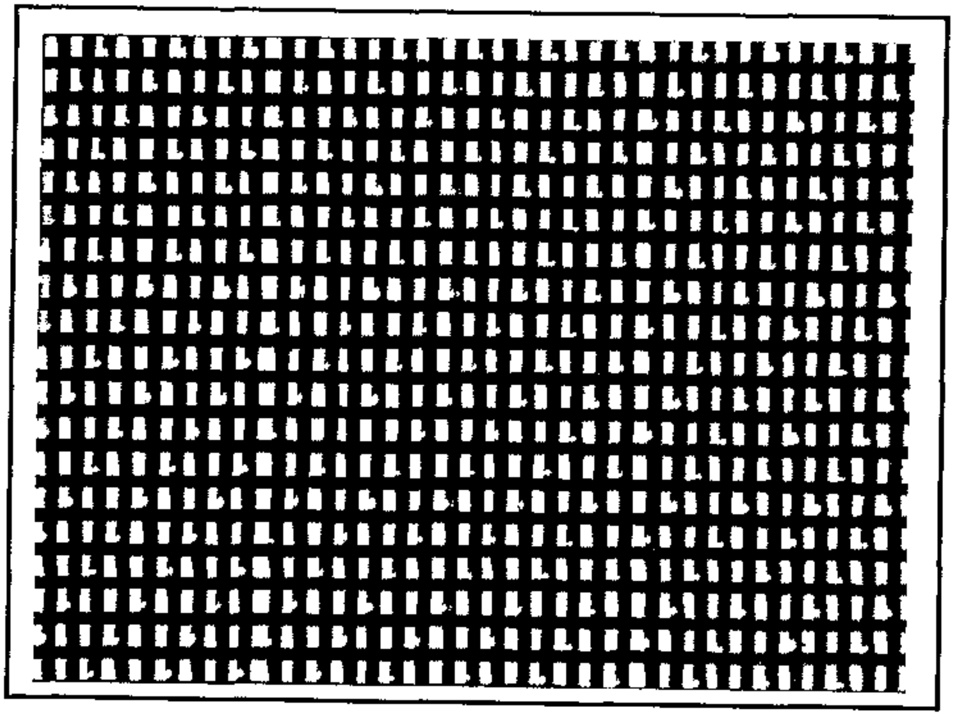
There are numerous items recommended for inclusion in a specification or MQA document for geotextiles used in waste containment facilities.

1. There should be verification and certification that the actual geotextile properties meet the manufacturers specification for that particular type and style.

2. Quality control certifications should include, at a minimum, mass per unit area per ASTM D-5261, grab tensile strength per ASTM D-4632, trapezoidal tear strength per ASTM D-4533, burst strength per ASTM D-3786, puncture strength per ASTM D-4833, thickness per ASTM D-5199, apparent opening size per ASTM D-4751, and permittivity per ASTM D-4491.

3. Values for each property should meet, or exceed, the project specification values, (note in some cases the property listed is a maximum value in which case lower values are acceptable).

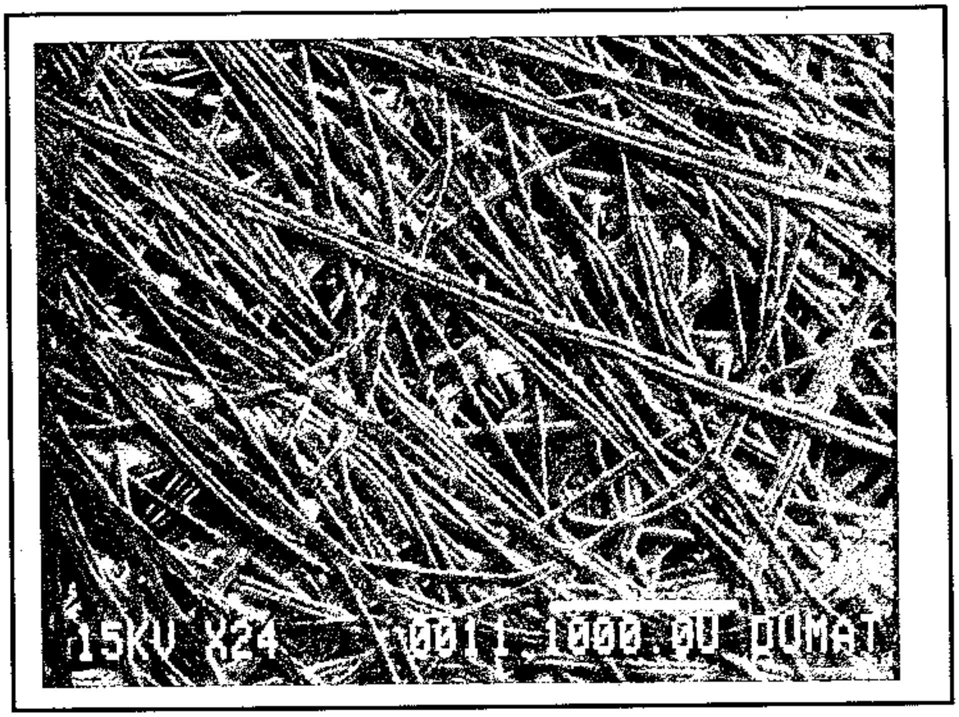
4. A statement should be included that the property values listed are based upon the minimum average roll value (MARV) concept.



(a) Woven Geotextile at 4X Magnification

(b) Nonwoven Needlepunched Geotextile at 24X Magnification

Figure 6.4 - Three Major Types of Geotextiles (Continued on Next Page).



(c) Nonwoven Heatbonded Geotextile at 24X Magnification

Figure 6.4 - Three Major Types of Geotextiles (Continued from Previous Page)

5. The ultraviolet light resistance should be specified which is usually a certain percentage of strength or elongation retained after exposure in a laboratory weathering device. Usually ASTM D-4355 is specified and retention after 500 hours is typically 50% to 90%.

6. The frequency of performing each of the preceding tests should be covered in the manufacturer's MQC plan and it should be implemented and followed.

7. Verification that needle-punched, nonwoven geotextiles have been inspected continuously for the presence of broken needles using an in-line metal detector with an adequate sweep rate should be provided. Furthermore, a needle removal system, e.g., magnets, should be implemented.

8. A statement indicating if, and to what extent, reworked polymer, or fibers, was added during manufacturing. If used, the statement should note that the rework polymer, or fibers, was of the same composition as the intended product.

9. Reclaimed or recycled, i.e., fibers or polymer that has been previously used, should not be added to the formulation unless specifically allowed for in the project

specifications. Note, however, that reclaimed fibers may be used in geotextiles in certain waste containment applications. The gas collection layer above the waste and the geotextile protection layer between drainage stone and a geomembrane are likely locations. These should be design decisions and should be made accordingly.

6.2.2 Handling of Geotextiles

A number of activities occur between the manufacture of geotextiles and their final positioning at the waste facility. These activities involve protective wrapping, storage at the manufacturing facility, shipment, storage at the site, product acceptance, conformance testing and final placement at the facility. Each of these topics will be described in this section.

6.2.2.1 Protective Wrapping

All rolls of geotextiles, irrespective of their type, must be enclosed in a protective wrapping that is opaque and waterproof. The object is to prevent any degradation from atmospheric exposure (ultraviolet light, ozone, etc.), moisture uptake (rain, snow) and to a limited extent, accidental damage. It must be recognized that geotextiles are the most sensitive of all geosynthetics to degradation induced by ultraviolet light exposure. Geotextile manufacturers use tightly wound plastic wraps or loosely fit plastic bags for this purpose. Quite often the plastic is polyethylene in the thickness range of 0.05 to 0.13 mm (2 to 5 mil). Several important issues should be considered in a specification or MQA document.

1. The protective wrapping should be wrapped around (or placed around) the geotextile in the manufacturing facility and should be included as the final step in the manufacturing process.

2. The packaging should not interfere with the handling of the rolls either by slings or by the utilization of the central core upon which the geotextile is wound.

3. The protective wrapping should prevent exposure of the geotextile to ultraviolet light, prevent it from moisture uptake and limit minor damage to the roll.

4. Every roll must be labeled with the manufacturers name, geotextile style and type, lot and roll numbers, and roll dimensions (length, width and gross weight). Details should conform to ASTM D-4873.

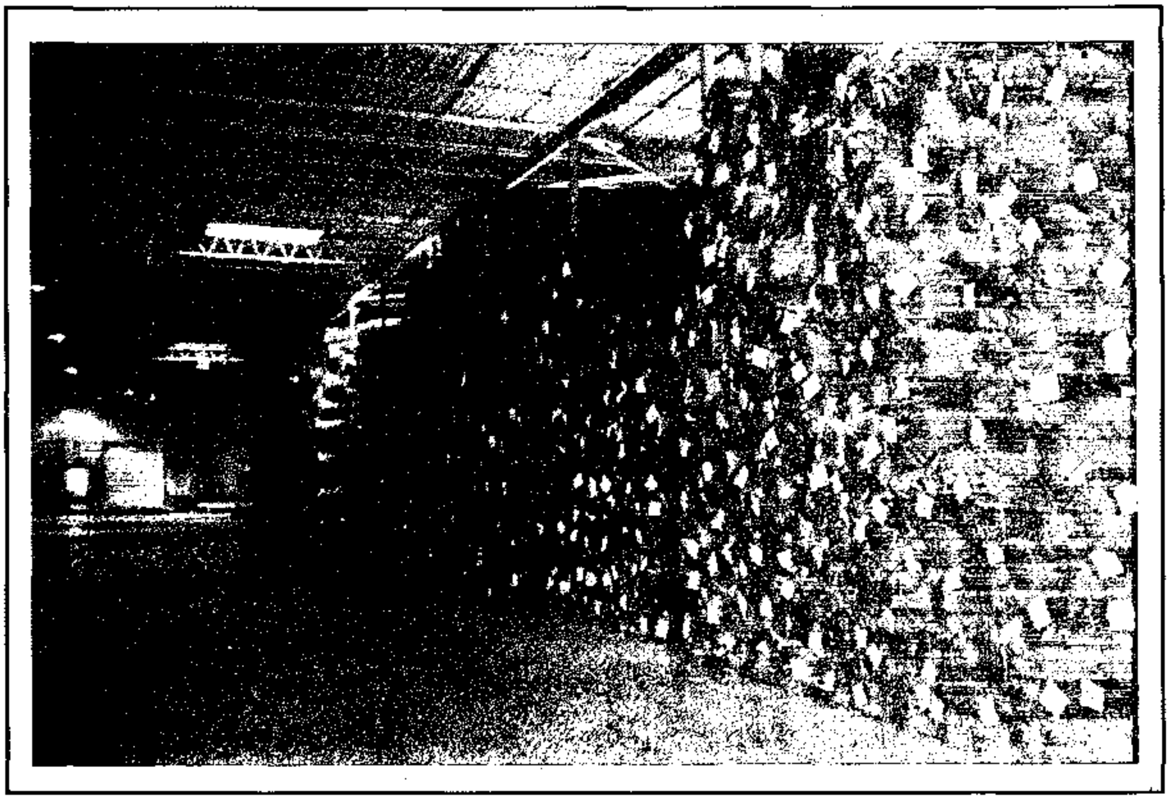
6.2.2.2 Storage at Manufacturing Facility

The manufacturing of geotextiles is such that temporary storage of rolls at the manufacturing facility is necessary. Storage times range from a few days to a year, or longer. Figure 6.5(a) shows geotextile storage at a manufacturer's facility.

Regarding specification and MQA document items, the following should be considered.

1. Handling of rolls of geotextiles should be done in a competent manner such that damage does not occur to the geotextile nor to its protective wrapping. In this regard ASTM D-4873 should be referenced and followed.

2. Rolls of geotextiles should not be stacked upon one another to the extent that deformation of the core occurs or to the point where accessibility can cause damage in handling.



(a) Storage at Manufacturing Facility

(b) Storage at Field Site

Figure 6.5 - Photographs of Temporary Storage of Geotextiles

3. Outdoor storage of rolls at the manufacturer's facility should not be longer than six months. For storage periods longer than six months a temporary enclosure should be put over the rolls, or they should be moved to within a enclosed facility.

6.2.2.3 Shipment

Geotextile rolls are shipped from the manufacturer's (or their representatives) storage facility to the job site via common carrier. Ships, railroads and trucks have all been used depending upon the locations of the origin and final destination. The usual carrier from within the USA, is truck. When using flat-bed trucks the rolls are usually loaded by means of a crane with slings wrapped around the individual rolls. When the truck bed is closed, i.e., an enclosed trailer, the rolls are usually loaded by fork lift with a "stinger" attached. The "stinger" is a long tapered rod which fits inside the core upon which the geotextile is wrapped.

Insofar as specification and MQA/CQA documents are concerned the following items should be considered.

1. The method of loading the geotextile rolls, transporting them and off-loading them at the job site should not cause any damage to the geotextile, its core, nor its protective wrapping.

2. Any protective wrapping that is accidentally damaged or stripped off of the rolls should be repaired immediately or the roll should be moved to a enclosed facility until its repair can be made to the approval of the CQA personnel.

6.2.2.4 Storage at Field Site

Off-loading of geotextile rolls at the site and temporary storage which must be done in an acceptable manner. Figure 6.5(b) shows typical storage at the field site. Some specification and CQA document items to consider are the following.

1. Handling of rolls of geotextiles should be done in a competent manner such that damage does not occur to the geotextile nor to its protective wrapping. In this regard ASTM D-4873 should be referenced and followed.

2. The location of field storage should not be in areas where water can accumulate. The rolls should be elevated off of the ground so as not to form a dam creating the ponding of water.

3. The rolls should be stacked in such a way that cores are not crushed nor is the geotextile damaged. Furthermore, they should be stacked in such a way that access for conformance testing is possible.

4. Outdoor storage of rolls should not exceed manufacturers recommendations or longer than six months, whichever is less. For storage periods longer than six months a temporary enclosure should be placed over the rolls, or they should be moved within an enclosed facility.

6.2.2.5 Acceptance and Conformance Testing

Upon delivery of the rolls of geotextiles to the project site, and temporary storage thereof, the CQA engineer should see that conformance test samples are obtained. These samples are then sent to the CQA laboratory for testing to ensure that the supplied geotextile conforms to the project plans and specifications. The samples are taken from selected rolls by removing the protective wrapping and cutting full-width, 1 m (3 ft) long samples off of the outer wrap of the selected roll(s). Sometimes the outer revolution of geotextile is discarded before the test sample is taken. The rolls are immediately re-wrapped and replaced in temporary field storage. The samples rolls must be relabeled for future identification. Alternatively, conformance testing could be performed at the manufacturer's facility and when completed the particular lot should be marked for the particular site under investigation. Items to be considered in a specification and CQA documents in this regard are the following:

1. The samples should be identified by type, style or, lot and roll numbers. The machine direction should be noted on the sample(s) with a waterproof marker.
2. A lot is defined as a unit of production, or a group of other units or packages having one or more common properties and being readily separable from other similar units. Other definitions are also possible and should be clearly stated in the CQA documents, see ASTM D-4354.
3. Sampling should be done according to the job specification and/or CQA documents. Unless otherwise stated, sampling should be based on one per lot. Note that a lot is sometimes defined as 10,000 m^2 (100,000 ft^2) of geotextile. Utilization of ASTM D-4354 may be referenced and followed in this regard but it might result in a different value for sampling than stated above.
4. Testing at the CQA laboratory may include mass per unit area per ASTM D-5261, grab tensile strength per ASTM D-4632, trapezoidal tear strength per ASTM D-4533, burst strength per ASTM D-3786, puncture strength per ASTM D-4833, and possibly apparent opening size per ASTM D-4751, and permittivity per ASTM D-4491. Other conformance tests may be required by the project specifications.
5. Conformance test results should be sent to the CQA engineer prior to deployment of any geotextile from the lot under review.
6. The CQA engineer should review the results and should report any nonconformance to the Owner/Operator's Project Manager.
7. The resolution of failing conformance tests must be clearly stipulated in the specifications or CQA documents. Statements should be based upon ASTM D-4759 entitled "Determining the Specification Conformance of Geosynthetics".
8. The geotextile rolls which are sampled should be immediately rewrapped in their protective covering to the satisfaction of the CQA personnel.

6.2.2.6 Placement

The geosynthetic installation contractor should remove the protective wrappings from the geotextile rolls to be deployed only after the substrate layer, soil or other geosynthetic, has been documented and approved by the CQA personnel. The specification and CQA documents should be written in such a manner as to ensure that the geotextiles are not damaged nor excessively exposed to ultraviolet degradation. The following items should be considered for inclusion in a specification or CQA document.

1. The installer should take the necessary precautions to protect the underlying layers upon which the geotextile will be placed. If the substrate is soil, construction equipment can be used provided that excess rutting is not created. Excess rutting should be clearly defined and quantified by the design engineer. In some cases 25 mm (1.0 in.) is the maximum rut depth allowed. If the ground freezes, the depth of ruts should be further reduced to a specified value. If the substrate is a geosynthetic material, deployment must be by hand, by use of small jack lifts on pneumatic tires having low ground contact pressure, or by use of all-terrain vehicles, ATV's, having low ground contact pressure.

2. During placement, care must be taken not to entrap (either within or beneath the geotextile) stones, excessive dust or moisture that could damage a geomembrane, cause clogging of drains or filters, or hamper subsequent seaming.

3. On side slopes, the geotextiles should be anchored at the top and then unrolled so as to keep the geotextile free of wrinkles and folds.

4. Trimming of the geotextiles should be performed using only an upward cutting hook blade.

5. Nonwoven geotextiles placed on textured geomembranes can be troublesome due to sticking and are difficult to align or even separate after they are placed on one another. A thin sheet of plastic on the geomembrane during deployment of the geotextile can be very helpful in this regard. Of course, it is removed after correct positioning of the geotextile.

6. The geotextile should be weighted with sandbags, or the equivalent, to provide resistance against wind uplift. This is a site-specific procedure and completely the installer's decision. Uplifted and moved geotextiles can generally be reused but only after approval by the owner and observation by the CQA personnel.

7. A visual examination of the deployed geotextile should be carried out to ensure that no potentially harmful objects are present, e.g., stones, sharp objects, small tools, sandbags, etc.

6.2.3 Seaming

Seaming of geotextiles, by sewing, is sometimes required (versus overlapping with no sewn seams) of all geotextiles placed in waste facilities. This generally should be the case for geotextiles used in filtration, but may be waived for geotextiles used in separation (e.g., as gas collection layers above the waste or as protective layers for geomembranes) as per the plans and specifications. In such cases, heat bonding is also an acceptable alternate method of joining separation geotextiles. In cases where overlapping is permitted, the overlapped distance requirements should be clearly stated in the specification and CQA documents. Geotextile seam types and procedures, seam tests and geotextile repairs are covered in this section.

6.2.3.1 Seam Types and Procedures

The three types of sewn geotextile seams are shown in Fig. 6.6. They are the "flat" or "prayer" seam, the "J" seam and the "butterfly" seam. While each can be made by a single thread, or by a two-thread chain stitch, as illustrated, the latter stitch is recommended. Furthermore, a single, double, or even triple, row of stitches can be made as illustrated by the dashed lines in the figures. Figure 6.7 shows a photograph of the fabrication of a flat seam and see Diaz (1990) for further details regarding geotextile seaming.

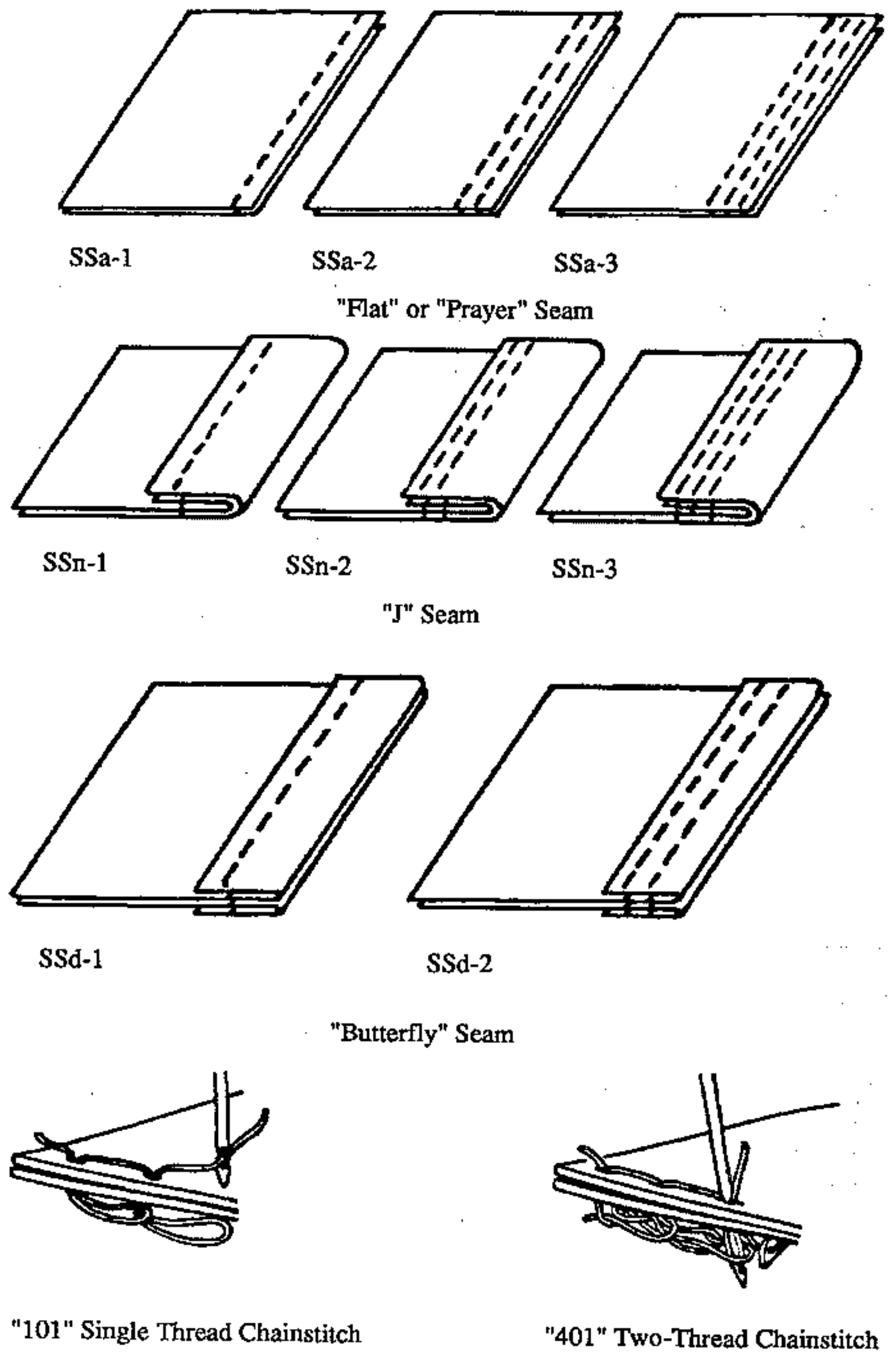


Figure 6.6 - Various Types of Sewn Seams for Joining Geotextiles (after Diaz, 1990)

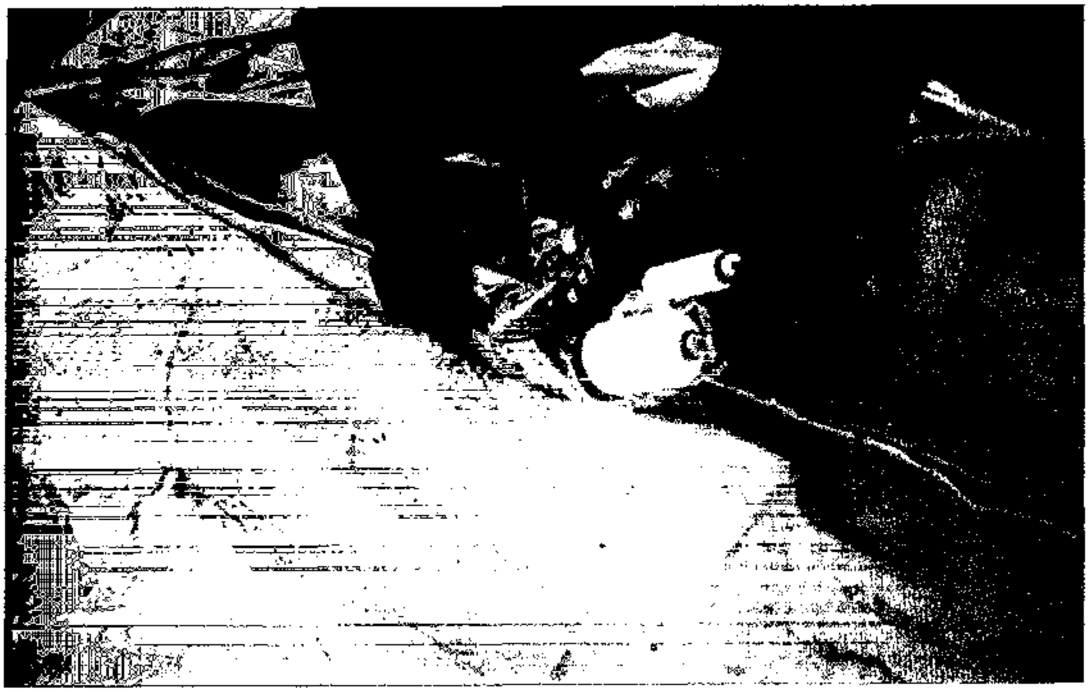


Figure 6.7 - Fabrication of a Geotextile Field Seam in a "Flat" or "Prayer" Seam Type

The project specification or CQA documents should address the following considerations.

1. The type of seam, type of stitch, stitch count or number of stitches per inch and number of rows should be specified based on the tendency of the fabric to fray, strength need and toughness of the fabric. For filtration and separation geotextiles a flat seam using a two-thread chain stitch and one row is usually specified. For reinforcement geotextiles, stronger and more complex seams are utilized. Alternatively, a minimum seam strength, per ASTM D-4884, could be specified.

2. The seams should be continuous, i.e., spot sewing is generally not allowed.

3. On slopes greater than approximately 5 (horiz.) to 1 (vert.), seams should be constructed parallel to the slope gradient. Exceptions are permitted for small patches and repairs.

4. The thread type must be polymeric with chemical and ultraviolet light resistant properties equal or greater than that of the geotextile itself.

5. The color of the sewing thread should contrast that of the color of the geotextile for ease in visual inspection. This may not be possible due to polymer composition in some cases.

6. Heat seaming of geotextiles may be permitted for certain seams. A number of methods are available such as hot plate, hot knife and ultrasonic devices.

7. Overlapped seams of geotextiles may be permitted for certain seams. The overlap distance should be stated depending on the site specific conditions.

6.2.3.2 Seam Tests

For geotextiles used in filtration and separation, seam samples and subsequent strength testing are not generally required. If they are, however, they should be stipulated in the specifications or CQA documents. Also, the sampling and testing frequency should be noted accordingly. The test method to evaluate sewn seam test specimens is ASTM D-4884.

6.2.3.3 Repairs

Holes, or tears, in geotextiles made during placement or anytime before backfilling should be repaired by patching. Some relevant specifications and CQA document items follow.

1. The patch material used for repair of a hole or tear should be the same type of polymeric material as the damaged geotextile, or as approved by the CQA engineer.

2. The patch should extend at least 30 cm (12 in.) beyond any portion of the damaged geotextile.

3. The patch should be sewn in place by hand or machine so as not to accidentally shift out of position or be moved during backfilling or covering operations.

4. The machine direction of the patch should be aligned with the machine direction of the geotextile being repaired.

5. The thread should be of contrasting color to the geotextile and of chemical and ultraviolet light resistance properties equal or greater than that of the geotextile itself.

6. The repair should be made to the satisfaction of the specification and CQA documents.

6.2.4 Backfilling or Covering

The layer of material placed above the deployed geotextile will be either soil, waste or another geosynthetic. Soils will vary from compacted clay layers to coarse aggregate drainage layers. Waste should be what is referred to as "select" waste, i.e., carefully separated and placed so as not to cause damage. Geosynthetics will vary from geomembranes to geosynthetic clay liners. Some considerations for a specification and CQA document to follow:

1. If soil is to cover the geotextile it should be done such that the geotextile is not shifted from its intended position and underlying materials are not exposed or damaged.

2. If a geosynthetic is to cover the geotextile, both the underlying geotextile and the newly deployed material should not be damaged during the process.

3. If solid waste is to cover the geotextile, the type of waste should be specified and visual observation by CQA personnel should be required.

4. The overlying material should not be deployed such that excess tensile stress is mobilized in the geotextile. On side slopes, this requires soil backfill to proceed from the bottom of the slope upward.

5. Soil backfilling or covering by another geosynthetic, should be done within the time frame stipulated for the particular type of geotextile. Typical time frames for geotextiles are within 14 days for polypropylene and 28 days for polyester geotextiles.

6.3 Geonets and Geonet/Geotextile Geocomposites

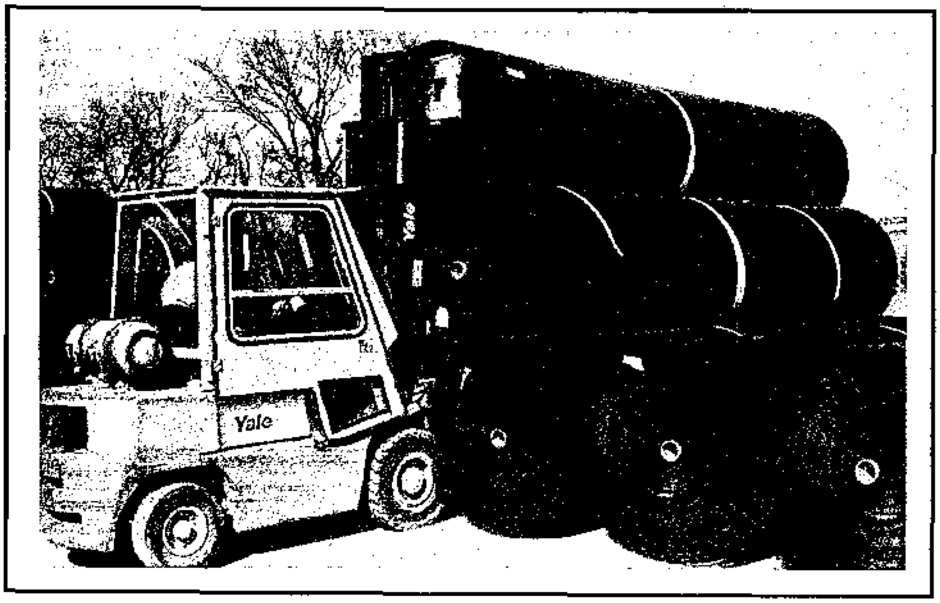
Geonets are unitized sets of parallel ribs positioned in layers such that liquid can be transmitted within their open spaces. Thus their primary function is drainage; recall Fig. 6.1. Figure 6.8(a) shows a photograph of rolls of geonets, while Fig. 6.8(b) shows a closeup of the intersection of a typical set of geonet ribs. Note that open space exists both in the plane of the geonet (above or under the parallel sets of ribs) and cross plane to the geonet (within the apertures between adjacent sets of ribs). In all cases, the apertures must be protected against migration and clogging by adjacent soil materials. Thus geonets always function with either geomembranes and/or geotextiles on their two planar surfaces. Whenever the geonet comes supplied with a geotextile on one or both of its surfaces, it is called a geocomposite. The geotextile(s) is usually bonded on the surface by heat fusing or by using an adhesive.

This section will describe the manufacturing and handling of geonets for waste containment facilities. Since continuity of liquid flow is necessary at the sides and ends of the rolls, joining methods will also be addressed, as will the placement of the covering layer. Also covered will be the bonding of geotextiles to geonets in the form of drainage geocomposites.

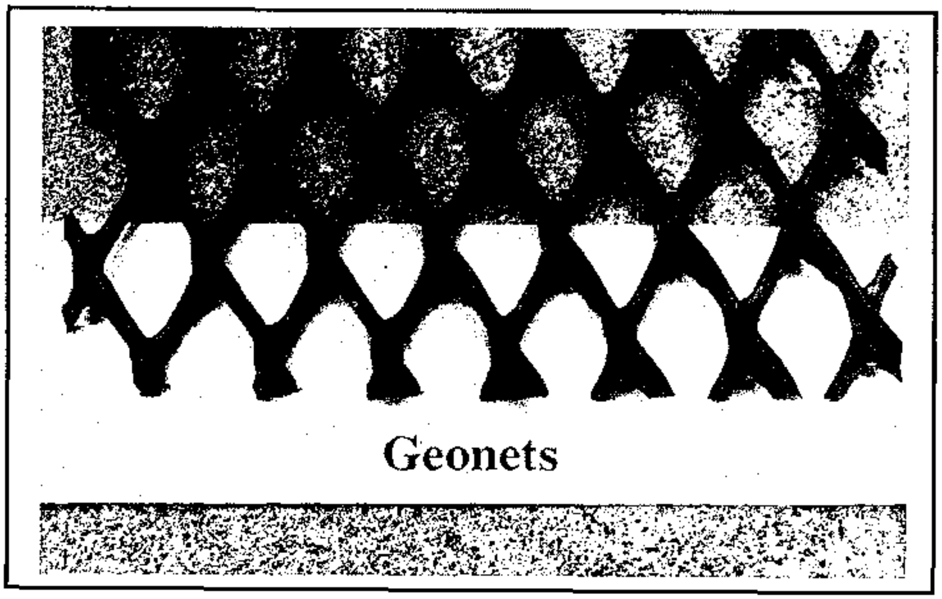
6.3.1 Manufacturing of Geonets

Geonets currently used in waste containment applications are formed using an extruder which accepts the intended polymer formulation and then melts, mixes, filters and feeds the molten material directly into a counter-rotating die. This die imparts parallel sets of ribs into the preform. Upon exiting the die, the ribs of the preform are opened by being forced over a steel spreading mandrel. Figure 6.9 shows a small laboratory size geonet as it is formed and expands into its final shape. The fully formed geonet is then water quenched, longitudinally cut in the machine direction, spread open as it exits the quench tank and rolled onto a handling core. The width of the rolls are determined by the maximum circumference of the spreading mandrel. Since the process is continuous in its operation, the roll length is determined on the basis of the manageable weight of a roll. The thickness of the geonet is based on the slot dimensions of the opposing halves of the counter-rotating mold. Thicknesses of commercially available geonets vary between 4.0 and 6.9 mm (160 - 270 mils).

Most of the commercially available resins used for geonets are polyethylene in the natural density range of 0.934 to 0.940 g/cc. Thus they are classified as medium density polyethylene according to ASTM D-1248. The final compound is approximately 97% polyethylene. An additional 2 to 3% is carbon black, added as a powder or as a concentrate, and the remaining 0.5 to 1.0% are additives. The additives are added as a powder as are antioxidants and processing aids, both of which are proprietary to the various geonet manufacturers. Formulations are often the same as for HDPE geomembranes (recall Chapter 3), or slight variations thereof.



(a) Rolls of Drainage Geonets



(b) Closeup of Rib Intersection

Figure 6.8 - Typical Geonets Used in Waste Containment Facilities

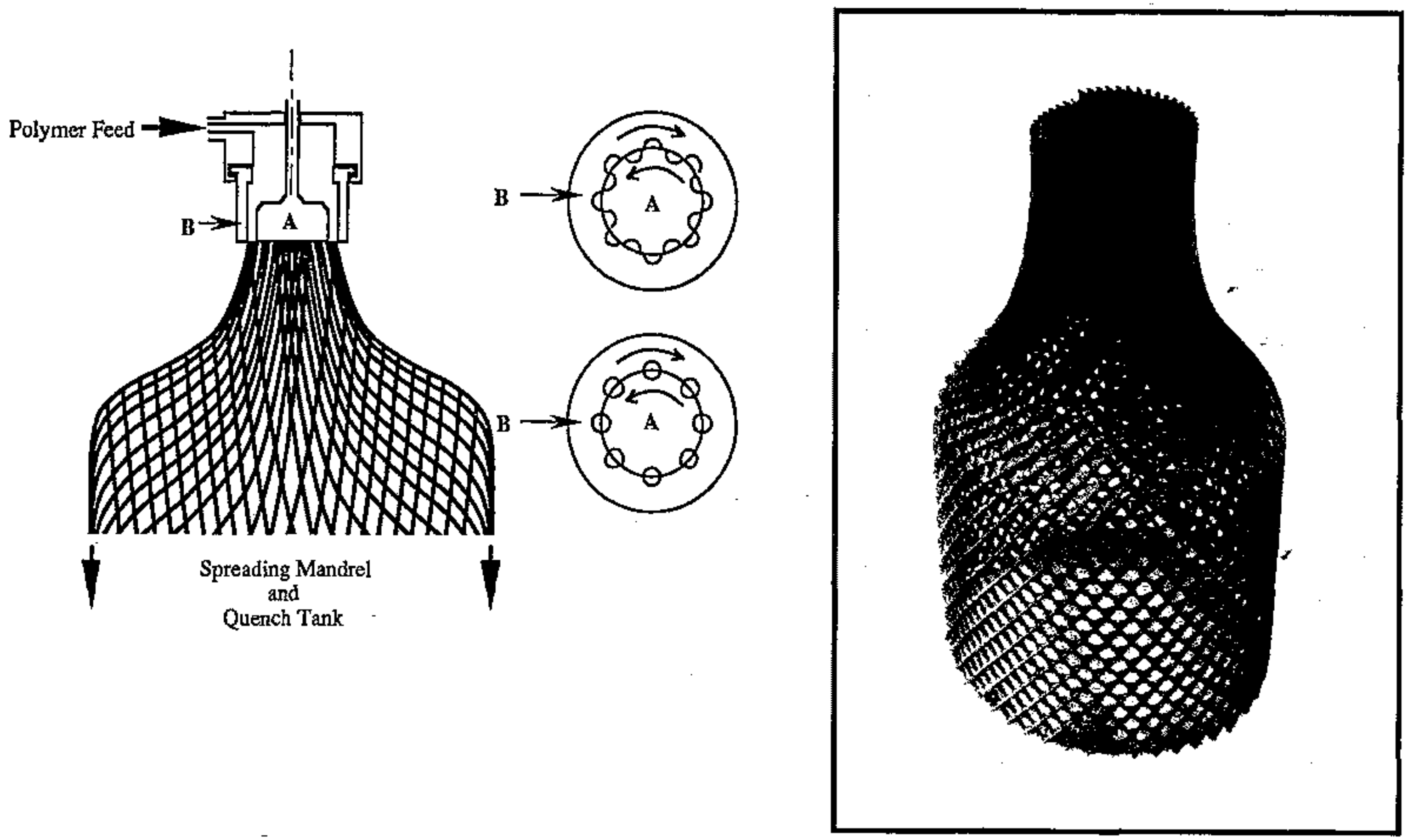


Figure 6.9 - Counter Rotating Die Technique (Left Sketch) for Manufacturing Drainage Geonets and Example of Laboratory Prototype (Right Photograph)

Regarding the preparation of a specification or MQA document for the resin component of HDPE geonets, the following items should be considered:

1. Specifications may call for the polyethylene resin to be made from virgin, uncontaminated ingredients. Alternatively, geonets can be made with off-spec geomembrane material as a large, or even major part, of their total composition provided this material is of the same formulation as the intended geonet and does not consist of recycled and/or reclaimed material. Recycled and/or reclaimed material is generally not allowed. It is acceptable, and is almost always the case, that the density of the resin is in the medium density range for polyethylene, i.e., that its density is equal to or less than 0.940 g/cc.

2. Typical quality control tests on the resin are density, via ASTM D-1505 or D-792 and melt flow index via ASTM D-1238.

3. An HDPE geonet formulation should consist of at least 97% of polyethylene resin, with the balance being carbon black and additives. No fillers, extenders, or other materials should be mixed into the formulation.

4. It should be noted that by adding carbon black and additives to the resin, the density of the final formulation is generally over 0.941 g/cc. Since this value is in the high density polyethylene category, according to ASTM D-1248, geonets of this type are customarily referred to as high density polyethylene (HDPE).

5. Regrind or reworked polymer which is previously processed HDPE geonet in chip form, is often added to the extruder during processing. It is acceptable if it is the same formulation as the geonet being produced.

6. No amount of "recycled" or "reclaimed" material, which has seen prior use in another product should be added to the formulation.

7. An acceptable variation of the process just described is to add a foaming agent into the extruder which then is processed in the standard manner. As the geonet is formed and is subsequently quenched, the foaming agent expands within the ribs creating innumerable small spherical voids. The voids are approximately 0.01 mm (0.5 mil) in diameter. This type of geonet is called a "foamed rib" geonet, in contrast to the standard type which is a "solid rib" geonet. Foamed rib geonets are currently seen less frequently in drainage systems than previously.

8. Quality control certificates from the manufacturer should include proper identification of the product and style and results of quality control tests.

9. The frequency of performing each of the preceding tests should be covered in the MQC plan and it should be implemented and followed.

6.3.2 Handling of Geonets

A number of activities occur between the manufacture of geonets and their final positioning where intended at the waste facility. These activities involve packaging, storage at the manufacturing facility, shipment, storage at the site, acceptance and conformance testing and final placement at the facility. Each of these topics will be described in this section.

6.3.2.1 Packaging

As geonets come from the quenching tank they are wound on a core until the desired length is reached. The geonet is then cut along its width and the entire roll contained by polymer straps so as not to unwind during subsequent handling. There is generally no protective wrapping placed around geonets, however, a plastic wrapping can be provided if necessary.

Specifications or a MQA document should be formed around a few important points.

1. The core must be stable enough to support the geonet roll while it is handled by either slings around it, or from a fork lift "stinger" inserted in it.
2. The core should have a minimum 100 mm (4.0 in.) inside diameter.
3. The banding straps around the outside of the roll should be made from materials with adequate strength yet should not damage the outer wrap(s) of the roll.

6.3.2.2 Storage at Manufacturing Facility

The storage of geonet rolls at the manufacturer's facility is similar to that described for HDPE geomembranes. Refer to Section 3.3.1 for a complete description.

6.3.2.3 Shipment

The shipment of geonet rolls from the manufacturer's facility to the project site is similar to that described for HDPE geomembranes. Refer to Section 3.3.2 for a complete description.

6.3.2.4 Storage at the Site

The storage of geonet rolls at the project site is similar to that described with HDPE geomembranes. Refer to section 3.3.2 for a complete description, see Fig. 6.10. An important exception is that a ground cloth should be placed under the geonets if they are stored on soil for any time longer than one month. This is to prevent weeds from growing into the lower rolls of the geonet. If weeds do grow in the geonet during storage, the broken pieces must be removed by hand on the job when the geonet is deployed.

6.3.2.5 Acceptance and Conformance Testing

The acceptance and conformance testing of geonets is similar to that described for HDPE geomembranes. Refer to Section 3.3.3 for a complete description. For geonets, the usual conformance tests are the following:

- density, per ASTM D-1505 or D-792
- mass per unit area, per ASTM D-5261
- thickness, per ASTM D-5199

Additional conformance tests such as compression per ASTM D-1621 and transmissivity per ASTM D-4716 may also be stipulated.

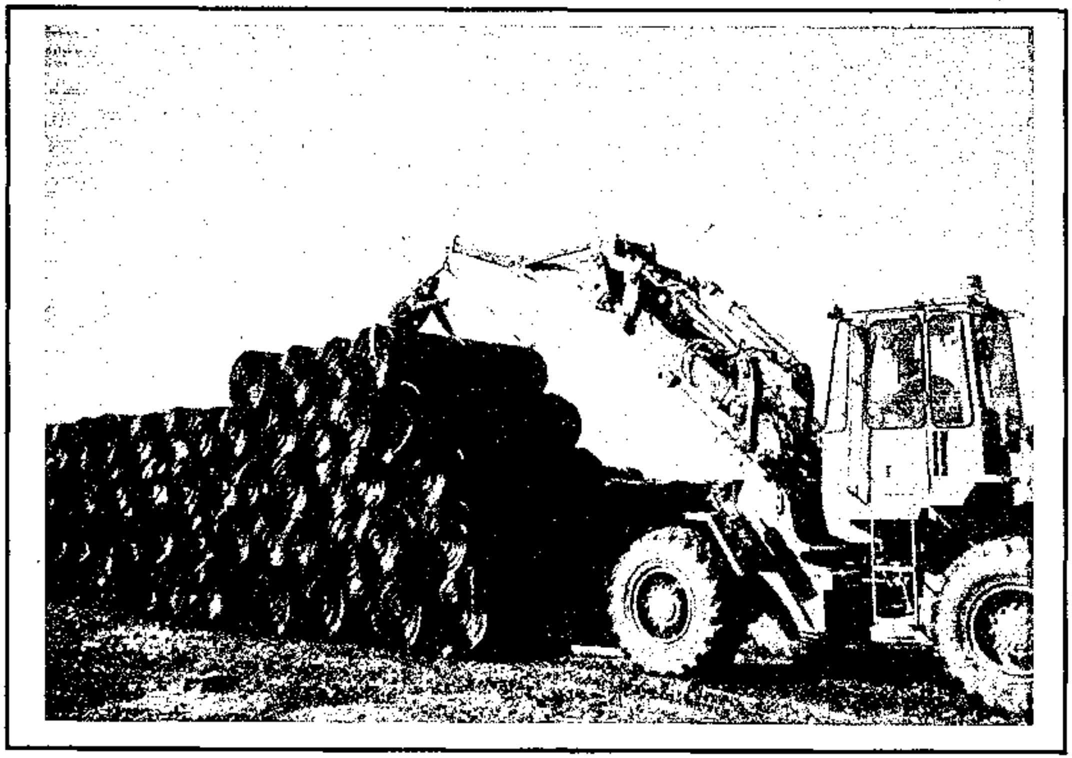


Figure 6.10 - Geonets Being Temporarily Stored at the Job Site

6.3.2.6 <u>Placement</u>

The placement of geonets in the field is similar to that described for geotextiles. Refer to Section 6.2.2.6 for a complete description.

6.3.3 <u>Joining of Geonets</u>

Geonets are generally joined together by providing a stipulated overlap and using plastic fasteners or polymer braid to tie adjacent ribs together at minimum intervals, see Fig. 6.11.

Recommended items for a specification or CQA document on the joining of geonets include the following:

1. Adjacent roll <u>edges</u> of geonets should be overlapped a minimum distance. This is typically 75-100 mm (3-4 in.).

2. The roll <u>ends</u> of geonets should be overlapped 150-200 mm (6-8 in.) since flow is usually in the machine direction.

Figure 6.11 - Photograph of Geonet Joining by Using Plastic Fasteners

3. All overlaps should be joined by tying with plastic fasteners or polymeric braid. Metallic ties or fasteners are not allowed.

4. The tying devices should be white or yellow, as contrasted to the black geonet, for ease of visual inspection.

5. The tying interval should be specified. Typically tie intervals are every 1.5 m (5.0 ft) along the edges and every 0.15 m (6.0 in.) along the ends and in anchor trenches.

6. Horizontal seams should not be allowed on side slopes. This requires that the length of the geonet should be at least as long as the side slope, anchor trench and a minimum run out at the bottom of the facility. If horizontal seams are allowed, they should be staggered from one roll to the adjacent roll.

7. In difficult areas, such as corners of side slopes, double layers of geonets are sometimes used. This should be stipulated in the plans and specifications.

8. If double geonets are used, they should be layered on top of one another such that interlocking does not occur.

9. If double geonets are used, roll edges and ends should be staggered so that the joints do not lie above one another.

10. Holes or tears in the geonet should be repaired by placing a geonet patch extending a minimum of 0.3 m (12 in.) beyond the edges of the hole or tear. The patch should be tied to the underlying geonet at 0.15 m (6.0 in.) spacings.

11. Holes or tears along more than 50% of the width of the geonet on side slopes should require the entire length of geonet to be removed and replaced.

6.3.4 Geonet/Geotextile Geocomposites

Geonets are always covered with either a geomembrane or a geotextile, i.e., they are never directly soil covered since the soil particles would fill the apertures of the geonet rendering it useless. Many geonets have a geotextile bonded to one, or both, surfaces. These are then referred to as geocomposites in the geonet manufacturer's literature. In this document, however, geocomposites will refer to many different types of drainage core structures. Clearly, covered geonets are included in this group. However, geocomposites also consist of fluted, nubbed and cuspated cores, covered with geotextiles and/or geomembranes and will be described separately in section 6.4. Still further, some manufacturers refer to the entire group of geosynthetic drainage materials as "geospacers".

Regarding a specification or CQA document for geonet/geotextile drainage geocomposites, a few comments are offered:

1. The geotextile(s) covering a geonet should be bonded together in such a way that neither component is compromised to the point where proper functioning is impeded. Thus adequate, but not excessive, bonding of the geotextile(s) to the geonet is necessary.

2. If bonding is by heating, the geotextile(s) strength cannot be compromised to the point where failure could occur. The transmissivity under load test, ASTM D-4716, should be performed on the intended geocomposite product.

3. If bonding is by adhesives, the type of adhesive must be identified, including its water solubility and organic content. Excessive adhesive cannot be used since it could fill up some of the geonet's void space. The transmissivity under load test, ASTM D-4716, should be performed on the intended geocomposite product. The geotextile's permittivity could be evaluated using ASTM D-4491.

4. If the shear strength of the geotextile(s) to the geonet is of concern an adapted form of an interface shear test, e.g., ASTM D-5321, can be performed with the geotextile firmly attached to a wooden substrate, or other satisfactory arrangement. Alternatively, a ply adhesion test may be adequate, see ASTM D-413 which might be suitably modified for geotextile-to-geonet adhesion.

5. For factory fabricated geocomposites with geotextiles placed on both sides of a geonet, the geonet must be free from all dirt, dust and accumulated debris before covering.

6. For field placed geotextiles, the geonet should be free of all soil, dust and accumulated debris before covering with a geomembrane or geotextile. In extreme cases this may require washing of the geonet to accumulate the particulate material at the low end (sump) area where it is subsequently removed by hand.

7. When placing geosynthetic clay liners (GCLs) above geocomposites, cleanliness is particularly important in assuring that fugitive bentonite clay particles do not find their way into the geonet.

8. Placement of a covering geomembrane should not shift the geotextile or geocomposite out of position nor damage the underlying geonet.

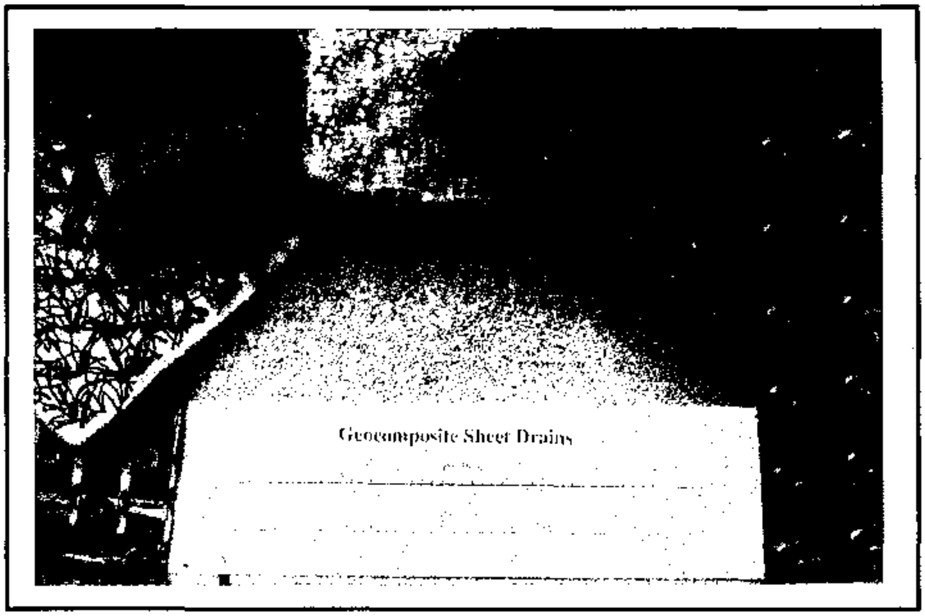
9. An overlying geomembrane or geotextile should not be deployed such that excess tensile stress is mobilized in the geocomposite.

6.4 Other Types of Geocomposites

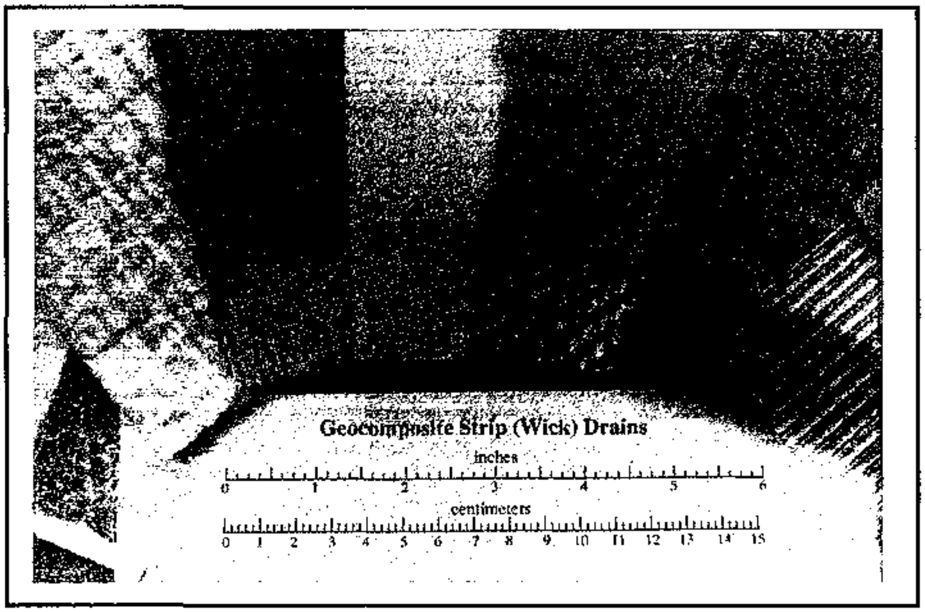
Geocomposite drainage systems consist of a polymer drainage core protected by a geotextile acting as both a filter and a separator to the adjacent material. Thus a geonet, with a geotextile attached to one surface or to both surfaces as described in section 6.3.4, is indeed a drainage geocomposite. However, for the drainage geocomposites discussed in this section the geotextile filter is always attached to the drainage core and the core can take a wide variety of non-geonet shapes and configurations. In some cases, the geotextile is only on one side of the core (the side oriented toward the inflowing liquid), in other cases it is wrapped completely around the drainage core.

There are three different types of drainage geocomposites referred to in this document; sheet drains, edge drains and strip (or wick) drains. Typical variations are shown in Fig. 6.12. For drainage systems associated with waste containment facilities, sheet drains, Fig. 6.12a, are sometimes used as surface water collectors and drains in cover systems of closed landfills and waste piles, refer to Fig. 6.1. Infiltration water that moves within the cover soil enters the sheet drain and flows gravitationally to the edge of the site (or cell) where it is generally collected by a perforated pipe, or edge drain. Pipes will be discussed separately in Chapter 8. The other possible use for sheet drains is for primary leachate collection systems in landfills. The required flow rate in some landfills is too great for a geonet, hence the greater drainage capacity of a geocomposite is sometimes required. Of course, when used in this application the drainage geocomposite must resist the compressive and shear stresses imposed by the waste and it must be chemically resistant to the leachate, but these are design considerations. The use of strip (wick) drains, Fig. 6.12b, in waste containment has been as vertical drains within a solid waste landfill to promote leachate communication between individual lifts. The edge drains, shown in Fig. 6.12(c), have potential applicability around the perimeter of a closed landfill facility to accumulate the surface water coming from a cap/closure system. A variety of perimeter drains could utilize such geocomposite edge drains.

Of the different types of drainage geocomposites shown in Fig. 6.12, only sheet drains will be described since they have the greatest applicability in waste containment systems.

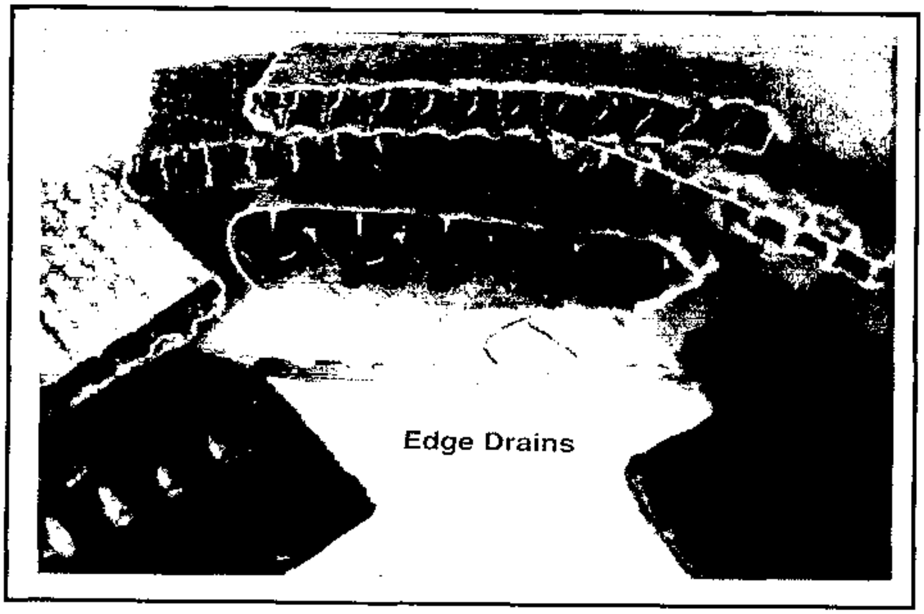


(a) Geocomposite Sheet Drains



(b) Geocomposite Strip (Wick) Drains

Figure 6.12 - Various Types of Drainage Geocomposites (Continued on Next Page)



(c) Geocomposite Edge Drains

Figure 6.12 - Various Types of Drainage Geocomposites (Continued from Previous Page)

6.4.1 Manufacturing of Drainage Composites

The manufacture of the drainage core of a geocomposite sheet drain is generally accomplished by taking the desired type of polymer sheet and then vacuum forming dimples, protrusions or cuspations which give rise to the protrusions. The polymer sheets of drainage geocomposites have been made from a wide variety of polymers. Commercial products that are currently available consist of the following polymer formulations:

- polystyrene
- nylon
- polypropylene
- polyvinyl chloride
- polyethylene
- polyethylene/polystyrene/polyethylene (coextrusion)

With coextrusion there exists a variety of possibilities in addition to those listed above. Recognize, however, that coarse fibers, entangled webs, filament mattings, and many other variations are also possible.

Upon deciding on the proper type and thickness of polymer sheet, a geocomposite core usually goes through a vacuum forming step. In this step a vacuum draws portions of the polymer sheet into cusps at prescribed locations. Depending on the particular product, the protrusions are at 12 to 25 mm (0.5 to 1.0 in.) centers and are of a controlled depth and shape. Figure 6.13 shows a sketch of a vacuum forming system. In many of the systems the protrusions are tapered for ease in manufacturing during release of the vacuum and for a convenient male-to-female coupling of the edges and/or ends of the product in the field. The different types of drainage geocomposites are made in either continuous rolls or in discrete panels.

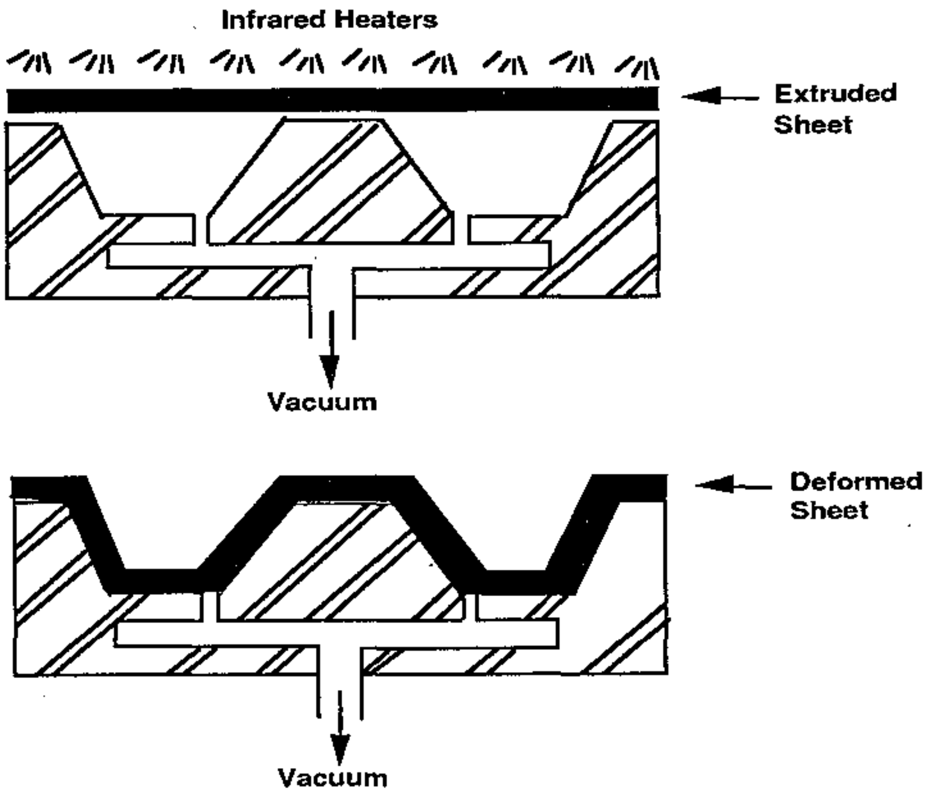


Figure 6.13 - Vacuum Forming System for Fabrication of a Drainage Geocomposite

The geotextile, which acts as both a filter to allow liquid into the drainage core and as a separator to keep soil out of the core by spanning from cusp to cusp is put onto the core as a secondary operation. Quite often an adhesive is placed on the tops of the cusps to adhere the geotextile to the core. Alternatively, heat bonding can be utilized. A variety of geotextiles can be used and the site specific design will dictate the actual selection. As far as the MQA/CQA of the geotextile it is the same as was described in Section 6.2.

There are several items which should be included in a specification or MQA document for drainage geocomposite cores.

1. There should be verification and certification that the actual geocomposite core properties meet the manufacturers specification for that particular type and style.

2. Quality control certificates should include at a minimum, polymer composition, thickness of sheet per ASTM D-5199, height of raised cusps, spacing of cusps, compressive strength behavior (both strength and deformation values at core failure) per ASTM D-1621, and transmissivity using site specific conditions per ASTM D-4716.

3. For drainage systems consisting of coarse fibers, entangled webs and/or filament mattings the thickness under load per ASTM D-5199 and transmissivity under load per ASTM D-4716 are the main tests for QC purposes.

4. Values for each property should meet, or exceed, the manufacturers listed values or the project specification values, whichever are higher.

5. A statement indicating if, and to what extent, regrind polymer was added during manufacturing. No amount of reclaimed polymer should be allowed.

6. The frequency of performing each of the preceding tests should be covered in the MQC plans and it should be implemented and followed.

Additionally, there are several items which should be included in a specification or MQA document for the geotextile(s)/drainage core geocomposite.

1. The type of geotextile(s) should be identified and properly evaluated. See section 6.2 for these details.

2. For strip (wick) drains and edge drains, see Figs. 6.12(b) and (c) respectively, the geotextile complete surrounds the drainage core and generally no fixity is required. For sheet drains, Fig. 6.12(a), this is not the case.

3. The geotextile(s) covering of a drainage core should be bonded in such a way that neither component is compromised to the point where proper functioning is impeded. Thus adequate, but not excessive, bonding of the geotextile(s) to the drainage core is necessary.

4. If bonding is by heating, the geotextile(s) strength cannot be compromised to the point where failure could occur. The transmissivity under load test, ASTM D-4716, should be performed on the intended geocomposite product.

5. If bonding is by adhesives, the type of adhesive must be identified, including its water solubility and organic content. Excessive adhesive cannot be used since it could fill up some of the drainage core's void space. The transmissivity under load test, ASTM D-4716, should be performed on the intended geocomposite product. The geotextile's permittivity could be evaluated using ASTM D-4491.

6. If the shear strength of the geotextile(s) to the core is of concern an adapted form of an interface shear test, e.g., ASTM D-5321, can be performed with a wooden substrate, or other satisfactory arrangement. Alternatively, a ply adhesion test may be adequate, see ASTM D-413 which might be suitably modified for geotextile-to-core adhesion.

7. For factory fabricated geocomposites with geotextiles placed on both sides of the drainage core, the core must be free from all dirt, dust and accumulated debris before covering.

6.4.2 Handling of Drainage Geocomposites

A number of activities occur between the manufacture of drainage geocomposites and their final positioning where intended at the waste facility. These activities involve packaging, storage at the manufacturing facility, shipment, storage at the site, acceptance and conformance testing, and final placement at the facility. Each of these topics will be described although most will be by reference to the appropriate geotextile section.

6.4.2.1 Packaging

Usually a manufacturer will not attach the geotextile to the core until an order is received and shipment is imminent. Thus warehousing is not a major issue. The cores are either rolled onto themselves or are laid flat if they are in panel form. When an order is received, the geotextile is bonded to the core, the rolls are banded together with polymer straps and, if panels, they are banded in a similar manner.

6.4.2.2 Storage at Manufacturing Facility

Storage of the drainage cores at the manufacturing facility is usually not a major issue. The cores are generally stored indoors and are thus protected from atmospheric conditions.

6.4.2.3 Shipment

Shipment of drainage geocomposites (with the geotextile attached) is quite simple due to the light weight of these geosynthetics compared to other types. The text in Section 6.2.2.3 should be utilized, however, since accidental damage can always occur.

6.4.2.4 Storage at Field Site

The storage of drainage geocomposites at the project site is similar to that described for geotextiles, recall Section 6.2.2.4.

6.4.2.5 Acceptance and Conformance Testing

The acceptance and conformance testing of the geotextile portion of a drainage geocomposite is the same as described in Section 6.2.2.5. The acceptance and conformance testing of the core portion of a drainage geocomposite is project specific with the exception of the conformance tests themselves which are different. The recommended conformance tests for geocomposite drainage cores are the following:

- thickness of sheet per ASTM D-5199 or thickness of the geocomposite per ASTM D-5199

- thickness of raised cusps per ASTM D-1621
- spacing of raised cusps per ASTM D-1621

Optional conformance tests such as compression per ASTM D-1621 and transmissivity per ASTM D-4716 may also be stipulated. The frequency of conformance tests of the drainage core must be stipulated. In general, one test per 5,000 m^2 (50,000 ft^2) should be the minimum test frequency.

6.4.2.6 Placement

The placement of drainage geocomposites in the field is similar to that described for geotextiles. Refer to Section 6.2.2.6 for details.

6.4.3 Joining of Drainage Geocomposites

Drainage geocomposites are usually joined together by folding back the geotextile from the lower core and inserting it into the bottom void space of the upper core, see Fig. 6.14. Where this is not possible a tab should be available at the edges of the core material for the purpose of overlapping. The geotextile must be refolded over the connection area assuring a complete covering of the core surface.

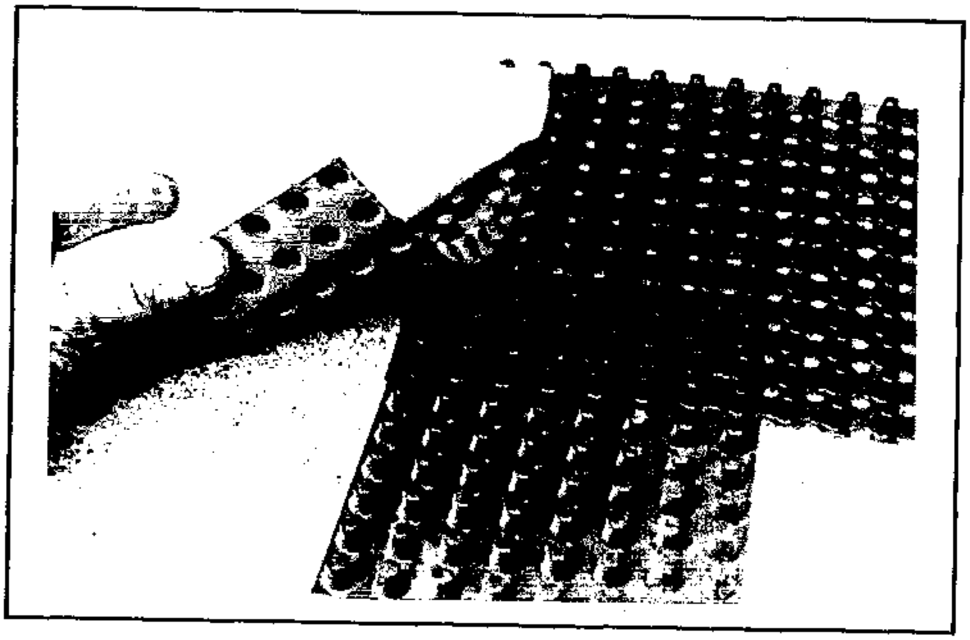


Figure 6.14 - Photograph of Drainage Core Joining via Male-to-Female Interlock

Recommended items for a specification or CQA document on the joining of drainage geocomposites include the following:

1. Adjacent edges of drainage cores should be overlapped for at least two rows of cusps.
2. The ends of drainage cores (in the direction of flow) should be overlapped for at least four rows of cusps.
3. The geotextiles covering the joined cores must provide a complete seal against backfill soil entering into the core.
4. Horizontal seams should not be allowed on sideslopes. This requires that the drainage geocomposite be provided in rolls which are at least as long as the side slope.
5. Holes or tears in drainage cores are repaired by placing a patch of the same type of material over the damaged area. The patch should extend at least four cusps beyond the edges of the hole or tear.
6. Holes or tears of more than 50% of the width of the drainage core on side slopes should require the entire length of the drainage core to be removed and replaced.
7. Holes or tears in the geotextile covering the drainage core should be repaired as described in Section 6.2.3.3.

6.4.4 <u>Covering</u>

Drainage geocomposites, with an attached geotextile, are covered with either soil, waste or in some cases a geomembrane. Regarding a specification or CQA document some comments should be included.

1. The core of the drainage geocomposite should be free of soil, dust and accumulated debris before backfilling or covering with a geomembrane. In extreme cases this may require washing of the core to accumulate the particulate material to the low end (sump) area for removal.
2. Placement of the backfilling soil, waste or geomembrane should not shift the position of the drainage geocomposite nor damage the underlying drainage geocomposite, geotextile or core.
3. When using soil or waste as backfill on side slopes, the work progress should begin at the toe of the slope and work upward.

6.5 <u>References</u>

ASTM D-413, "Rubber Property-Adhesion to Flexible Substrate"

ASTM D-792, "Specific Gravity and Density of Plastics by Displacement"

ASTM D-1238, "Flow Rates of Thermoplastics by Extrusion Plastometer"

ASTM D-1248, "Polyethylene Plastics and Extrusion Materials"

ASTM D-1505, "Density of Plastics by the Density-Gradient Technique"

ASTM D-1603, "Carbon Black in Olefin Plastics"

ASTM D-1621, "Compressive Properties of Rapid Cellular Plastics"

ASTM D-3786, "Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method"

ASTM D-4354, "Sampling of Geosynthetics for Testing"

ASTM D-4355, "Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)"

ASTM D-4491, "Water Permeability of Geotextiles by Permittivity"

ASTM D-4533, "Trapezoidal Tearing Strength of Geotextiles"

ASTM D-4632, "Breaking Load and Elongation of Geotextiles (Grab Method)"

ASTM D-4716, "Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products"

ASTM D-4751, "Determining the Apparent Opening Size of a Geotextile"

ASTM D-4759, "Determining the Specification Conformance of Geosynthetics"

ASTM D-4833, "Index Puncture Resistance of Geotextiles, Geomembranes and Related Products"

ASTM D-4873, "Identification, Storage and Handling of Geosynthetics"

ASTM D-4884, "Seam Strength of Sewn Geotextiles"

ASTM D-5199, "Measuring Nominal Thickness of Geotextiles and Geomembranes"

ASTM D-5261, "Measuring Mass Per Unit Area of Geotextiles"

ASTM D-5321, "Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method"

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Chapter 7

Vertical Cutoff Walls

7.1 Introduction

Situations occasionally arise in which it is necessary or desirable to restrict horizontal movement of liquids with vertical cutoff walls. Examples of the use of vertical cutoff walls include the following:

1. Control of ground water seepage into an excavated disposal cell to maintain stable side slopes or to limit the amount of water that must be pumped from the excavation during construction (Fig. 7.1).

2. Control of horizontal ground water flow into buried wastes at older waste disposal sites that do not contain a liner (Fig. 7.2).

3. Provide a "seal" into an aquitard (low-permeability stratum), thus "encapsulating" the waste to limit inward movement of clean ground water in areas where ground water is being pumped out and treated (Fig. 7.3).

4. Long-term barrier to impede contaminant transport (Fig. 7.4).

Vertical walls are also sometimes used to provide drainage. Drainage applications are discussed in Chapters 5 and 6.

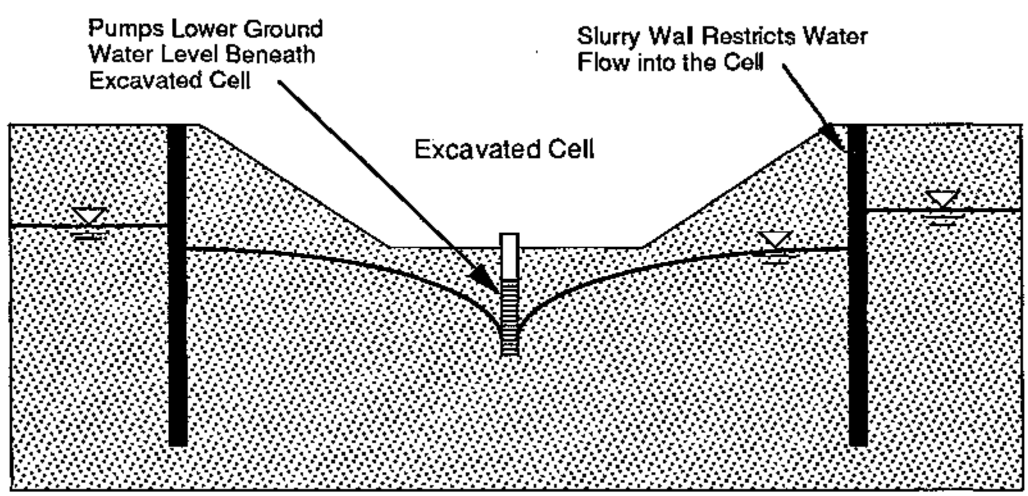

Figure 7.1 - Example of Vertical Cutoff Wall to Limit Flow of Ground Water into Excavation.

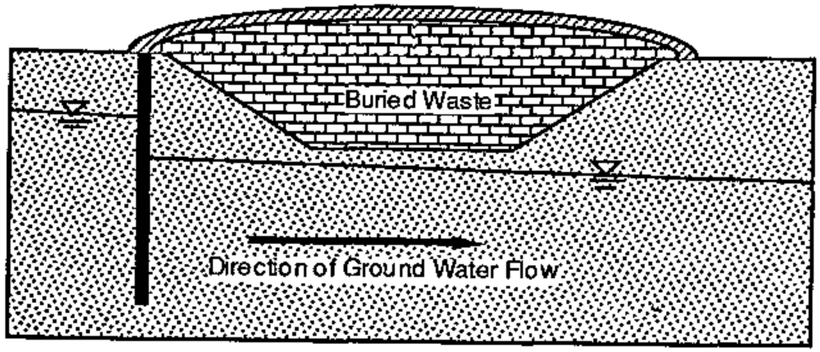

Figure 7.2 - Example of Vertical Cutoff Wall to Limit Flow of Ground Water through Buried Waste.

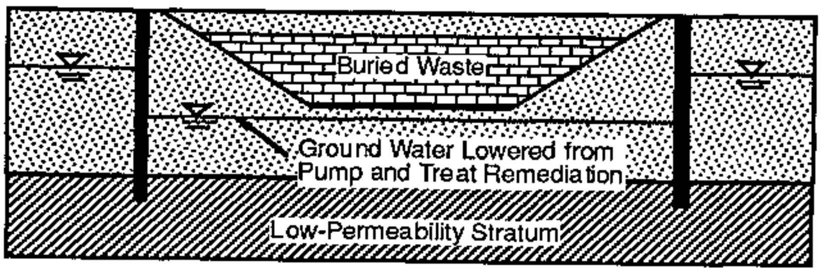

Figure 7.3 - Example of Vertical Cutoff Wall to Restrict Inward Migration of Ground Water.

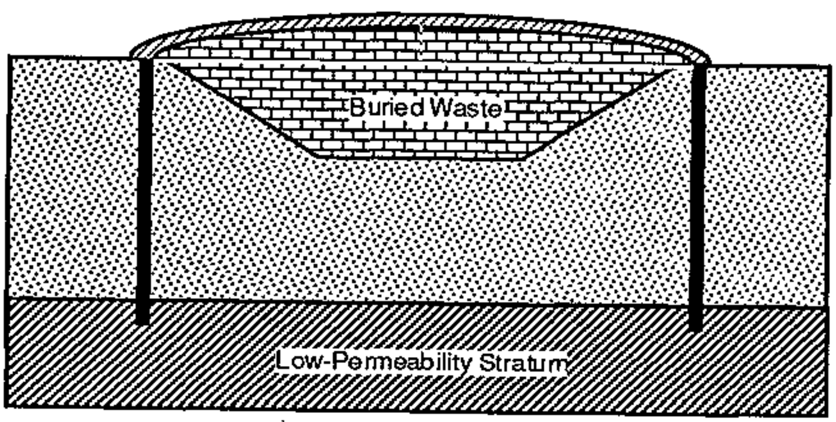

Figure 7.4 - Example of Vertical Cutoff Wall to Limit Long-Term Contaminant Transport.

7.2 Types of Vertical Cutoff Walls

The principal types of vertical cutoff walls are sheet pile walls, geomembrane walls, and slurry trench cutoff walls. Other techniques, such as grouting and deep soil mixing, are also possible, but have rarely been used for waste containment applications.

7.2.1 Sheet Pile Walls

Sheet pile walls are interlocking sections of steel or plastic materials (Fig. 7.5). Steel sheet piles are used for a variety of excavation shoring applications; the same type of steel sheet piles are used for vertical cutoff walls. Plastic sheet piles are a relatively recent development and are used on a limited basis for vertical cutoff walls. Sheet piles measure approximately 0.5 m (18 in.) in width, and interlocks join individual sheets together (Fig. 7.5). Lengths are essentially unlimited, but sheet piles are rarely longer than about 10 to 15 m (30 to 45 ft).

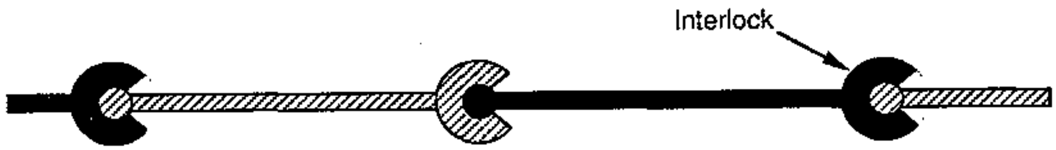

Figure 7.5 - Interlocking Steel Sheet Piles.

Plastic sheet piles are different from geomembrane panels, which are discussed later. Plastic sheet piles tend to be relatively thick-walled (wall thickness > 3 mm or 1/8 in.) and rigid; geomembrane panels tend to have a smaller thickness (< 2.5 mm or 0.1 in.), greater width, and lower rigidity.

Sheet pile walls are installed by driving or vibrating interlocking steel sheet piles into the ground. Alternatively, plastic sheet piles can be used, but special installation devices may be needed, e.g., a steel driving plate to which the plastic sheet piles are attached. To promote a seal, a cord of material that expands when hydrated and attains a very low permeability may be inserted in the interlock. Other schemes have been devised and will continue to be developed for attaining a water-tight seal in the interlock.

Sheet pile walls have a long history of use for dewatering applications, particularly where the sheet pile wall is also used as a structural wall. Sheet pile walls also have been used on several occasions to cutoff horizontal seepage through permeable strata that underlie dams (Sherard et al., 1963).

Sheet pile walls have historically suffered from problems with leakage through interlocks, although much of the older experience may not be applicable to modern sheet piles with expanding material located in the interlock (the expandable material is a relatively recent development).

Leakage through sheet pile interlocks depends primarily on the average width of openings in the interlocking connections, the percentage of the interlocks that leak, and the quality and integrity of any sealant placed in the interlock. The sheet piles may be damaged during installation, which can create ruptures in the sheet pile material or separation of sheet piles at interlocks. Because of these problems, sheet pile cutoffs have not been used for waste containment facilities as extensively as some other types of vertical cutoff walls. Sheet pile walls are not discussed further in this report.

7.2.2 Geomembrane Walls

Geomembrane walls represent a relatively new type of vertical barrier that is rapidly gaining in popularity. The geomembrane wall consists of a series of geomembrane panels joined with special interlocks (examples of interlocks are sketched in Fig. 7.6) or installed as a single unit. If the geomembrane panels contain interlocks, a water-expanding cord is used to seal the interlock.

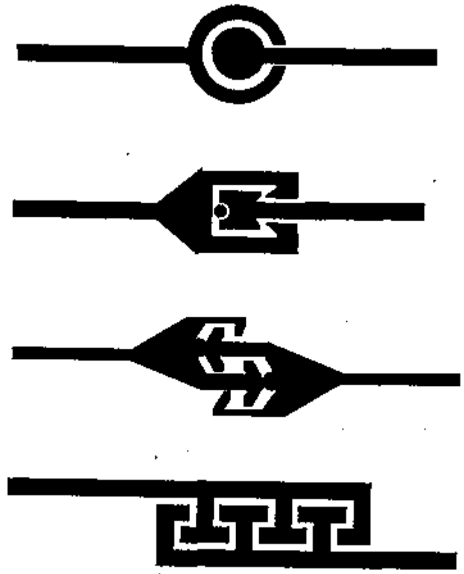

Figure 7.6 - Examples of Interlocks for Geomembrane Walls (Modified from Manassero and Pasqualini, 1992)

The technology has its roots in Europe, where slurry trench cutoff walls that are backfilled with cement-bentonite have been commonly used for several decades. One of the problems with cement-bentonite backfill, as discussed later, is that it is difficult to make the hydraulic conductivity of the cement-bentonite backfill less than or equal to 1 x 10^{-7} cm/s, which is often required of regulatory agencies in the U.S. To overcome this limitation in hydraulic conductivity and to improve the overall containment provided by the vertical cutoff wall, a geomembrane may be inserted into the cement-bentonite backfill. The geomembrane may actually be installed either in a slurry-filled trench or it may be installed directly into the ground using a special insertion plate.

7.2.3 Walls Constructed with Slurry Techniques

Walls constructed by slurry techniques (sometimes called "slurry trench cutoff walls") are described by Xanthakos (1979), D'Appolonia (1980), EPA (1984), Ryan (1987), and Evans (1993). With this technique, an excavation is made to the desired depth using a backhoe or clamshell. The trench is filled with a clay-water suspension ("mud" or "slurry"), which maintains stability of sidewalls via hydrostatic pressure. As the trench is advanced, the slurry tends to flow into the surrounding soil. Clay particles are filtered out, forming a thin skin of relatively impermeable material along the wall of the trench called a "filter cake." The filter cake has a very low hydraulic conductivity and allows the pressure from the slurry to maintain stable walls on the trench (Fig. 7.7). However, the level of slurry must generally be higher than the surrounding ground water table in order to maintain stability. If the water table is at or above the surface, a dike may be constructed to raise the surface elevation along the alignment of the slurry trench cutoff wall.

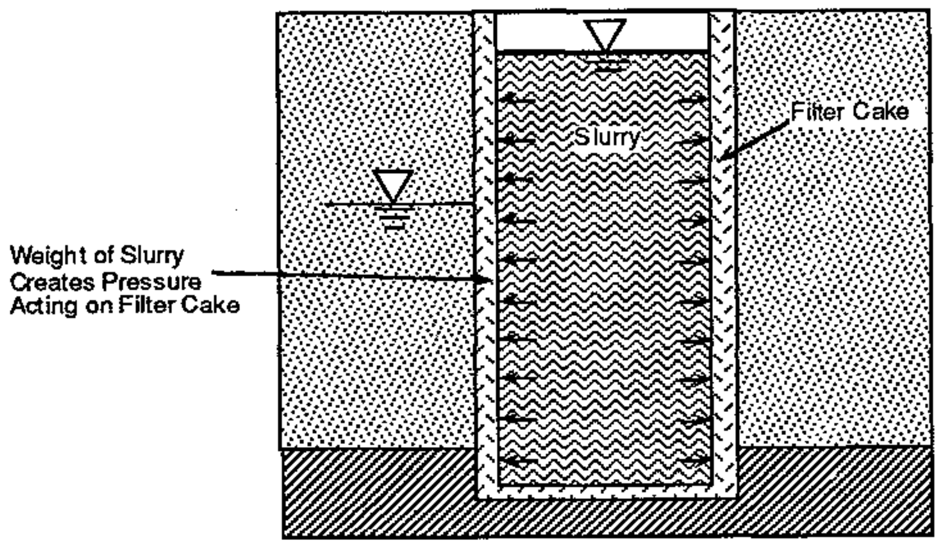

Figure 7.7 - Hydrostatic Pressure from Slurry Maintains Stable Walls of Trench.

In most cases, sodium bentonite is the clay used in the slurry. A problem with bentonite is that it does not gel properly in highly saline water or in some heavily contaminated ground waters. In such cases, an alternative clay mineral such as attapulgite may be used, or other special materials may be used to maintain a viscous slurry.

The slurry trench must either be backfilled or the slurry itself must harden into a stable material -- otherwise clay will settle out of suspension, the slurry will cease to support the walls of the trench, and the walls may eventually collapse. If the slurry is allowed to harden in place, the slurry is usually a cement-bentonite (CB) mixture. If the slurry trench is backfilled, the backfill is usually a soil-bentonite (SB) mixture, although plastic concrete may also be used (Evans, 1993).

In the U.S., slurry trenches backfilled with SB have been the most commonly used vertical cutoff trenches for waste containment applications. In Europe, the CB method of construction has been used more commonly. The reason for the different practices in the U.S. and Europe stems at least in part upon the fact that abundant supplies of high-quality sodium bentonite are readily available in the U.S. but not in Europe. Also, in most situations, SB backfill will have a somewhat lower hydraulic conductivity than cured CB slurry, and in the U.S. regulations have tended to drive the requirements for hydraulic conductivity to lower values than in Europe.

The construction sequence for a soil-bentonite backfilled trench is shown schematically in Fig. 7.8.

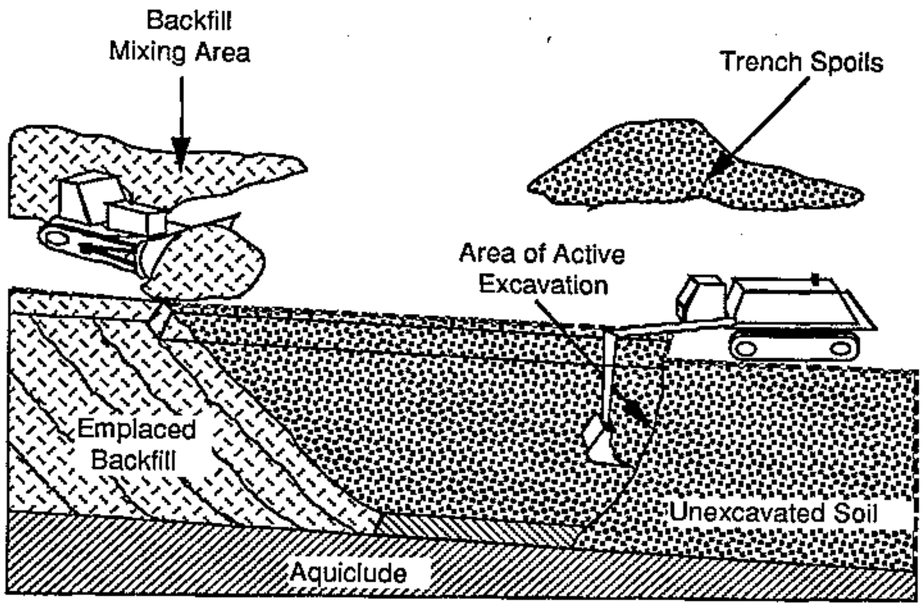

Figure 7.8 - Diagram of Construction Process for Soil-Bentonite-Backfilled Slurry Trench Cutoff Wall.

The main reasons why slurry trench cutoff walls are so commonly used for vertical cutoff walls are:

1. The depth of the trench may be checked to confirm penetration to the desired depth, and excavated materials may be examined to confirm penetration into a particular stratum;

2. The backfill can be checked prior to placement to make sure that its properties are as desired and specified;

3. The wall is relatively thick (compared to a sheet pile wall or a geomembrane wall);

4. There are no joints between panels or construction segments with the most common type of slurry trench cutoff wall construction.

In general, in comparison to sheet-pile walls, deep-soil-mixed walls, and grouted walls, there is more opportunity with a slurry trench cutoff wall to check the condition of the wall and confirm that the wall has been constructed as designed. In contrast, it is much more difficult to confirm that a sheet pile wall has been installed without damage, that grout has fully penetrated all of the desired pore spaces in the soil, or that deep mixing as taken place as desired.

7.3 Construction of Slurry Trench Cutoff Walls

The major construction activities involved in building a slurry cutoff wall are preconstruction planning and mobilization, preparation of the site, slurry mixing and hydration, excavation of soil, backfill preparation, placement of backfill, clean-up of the site, and demobilization. These activities are described briefly in the paragraphs that follow.

7.3.1 Mobilization

The first major construction activity is to make an assessment of the site and to mobilize for construction. The contractor locates the slurry trench cutoff wall in the field with appropriate surveys. The contractor determines the equipment that will be needed, amounts of materials, and facilities that may be required. Plans are made for mobilizing personnel and moving equipment to the site.

A preconstruction meeting between the designer, contractor, and CQA engineer is recommended. In this meeting, materials, construction procedures, procedures for MQA of the bentonite and CQA of all aspects of the project, and corrective actions are discussed (see Chapter 1).

7.3.2 Site Preparation

Construction begins with preparation of the site. Obstacles are removed, necessary relocations of utilities are made, and the surface is prepared. One of the requirements of slurry trench construction is that the level of slurry in the trench be greater than the level of ground water. If the ground water table is high, it may be necessary to construct a dike to ensure that the level of slurry in the trench is above the ground water level (Fig. 7.9). There may be grade restrictions in the construction specifications which will require some regrading of the surface or construction of dikes in low-lying areas. The site preparation work will typically also include preparation of working surfaces for mixing materials. Special techniques may be required for exacavation around utility lines.

7.3.3 Slurry Preparation and Properties

Before excavation begins, as well as during excavation, the slurry must be prepared. The slurry usually consists of a mixture of bentonitic clay with water, but sometimes other clays such as attapulgite are used. If the clay is bentonite, the specifications should stipulate the criteria to be met, e.g., filtrate loss, and the testing technique by which the parameter is to be determined. The criteria can vary considerably from project to project.

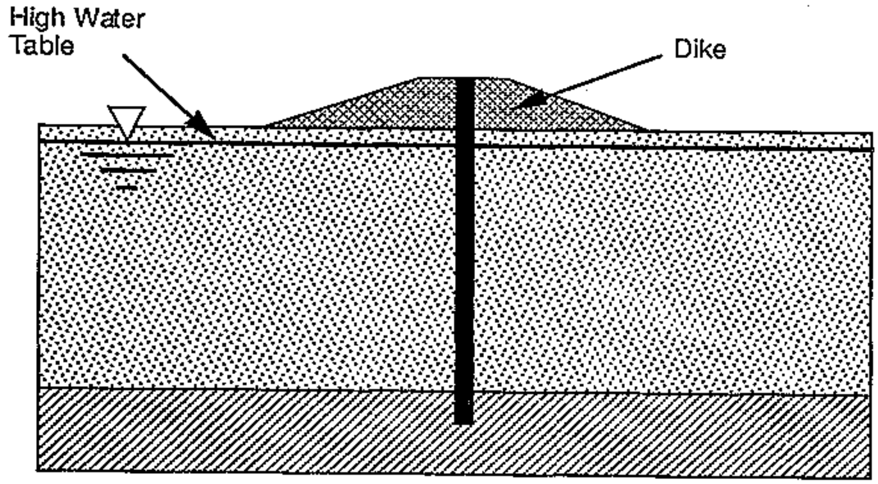

Figure 7.9 - Construction of Dike to Raise Ground Surface for Construction of Slurry Trench.

The clay may be mixed with water in either a batch or flash mixing operation. In the batch system specified quantities of water and bentonite are added in a tank and mixed at high speeds with a pump, paddle mixer, or other device that provides adequate high-speed colloidal shear mixing. Water and clay are mixed until hydration is complete and the desired properties of the slurry have been achieved. Complete mixing is usually achieved in a few minutes. The size of batch mixers varies, but typically a batch mixer will produce several cubic meters of mixed slurry at a time.

Flash mixing is achieved with a venturi mixer. With this system, bentonite is fed at a predetermined rate into a metered water stream that is forced through a nozzle at a constant rate. The slurry is subjected to high shear mixing for only a fraction of a second. The problem with this technique is that complete hydration does not take place in the short period of mixing. After the clay is mixed with water, the resulting slurry is tested to make sure the density and viscosity are within the requirements set forth in the CQA plan.

The mixed slurry may be pumped directly to the trench or to a holding pond or tank. If the slurry is stored in a tank or pond, CQA personnel should check the properties of the slurry periodically to make sure that the properties have not changed due to thixotropic processes or sedimentation of material from the slurry. The specifications for the project should stipulate mixing or circulation requirements for slurry that is stored after mixing.

The properties of the slurry used to maintain the stability of the trench are important. The following pertains to a bentonite slurry that will ultimately be displaced by soil-bentonite or other backfill; requirements for cement-bentonite slurry are discussed later in section 7.3.6. The slurry must be sufficiently dense and viscous to maintain stability of the trench. However, the slurry must not be too dense or viscous: otherwise, it will be difficult to displace the slurry when backfill is placed. Construction specifications normally set limits on the properties of the slurry. Typically about 4-8% bentonite by weight is added to fresh water to form a slurry that has a specific gravity of about 1.05 to 1.15. During excavation of the trench additional fines may become suspended in the slurry, and the specific gravity is likely to be greater than the value of the freshly mixed slurry. The specific gravity of the slurry during excavation is typically on the order of 1.10 - 1.25.

The density of the slurry is measured with the procedures outlined in ASTM D-4380. A known volume of slurry is poured into a special "mud balance," which contains a cup on one end of a balance. The weight is determined and density calculated from the known volume of the cup.

The viscosity of the slurry is usually measured with a Marsh funnel. To determine the Marsh viscosity, fluid is poured into the funnel to a prescribed level. The number of seconds required to discharge 946 mL (1 quart) of slurry into a cup is measured. Water has a Marsh viscosity of about 26 seconds at 23°C. Freshly hydrated bentonite slurry should have a Marsh viscosity in the range of about 40 - 50 seconds. During excavation, the viscosity typically increases to as high as about 65 Marsh seconds. If the viscosity becomes too large the thick slurry must be replaced, treated (e.g., to remove sand), or diluted with additional fresh slurry.

The sand content of a slurry may also be specified. Although sand is not added to fresh slurry, the slurry may pick up sand in the trench during the construction process. The sand content by volume is measured with ASTM D-4381. A special glass measuring tube is used for the test. The slurry is poured onto a No. 200 sieve (0.075 mm openings), which is repeatedly washed until the water running through the sieve is clear. The sand is washed into the special glass measuring tube, and the sand content (volumetric) is read directly from graduation marks.

Other criteria may be established for the slurry. However, filtrate loss and density, coupled with viscosity, are the primary control variables. The specifications should set limits on these parameters as well as specify the test method. Standards of the American Petroleum Institute (1990) are often cited for slurry test methods. Limits may also be set on pH, gel strength, and other parameters, depending on the specific application.

The primarily responsibility for monitoring the properties of the slurry rests with the construction quality control (CQC) team. The properties of the slurry directly affect construction operations but may also impact the final quality of the slurry trench cutoff wall . For example, if the slurry is too dense or viscous, the slurry may not be properly displaced by backfill. On the other hand, if the slurry is too thin and lacks adequate bentonite, the soil-bentonite backfill (formed by mixing soil with the bentonite slurry) may also lack adequate bentonite. The CQA inspectors may periodically perform tests on the slurry, but these tests are usually conducted primarily to verify test results from the CQC team. CQA personnel should be especially watchful to make sure that: (1) the slurry has a sufficiently high viscosity and density (if not, the trench walls may collapse); (2) the level of the slurry is maintained near the top of the trench and above the water table (usually the level must be at least 1 m above the ground water table to maintain a stable trench); and (3) the slurry does not become too viscous or dense (otherwise backfill will not properly displace the slurry).

7.3.4 Excavation of Slurry Trench

The slurry trench is excavated with a backhoe (Fig. 7.10) or a clam shell (Fig. 7.11). Long-stick backhoes can dig to depths of approximately 20 to 25 m (60 to 80 ft). For slurry trenches that can be excavated with a backhoe, the backhoe is almost always the most economical means of excavation. For trenches that are too deep to be excavated with a backhoe, a clam shell is normally used. The trench may be excavated first with a backhoe to the maximum depth of excavation that is achievable with the backhoe and to further depths with a clam shell. Special chopping, chiseling, or other equipment may be used as necessary. The width of the excavation tool is usually equal to the width of the trench and is typically 0.6 to 1.2 m (2 to 4 ft).

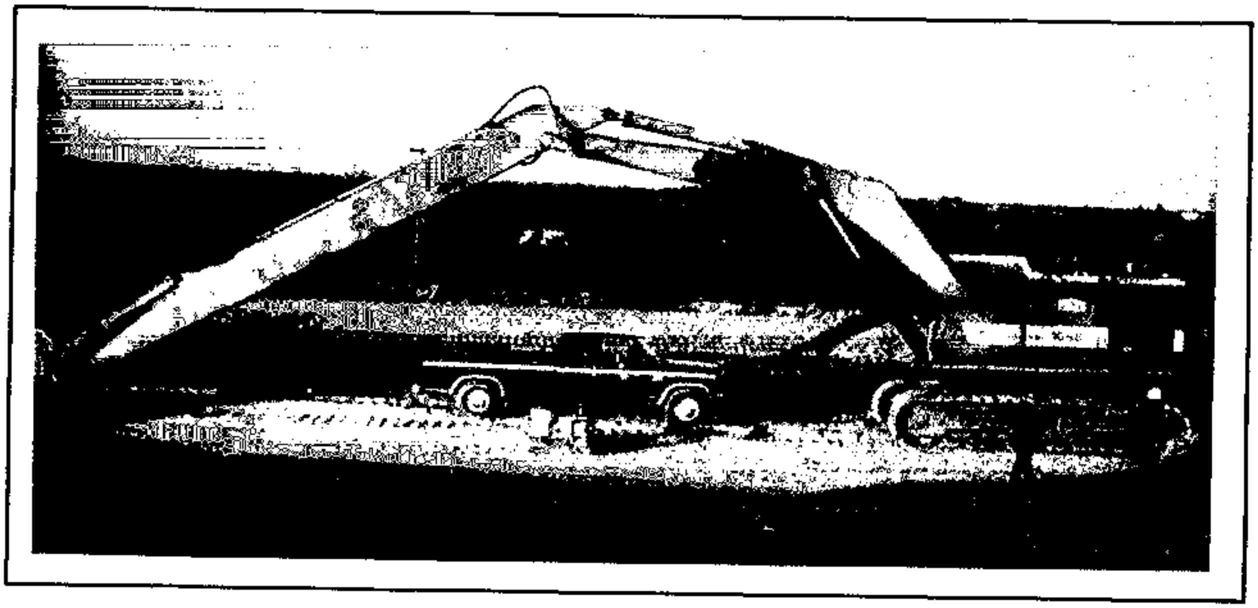

Figure 7.10 - Backhoe for Excavating Slurry Trench.

In most instances, the slurry trench cutoff wall is keyed into a stratum of relatively low hydraulic conductivity. In some instances, the vertical cutoff wall may be relatively shallow. For example, if a floating non-aqueous phase liquid such as gasoline is to be contained, the slurry trench cutoff wall may need to extend only a short distance below the water table surface, depending upon the site-specific circumstances. CQC/CQA personnel monitor the depth of excavation of the slurry trench and should log excavated materials to verify the types of materials present and to ensure specified penetration into a low-permeability layer. Monitoring normally involves examining soils that are excavated and direct measurement of the depth of trench by lowering a weight on a measuring tape down through the slurry. Additional equipment such as air lifts may be needed to remove sandy materials from the bottom of the trench prior to backfill.

7.3.5 Soil-Bentonite (SB) Backfill

Soil is mixed with the bentonite-water slurry to form soil-bentonite (SB) backfill. If the soil is too coarse, additional fines can be added. Dry, powdered bentonite may also be added, although it is difficult to ensure that the dry bentonite is uniformly distributed. In special applications in which the properties of the bentonite are degraded by the ground water, other types of clay may be used, e.g., attapulgite, to form a mineral-soil backfill. If possible, soil excavated from the trench is used for the soil component of SB backfill. However, if excavated soil is excessively contaminated or does not have the proper gradation, excavated soil may be hauled off for treatment and disposal.

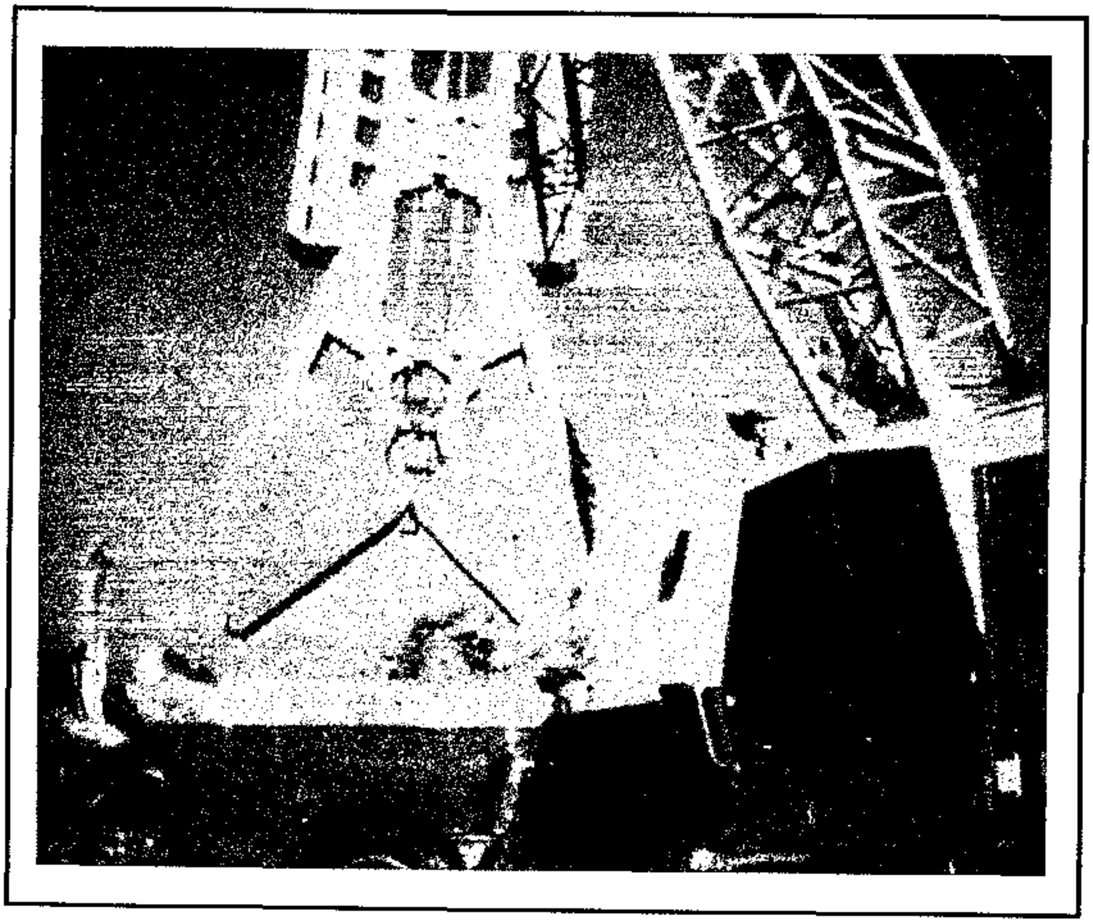

Figure 7.11. Clamshell for Excavating Slurry Trench.

Two parameters concerning the backfill are very important: (1) the presence of extremely coarse material (i.e., coarse gravel and cobbles), and (2) the presence of fine material. Coarse gravel is defined as material with particle sizes between 19 and 75 mm (ASTM D-2487). Cobbles are materials with particle sizes greater than 75 mm. Fine material is material passing the No. 200 sieve, which has openings of 0.075 mm. Cobbles will tend to settle and segregate in the backfill; coarse gravel may also segregate, but the degree of segregation depends on site-specific conditions. In some cases, the backfill may have to be screened to remove pieces that exceed the maximum size allowed in the specifications. The hydraulic conductivity of the backfill is affected by the percentage of fines present (D'Appolonia, 1980; Ryan, 1987; and Evans, 1993). Often, a minimum percentage of fines is specified. Ideally, the backfill material should contain at least 10 to 30% fines to achieve low hydraulic conductivity ($< 10^{-7}$ cm/s).

The bentonite may be added in two ways: (1) soil is mixed with the bentonite slurry (usually with a dozer, as shown in Fig. 7.12) to form a viscous SB material; and (2) additional dry powdered bentonite may be added to the soil-bentonite slurry mixture. Dry, powdered bentonite may or may not be needed. D'Appolonia (1980) and Ryan (1987) discuss many of the details of SB backfill design.

Figure 7.12 - Mixing Backfill with Bentonite Slurry.

When SB backfill is used, a more-or-less continuous process of excavation, preparation of backfill, and backfilling is used. To initiate the process, backfill is placed by lowering it to the bottom of the trench, e.g., with a clamshell bucket, or placing it below the slurry surface with a tremie pipe (similar to a very long funnel) until the backfill rises above the surface of the slurry trench at the starting point of the trench. Additional SB backfill is then typically pushed into the trench with a dozer (Fig. 7.13). The viscous backfill sloughs downward and displaces the slurry in the trench. As an alternative method to initiate backfilling, a separate trench that is not part of the final slurry trench cutoff wall, called a lead-in trench, may be excavated outside at a point outside of the limits of the final slurry trench and backfilled with the process just described, to achieve full backfill at the point of initiation of the desired slurry trench.

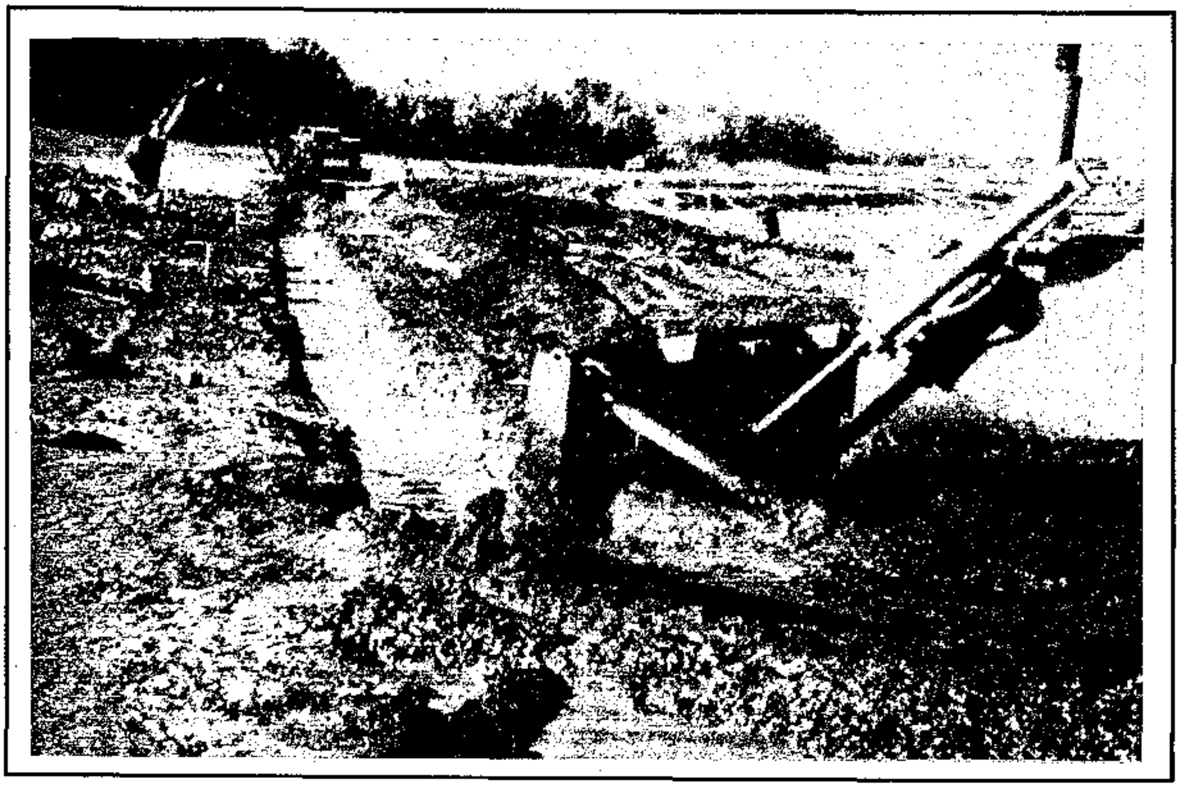

Figure 7.13 - Pushing Soil-Bentonite Backfill Into Slurry Trench with Dozer.

After the trench has been backfilled, low hydraulic conductivity is achieved via two mechanisms: (1) the SB backfill itself has low hydraulic conductivity (typical design value is $\leq 10^{-7}$ cm/s), and (2) the filter cake enhances the overall function of the wall as a barrier. Designers do not normally count on the filter cake as a component of the barrier; it is viewed as a possible source of added impermeability that enhances the reliability of the wall.

The compatibility of the backfill material with the ground water at a site should be assessed prior to construction. However, CQA personnel should be watchful for ground water conditions that may differ from those assumed in the compatibility testing program. CQA personnel should familiarize themselves with the compatibility testing program. Substances that are particularly aggressive to clay backfills include non-water-soluble organic chemicals, high and low pH liquids, and highly saline water. If there is any question about ground water conditions in relationship to the conditions covered in the compatibility testing program, the CQA engineer and/or design engineer should be consulted.

Improper backfilling of slurry trench cutoff walls can produce defects (Fig. 7.14). More details are given by Evans (1993). CQA personnel should watch out for accumulation of sandy materials during pauses in construction, e.g., during shutdowns or overnight; an airlift can be used to remove or resuspend the sand, if necessary.

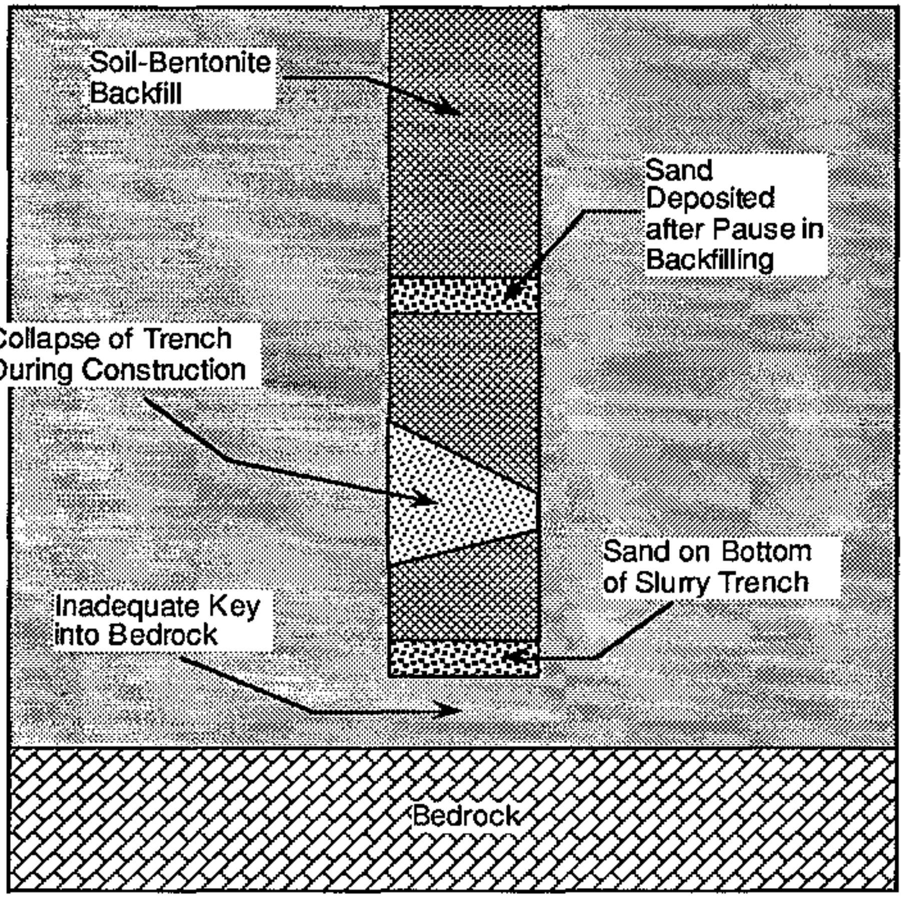

Figure 7.14 - Examples of Problems Produced by Improper Backfilling of Slurry Trench.

Some slurry trench cutoff walls fully encircle an area. As the slurry trench reaches the point of initiation of the slurry trench cutoff wall, closure is accomplished by excavating into the previously-backfilled wall.

Hydraulic conductivity of SB backfill is normally measured by testing of small cylinders of material formed from field samples. Ideally, a sample of backfill material is scooped up from the backfill, placed in a cylinder of a specified type, consolidated to a prescribed effective stress, and permeated. It is rare for borings to be drilled into the backfill to obtain samples for testing.

7.3.6 Cement-Bentonite (CB) Cutoff Walls

A cement-bentonite (CB) cutoff wall is constructed with a cement-bentonite-water mixture that hardens and attains low hydraulic conductivity. The slurry trench is excavated, and excavated soils are hauled away. Then the trench is backfilled in one of two ways. In the usual method, the slurry used to maintain a stable trench during construction is CB rather than just bentonite-water, and the slurry is left in place to harden. A much-less-common technique is to construct the slurry trench with a bentonite-water slurry in discrete diaphragm cells (Fig. 7.15), and to displace the bentonite-water slurry with CB in each cell.

The CB mixture cures with time and hardens to the consistency of a medium to stiff clay (CB backfill is not nearly as strong as structural concrete). A typical CB slurry consists on a weight basis of 75 to 80% water, 15 to 20% cement, 5% bentonite, and a small amount of viscosity reducing material. Unfortunately, CB backfill is usually more permeable than SB backfill. Hydraulic conductivity of CB backfill is often in the range of 10^{-6} to 10^{-5} cm/s, which is about an order of magnitude or more greater than typical SB cutoff walls.

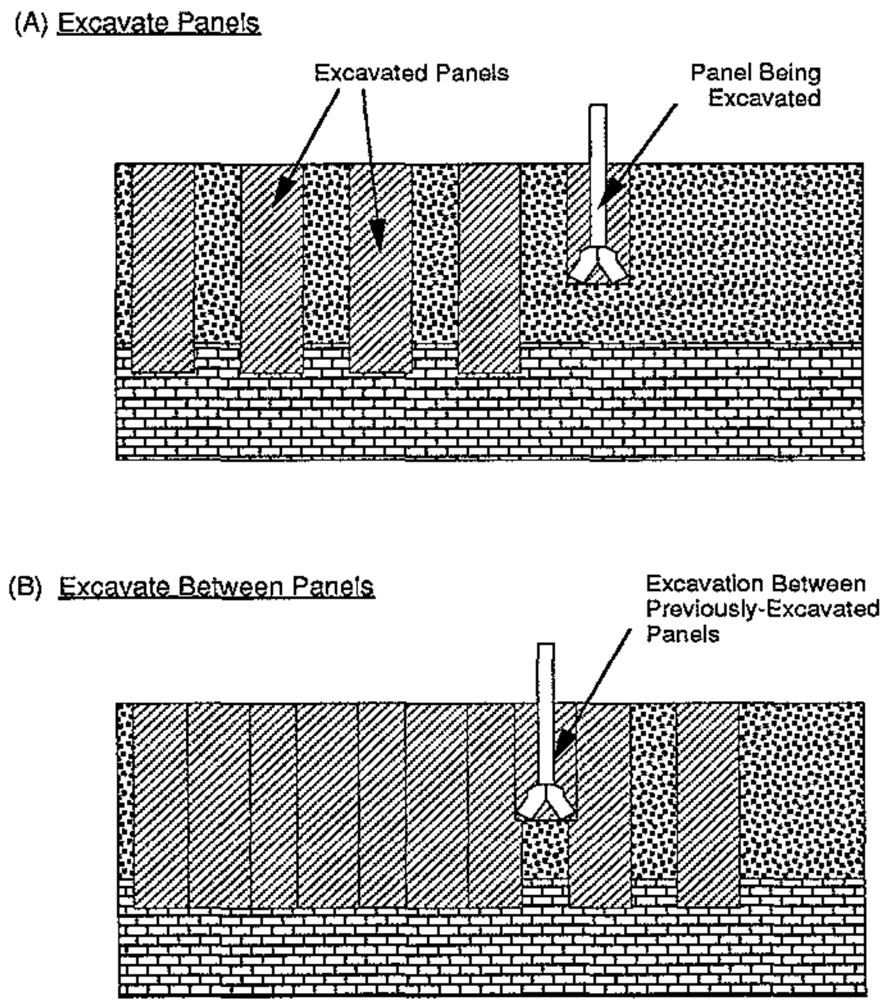

Figure 7.15 - Diaphragm-Wall Construction.

The CB cutoff wall is constructed using procedures almost identical to those employed in building structural diaphragm walls . In Europe, CB backfilled slurry trench cutoff walls are much more common than in the U.S., at least partly because the diaphragm-wall construction capability is more broadly available in Europe and because high-grade sodium bentonite (which is critical for soil-bentonite backfilled walls) is not readily available in Europe. In Europe, the CB often contains other ingredients besides cement, bentonite, and water, e.g., slag and fly ash.

7.3.7 Geomembrane in Slurry Trench Cutoff Walls

Geomembranes may be used to form a vertical cutoff wall. The geomembrane may be installed in one of at least two ways:

1. The geomembrane may be inserted in a trench filled with CB slurry to provide a composite CB-geomembrane barrier (Manassero and Pasqualini, 1992). The geomembrane is typically mounted to a frame, and the frame is lowered into the slurry. The base of the geomembrane contains a weight such that when the geomembrane is released from the frame, the frame can be removed without the geomembrane floating to the top. CQA personnel should be particularly watchful to ensure that the geomembrane is properly weighted and does not float out of position. Interlocks between geomembrane panels (Fig. 7.6) provide a seal between panels. The panels are typically relatively wide (of the order of 3 to 7 m) to minimize the number of interlocks and to speed installation. The width of a panel may be controlled by the width of excavated sections of CB-filled panels (Fig. 7.15).

2. The geomembrane may be driven directly into the CB backfill or into the native ground. Panels of geomembrane with widths of the order of 0.5 to 1 m (18 to 36 in.) are attached to a guide or insertion plate, which is driven or vibrated into the subsurface. If the panels are driven into a CB backfill material, the panels should be driven before the backfill sets up. Interlocks between geomembrane panels (Fig. 7.6) provide a seal between panels. This methodology is essentially the same as that of a sheet pile wall.

Although use of geomembranes in slurry trench cutoff walls is relatively new, the technology is gaining popularity. The promise of a practically impermeable vertical barrier, plus excellent chemical resistance of HDPE geomembranes, are compelling advantages. Development of more efficient construction procedures will make this type of cutoff wall increasingly attractive.

7.3.8 Other Backfills

Structural concrete could be used as a backfill, but if concrete is used, the material normally contains bentonite and is termed *plastic concrete* (Evans, 1993). Plastic concrete is a mixture of cement, bentonite, water, and aggregate. Plastic concrete is different from structural concrete because it contains bentonite and is different from SB backfill because plastic concrete contains aggregate. Other ingredients, e.g., fly ash, may be incorporated into the plastic concrete. Construction is typically with the panel method (Fig. 7.15). Hydraulic conductivity of the backfill can be $< 10^{-8}$ cm/s. High cost of plastic concrete limits its use.

A relatively new type of backfill is termed soil-cement-bentonite (SCB). The SCB wall uses native soils (not aggregates, as with plastic concrete). Placement is in a continuous trench rather than panel method.

7.3.9 Caps

A cutoff wall cap represents the final surface cap on top of the slurry trench cutoff wall. The cap may be designed to minimize infiltration, withstand traffic loadings, or serve other purposes. CQA personnel should also inspect the cap as well as the wall itself to ensure that the cap conforms with specification.

7.4 Other Types of Cutoff Walls

Evans (1993) discusses other types of cutoff walls. These include vibrating beam cutoff walls, deep soil mixed walls, and other types of cutoff walls. These are not discussed in detail here because these types of walls have been used much less frequently than the other types.

7.5 Specific CQA Requirements

No standard types of tests or frequencies of testing have evolved in the industry for construction of vertical cutoff walls. Among the reasons for this is the fact that construction materials and technology are continually improving. Recommendations from this section were taken largely from recommendations provided by Evans (personal communication).

For slurry trench cutoff walls, the following comments are applicable. The raw bentonite (or other clay) that is used to make the slurry may have specific requirements that must be met. If so, tests should be performed to verify those properties. There are no standard tests or frequency of tests for the bentonite. The reader may wish to consult Section 2.6.5 for a general discussion of tests and testing frequencies for bentonite-soil liners. For the slurry itself, common tests include viscosity, unit weight, and filtrate loss, and other tests often include pH and sand content. The properties of the slurry are normally measured on a regular basis by the contractor's CQC personnel; CQA personnel may perform occasional independent checks.

The soil that is excavated from the trench should be continuously logged by CQA personnel to verify that subsurface conditions are similar to those that were anticipated. The CQA personnel should look for evidence of instability in the walls of the trench (e.g., sloughing at the surface next to the trench or development of tension cracks). If the trench is to extend into a particular stratum (e.g., an aquitard), CQA personnel should verify that adequate penetration has occurred. The recommended procedure is to measure the depth of the trench once the excavator has encountered the aquitard and to measure the depth again, after adequate penetration is thought to have been made into the aquitard.

After the slurry has been prepared, and CQC tests indicate that the properties are adequate, additional samples are often taken of the slurry from the trench. The samples are often taken from near the base of the trench using a special sampler that is capable of trapping slurry from the bottom of the trench. The unit weight is particularly important because sediment may collect near the bottom of the trench. For SB backfill, the slurry must not be heavier than the backfill. The depth of the trench should also be confirmed by CQA personnel just prior to backfilling. Often, sediments can accumulate near the base of the trench -- the best time to check for accumulation is just prior to backfilling. CQA personnel should be particularly careful to check for sedimentation after periods when the slurry has not been agitated, e.g., after an overnight work stoppage.

Testing of SB backfill usually includes unit weight, slump, gradation, and hydraulic conductivity. Bentonite content may also be measured, e.g., using the methylene blue test (Alther, 1983). Slump testing is the same as for concrete (ASTM C-143). Hydraulic conductivity testing is often performed using the API (1990) fixed-ring device for the filter press test. Occasional comparative tests with ASTM D-5084 should be conducted. There is no widely-applied frequency of testing backfill materials.

7.6 Post Construction Tests for Continuity

At the present time, no testing procedures are available to determine the continuity of a completed vertical cutoff wall.

7.7 References

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ASTM D-2487, "Classification of Soils for Engineering Purposes (Unified Soil Classification System)."

ASTM D-4380, "Density of Bentonitic Slurries."

ASTM D-4381, "Sand Content by Volume of Bentonite Slurries."

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Chapter 8

Ancillary Materials, Appurtenances and Other Details

This chapter is devoted toward ancillary materials used within a waste containment facility, various appurtenances which are necessary for proper functioning of the system and other important details. Ancillary materials such as plastic pipe for leachate transmission, sumps for collection of leachate, manholes and pipe risers for removal of leachate will be covered in this chapter. Appurtenances, such as penetrations made through various barrier materials, will be covered. Lastly, other important details requiring careful inspection, such as anchor trenches, internal dikes and berms, and access ramps, will also be addressed.

8.1 Plastic Pipe (aka "Geopipe")

Whenever the primary or secondary leachate collection system at the bottom of a waste containment facility is a natural soil material, such as sand or gravel, a perforated piping system should be located within it to rapidly transmit the leachate to a sump and removal system. Figure 8.1 illustrates the cross section of such a pipe system which is generally located directly on top of the geomembrane or geotextile to 225 mm (9.0 in.) above the primary liner material. This is a design issue and the plans and specifications must be clear and detailed regarding these dimensions.

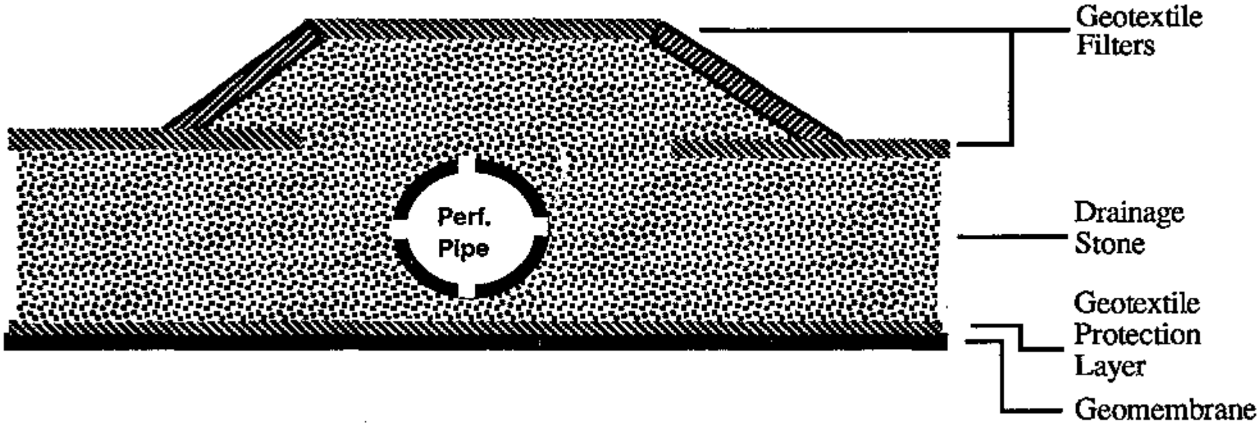


Figure 8.1 - Cross Section of a Possible Removal Pipe Scheme in a Primary Leachate Collection and Removal System (for illustration purposes only).

The pipes are sometimes placed in a manifold configuration with feeder lines framing into a larger main trunk line thus covering the entire footprint of the landfill unit or cell, see Fig. 8.2. The entire pipe network flows gravitationally to a low point where the sump and removal system

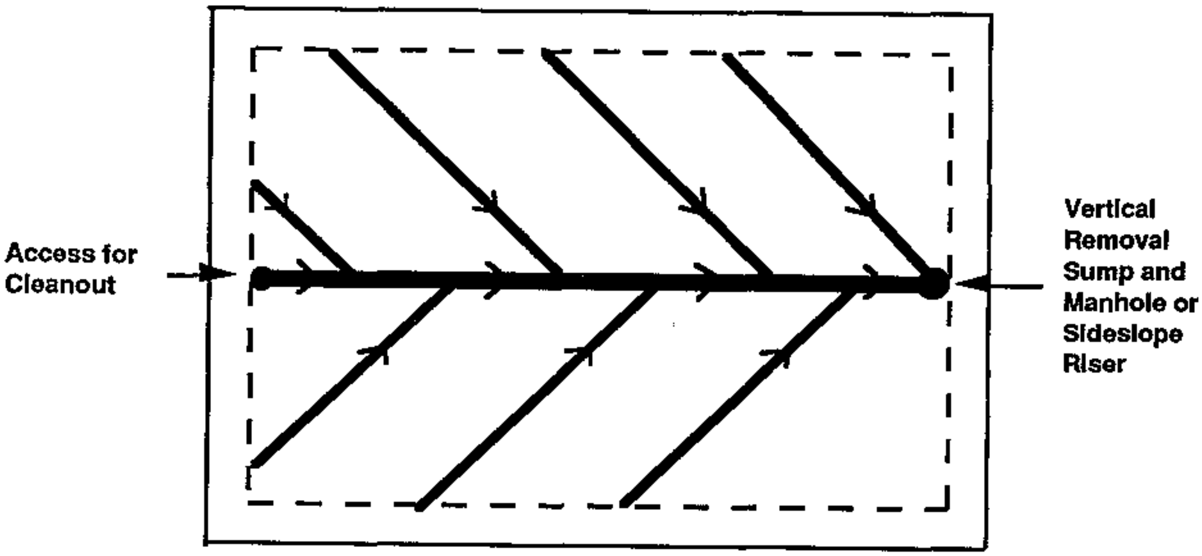


Figure 8.2 - Plan View of a Possible Removal Pipe Scheme in a Primary Leachate Collection and Removal System (for illustration purposes only).

consisting of either a manhole or pipe riser is located. The diagonal feeder pipes, if included, are always perforated to allow the leachate to enter into them. The central trunk lines may or may not be perforated depending on the site specific design. It must be recognized, however, that there is a large variety of schemes that are possible and it is clearly a design issue which must be unequivocally presented in the plans and specifications.

Leachate collection and transmission lines in most waste containment facilities are plastic pipe, with polyvinyl chloride (PVC) and high density polyethylene (HDPE) being the two major material types in current use. Furthermore, there are two types of HDPE pipe in current use, solid wall and corrugated types. Each of these types of plastic pipes will be described.

8.1.1 Polyvinyl Chloride (PVC) Pipe

Polyvinyl chloride (PVC) pipe has been used in waste containment systems for leachate collection and removal in a number of different locations and configurations. The pipes can be perforated or not depending on the site specific design. The pipes are often supplied in 6.1 m (20 ft) lengths which are joined by couplings or utilize bell and spigot ends. The PVC material typically consists of resin, fillers, carbon black/pigment and additives. PVC pipe does not contain any liquid plasticizers, see Fig. 8.3.

Regarding a specification or a MQA document for PVC pipe and fittings the following items should be considered.

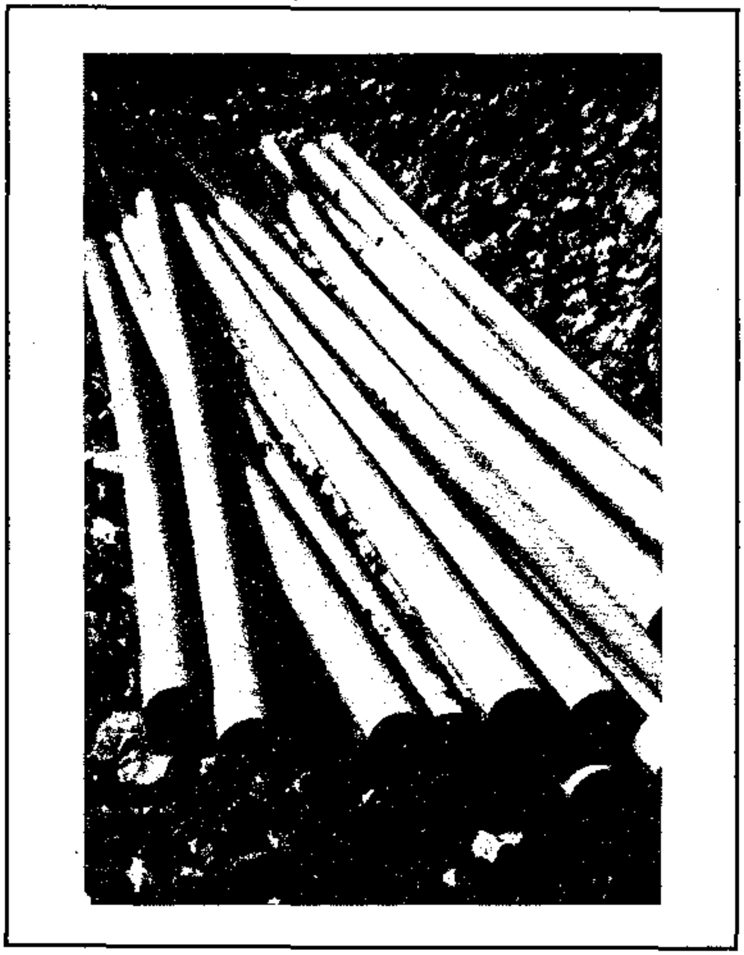


Figure 8.3 - Photograph of PVC Pipe to be Used in a Landfill Leachate Collection System.

1. The basic resin should be made from PVC as defined in ASTM D-1755. Details are contained therein.

2. Other materials in the formulation, such as fillers, carbon black/pigment and additives should be stipulated and certified as to the extent of their prior use in plastic pipe.

3. Clean rework material, generated from the manufacturer's own pipe or fitting production may be used by the same manufacturer providing that the rework material meets the above requirements. See section 3.2.2 for a description of possible use of reworked and/or recycled material.

4. Pipe tolerances and properties must meet the applicable standards for the particular grade required by the plans and specifications. For PVC pipe specified as Schedule 40, 80 and 120, the appropriate specification is ASTM D-1785. For PVC pipe in the standard dimension ratio (SDR) series, the applicable specification is ASTM D-2241.

5. Both of the above referenced ASTM Standards have sections on product marking and identification which should be followed as well as requiring the manufacturer to provide a certification statement stating that the applicable standard has been followed.

6. PVC pipe fittings should be in accordance with ASTM D-3034. This standard includes comments on solvent cement and elastomeric gasket joints as well as a section on product marking and certification.

8.1.2 High Density Polyethylene (HDPE) Smooth Wall Pipe

High density polyethylene (HDPE) smooth wall pipe has been used in waste containment systems for leachate collection and removal in a number of different locations and configurations. The pipe can be perforated or not depending on the site specific design. The pipes are often supplied in 6.1 m (20 ft) lengths which are generally joined together using butt-end fusion using a hot plate as per the gas pipe construction industry. Other joining variations such as bell and spigot, male-to-female and threading are also available. The HDPE material itself consists of 97-98% resin, approximately 2% carbon black and up to 1% additives. Figure 8.4 illustrates the use of HDPE smooth pipe.

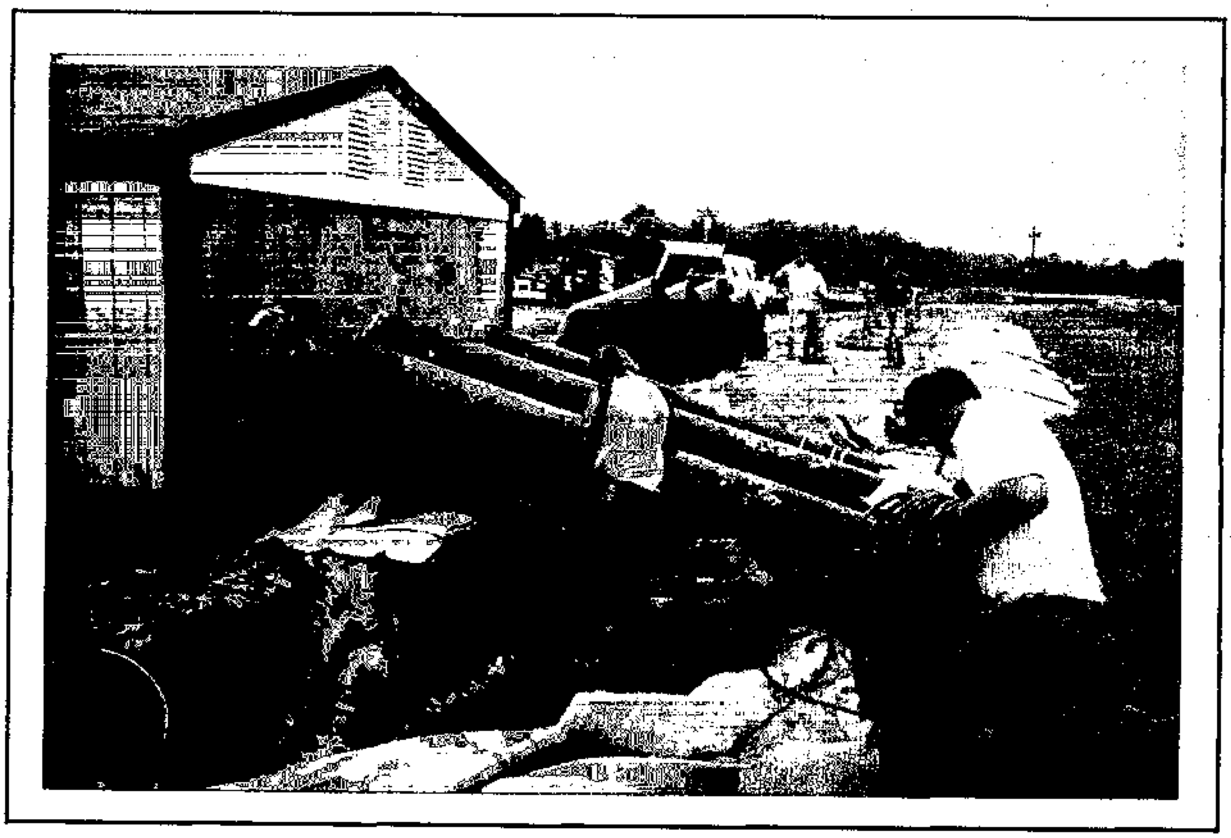


Figure 8.4 - Photograph of HDPE Smooth Wall Pipe Risers Used as Primary and Secondary Removal Systems from Sump Area to Pump and Monitoring Station.

The following items should be considered regarding the contract specification or MQA document on HDPE solid wall pipe and fittings:

1. The basic material should be made of HDPE resin and should conform to the requirements of ASTM D-1248. Details are contained therein.

2. Quality control tests on the resin are typically density and melt flow index. The appropriate designations are ASTM D-1505 or D-792 and D-1238, respectively. Other in-house quality control tests should be encouraged and followed by the manufacturer.

3. Typical densities for HDPE pipe resins are 0.950 to 0.960 g/cc. This is a Type III HDPE resin according to ASTM D-1248 and is higher than the density of the resin used in HDPE geomembranes and geonets.

4. Carbon black can be added as a concentrate, as it customarily is, or as a powder. The type and amount of carbon black, as well as the type of carrier resin if concentrated pellets are used, should be stated and certified by the manufacturer.

5. The amount of additives used should be stated by the manufacturer. If certification is required it would typically not state the type of additive, since they are usually proprietary, but should state that the additive package has successfully been used in the past and to what extent.

8.1.3 High Density Polyethylene (HDPE) Corrugated Pipe

Corrugated high density polyethylene (HDPE), also called "profiled" pipe, has been used in waste containment systems for leachate collection and removal in a number of different locations and configurations. The pipe can be perforated or slotted depending on the site specific design. The inside can be smooth lined or not depending on the site specific design. The pipes are often supplied in 6.1 m (20 ft) lengths which are joined together by couplings made by the same manufacturer as the pipe itself. This is important since the couplings are generally not interchangeable among different pipe manufacturer's products. The HDPE material itself consists of 97-98% resin, approximately 2% carbon black and up to 1% additives. Figure 8.5 illustrates HDPE corrugated pipe.

Regarding the contract specification or MQA document on HDPE corrugated pipe and fittings, the following items should be considered:

1. The basic material should be made of HDPE resin and should conform to the requirements of ASTM D-1248. Details are contained therein.

2. Quality control tests are typically density and melt flow index. Their designations are ASTM D-1505 or D-792 and D-1238, respectively. Other in-house quality control tests are to be encouraged and followed by the manufacturer.

3. Typical densities for HDPE pipe resins are 0.950 to 0.960 g/cc. This is a Type III HDPE resin according to ASTM D-1248 and is higher than the resin density used in HDPE geomembranes.

4. Carbon black can be added as a concentrate as it customarily is, or as a powder. The type and amount of carbon black, as well as the type of carrier resin if concentrated pellets are used, should be stated and certified by the manufacturer.

5. The amount of additives used should be stated by the manufacturer. If certification is required it would typically not state the type of additive, since they are usually proprietary, but should state that the additive package has successfully been used in the past.

6. The lack of ASTM documents for HDPE corrugated pipe should be noted. There is an AASHTO Specification available for corrugated polyethylene pipe in the 300 to 900 mm (12 to 36 in.) diameter range under the designation M294-90 and another for 75 to 250 mm (3 to 10 in.) diameter pipe under the designation of M252-90.

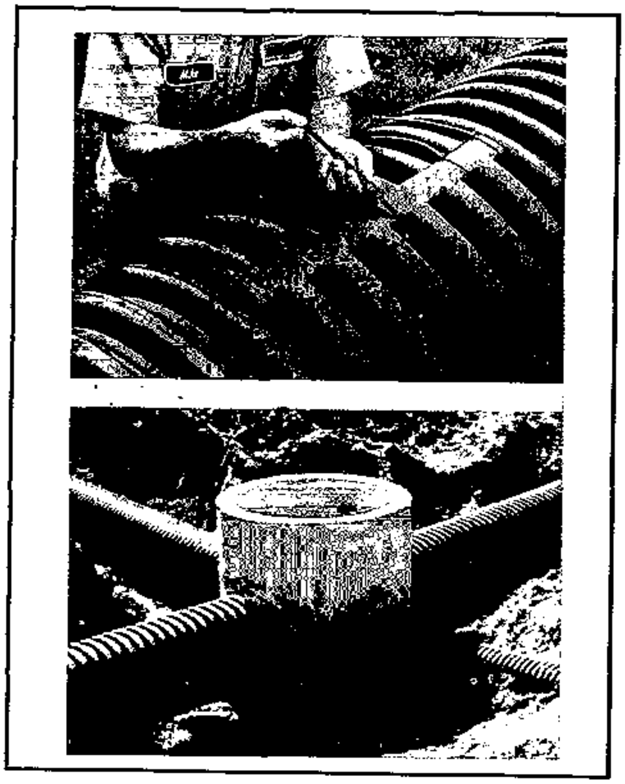


Figure 8.5 - Photograph of HDPE Corrugated Pipe Being Coupled and After Installed.

8.1.4 Handling of Plastic Pipe

As with all other geosynthetic materials a number of activities occur between the manufacturing of the pipe and its final positioning in the waste facility. These activities include packaging, storage at the manufacturers facility, shipment, storage at the field site, conformance testing and the actual placement.

8.1.4.1 Packaging

Both PVC pipe and HDPE pipe are manufactured in long lengths of approximately 6.1 m (20 ft) with varying wall thicknesses and configurations. They are placed on wooden pallets and bundled together with plastic straps for bulk handling and shipment. The packaging is such that either fork lifts or cranes using slings can be used for handling and movement. As the diameter and wall thickness increases, however, this may not be the case and above 610 mm (24 in.) diameter the pipes are generally handled individually.

8.1.4.2 Storage at Manufacturing Facility

Bundles of plastic pipe can be stored at the manufacturing facility for relatively long periods of time with respect to other geosynthetics. However, if stored outdoors for over 12 months duration, a temporary enclosure should be used to cover the pipe from ultraviolet exposure and high temperatures. Indoors, there is no defined storage time limitation. Pipe fittings are usually stored in a container or plastic net.

8.1.4.3 Shipment

Bundled pallets of plastic pipe are shipped from the manufacturer's or their representative's storage facility to the job site via common carrier. Ships, railroads and trucks have all been used depending upon the locations of the origin and final destination. The usual carrier from within the USA, is truck. When using flatbed trucks, the pallated pipe is usually loaded by means of a fork lift or a crane with slings wrapped around the entire unit. When the truck bed is closed, i.e., an enclosed trailer, the units are usually loaded by fork lift. Large size pipes above 610 mm (24 in.) in diameter are handled individually.

8.1.4.4 Storage at Field Site

Offloading of palleted plastic pipe at the site and temporary storage is a necessary follow-up task which must be done in an acceptable manner.

Items to be considered for the contract specification or CQA document are the following:

1. Handling of pallets of plastic pipe should be done in a competent manner such that damage does not occur to the pipe.

2. The location of field storage should not be in areas where water can accumulate. The pallets should be on level ground and oriented so as not to form a dam creating the ponding of water.

3. The pallets should not be stacked more than three high. Furthermore, they should be stacked in such a way that access for conformance testing is possible.

4. Outdoor storage of plastic pipe should not be longer than 12 months. For storage periods longer than 12 months a temporary covering should be placed over the pipes, or they should be moved to within an enclosed facility.

8.1.5 Conformance Testing and Acceptance

Upon delivery of the plastic pipe to the project site, and temporary storage thereof, the CQA engineer should see that conformance test samples are obtained. These samples are then sent to the

CQA laboratory for testing to ensure that the pipe supplied conforms to the project plans and specifications.

Items to consider for the contract specification or CQA document in this regard are the following:

1. The pipe should be identified according to its proper ASTM standard:

   (a) for PVC Schedule 40, 80 and 120: see ASTM D-1785

   (b) for PVC SDR Series: see ASTM D-2241

   (c) for PVC pipe fittings: see ASTM D-3034

   (d) for HDPE SDR Series: see ASTM D-1248 and ASTM F-714

   (e) for HDPE corrugated pipe and fittings: see AASHTO M294-90 and M252-90.

2. The conformance test samples should make use of the same identification system as the appropriate ASTM standard, if one is available.

3. A lot should be defined as a group of consecutively numbered pipe sections from the same manufacturing line. Other definitions are also possible and should be clearly stated in the CQA documents.

4. Sampling should be done according to the contract specification and/or CQA documents. Unless otherwise stated, sampling should be based on one sample per lot, not to exceed one sample per 300 m (1000 ft) of pipe.

5. Conformance tests at the CQA Laboratory should include the following:

   (a) for PVC pipe and fitting: physical dimensions according to ASTM D-2122, density according to ASTM D-792, plate bearing test according to ASTM D-2412, and impact resistance according to ASTM D-2444.

   (b) for HDPE solid-wall and corrugated pipe: physical dimensions according to ASTM D-2122, density according to ASTM D-1505, plate bearing test according to ASTM D-2412 and impact resistance according to ASTM D-2444.

   (c) for HDPE corrugated pipe in the 300 to 900 mm (12 to 36 in.) range see AASHTO M294-90 and in the 75 to 250 mm (3 to 10 in.) range see AASHTO M252-90.

6. Conformance test results should be sent to the CQA engineer prior to deployment of any pipe from the lot under review.

7. The CQA engineer should review the results and should report any non-conformance to the Project Manager.

8. The resolution of failing conformance tests should be clearly stipulated in the specifications or CQA documents.

8.1.6 Placement

Plastic pipe is usually placed in a prepared trench or within other prepared subgrade materials. If the pipe is to be placed on or near to a geomembrane, as in the leachate collection system shown in Fig. 8.1, the drainage sand or stone should be placed first. There may be a requirement to lightly compact sand to 90% relative density according to ASTM D-4254. Small excavations of slightly greater than the diameter of the pipe are then made, and the pipe is placed in these shallow excavations. Thus a trench, albeit a shallow one, is constructed in all cases of pipe placement in leachate collection sand or stone.

Where plastic pipe is placed at other locations adjacent to the containment facility and the soil is cohesive, compaction is critical if high stresses are to be encountered. Compaction control is necessary, e.g., 95% of standard Proctor compaction ASTM D-698 is recommended so as to prevent subsidence of the pipe while in service.

The importance of the density of the material beneath, adjacent and immediately above a plastic pipe insofar as its load-carrying capability is concerned cannot be overstated. Figure 8.6 shows the usual configuration and soil backfill terminology related to the various materials and their locations.

Regarding a specification or CQA document for plastic pipe placement, ASTM D-2321 should be referenced. For waste containment facilities the following should be considered:

1. The soil beneath, around and above the pipe shall be Class IA, IB or II according to ASTM D-2321.
2. The backfill soil should extend a minimum of one pipe diameter above the pipe, or 300 mm (12 in.) which ever is smaller.
3. Other conditions should be taken directly according to ASTM D-2321.
4. Pipe fittings should be in accordance with the specific pipe manufacturer's recommendations.

8.2 Sumps, Manholes and Risers

Leachate which migrates along the bottom of landfills and waste piles flows gravitationally to a low point in the facility or cell where it is collected in a sump. Two general variations exist; one is a prefabricated sump, made either in-situ or off-site, with a manhole extension rising vertically through the waste and final cover, the other is a low area formed in the liner itself with a solid wall pipe riser coming up the side slope where it eventually penetrates the final cover. Both variations are shown schematically in the sketches of Fig. 8.7. In addition, the sump and sidewall riser of a secondary leachate collection system typically used in double lined facilities is shown in the right sketch of Fig. 8.7(b), i.e., a leak detection system. Each type of system will be briefly described.

Many existing landfills have been constructed with primary leachate collection and removal sumps and manholes constructed to the site specific plans and specifications as shown in the left hand sketch of Fig. 8.7(a). The vertical riser is either a concrete or plastic standpipe placed in 3 m (10 ft) sections. It is extended as the waste is placed in the facility and eventually it must penetrate the final cover. Leachate is removed from this manhole, on an as demanded basis, by a submersible pump which is permanently located in the sump.

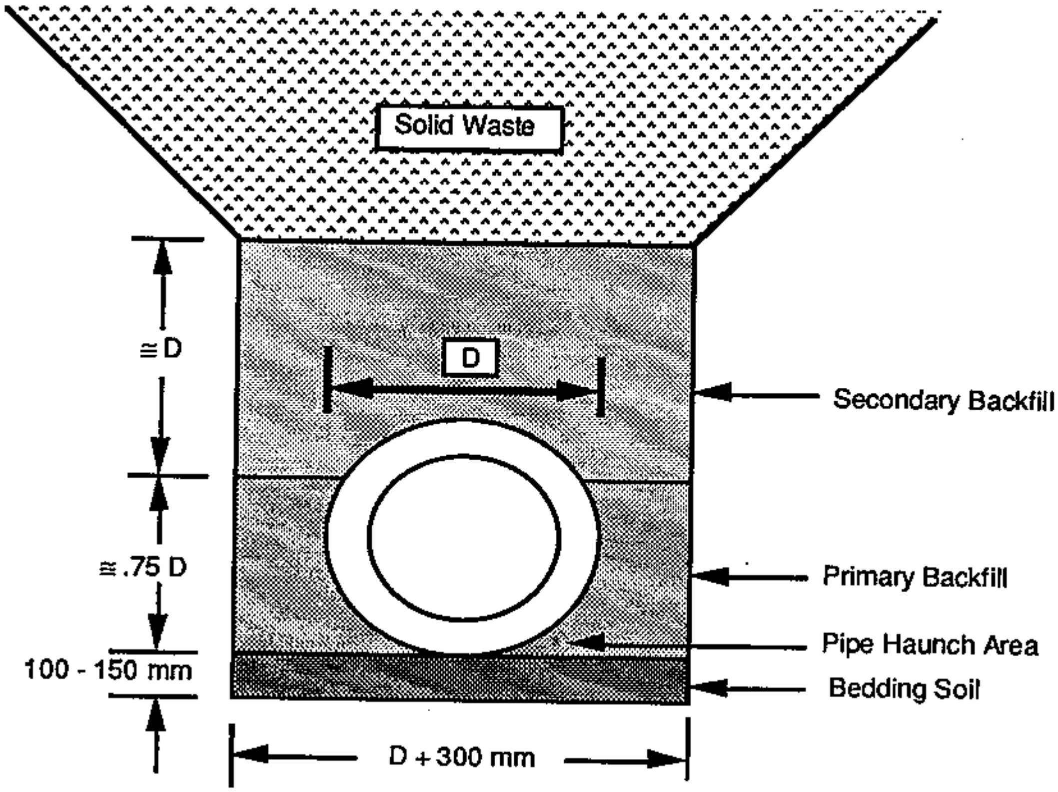
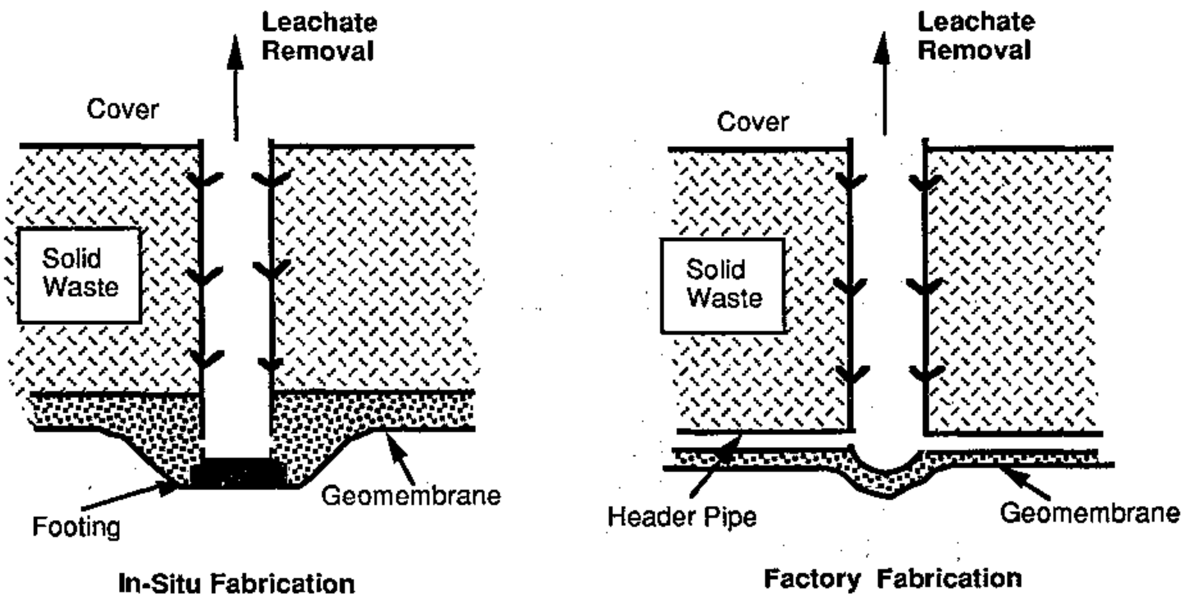


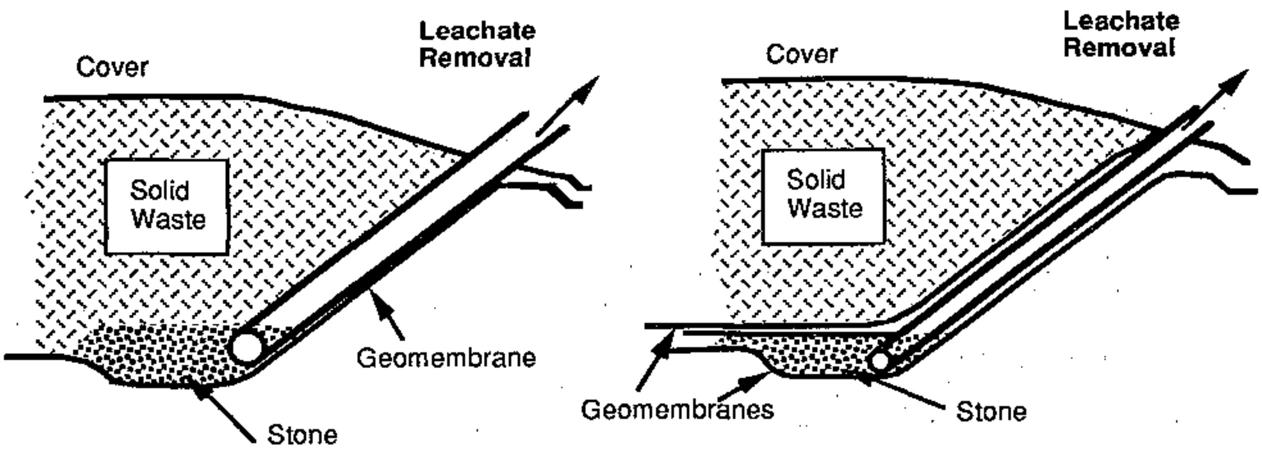
Figure 8.6 - A Possible Buried Pipe Trench Cross Section Scheme Showing Soil Backfill Terminology and Approximate Dimensions (for illustration purposes only).

A more recent variation of the above removal system is an off-site factory fabricated sump and manhole system wherein the leachate collection pipe network frames directly into the sump, see the right hand sketch of Fig. 8.7(a). Various standardized sump capacities are available. This type of system requires the least amount of field fabrication. The riser is extended in sections as the waste is placed in the facility and eventually it must penetrate the final cover. Leachate is removed from the manhole by a submersible pump which is permanently located in the sump.

Quite a different variation for primary leachate removal is a well defined low area in the primary geomembrane into which the leachate collection pipe network flows. This low area creates a sump which is then filled with crushed stone and from which a pipe riser extends up the side slope. The pipe riser is usually a solid wall pipe with no perforations. When the facility is eventually filled with solid waste, the riser must penetrate the cover as shown in the left hand sketch of Fig. 8.7(b). The leachate is withdrawn using a submersible pump which is lowered down the pipe riser on a sled and left in place except for maintenance and/or replacement, recall Fig. 8.4.



(a) Types of Primary Leachate Collection Sumps and Manholes with Vertical Standpipe Going through the Waste and Cover



(b) Types of Primary (Left) and Secondary (Right) Leachate Collection Sumps and Pipe Risers Going Up the Side Slopes

Figure 8.7 - Various Possible Schemes for Leachate Removal

In a similar manner as above, but now for secondary leachate removal, a sump can be formed in the secondary liner system which is filled with gravel as shown in the right hand sketch of Fig. 8.7(b). A solid wall pipe riser, perforated in its lower section, extends up the sidewall between the primary and secondary liner where it must penetrate both the primary liner, and eventually the cover system liner, see the right hand sketch of Fig. 8.7(b). This pipe riser is often a solid wall pipe in the 100-200 (4 to 8 in.) diameter range with no perforations. The leachate is withdrawn and/or monitored using a small diameter sampling pump which is lowered down the riser and left in place except for maintenance and/or replacement, recall Fig. 8.4.

Some specification and CQA document considerations for the various sump, manhole and riser schemes just described are as follows. Note, however, that there are other possible design schemes that are available in addition to those mentioned above.

1. In-situ fabrication of sumps requires a considerable amount of hand labor in the field. Seams for HDPE and VLDPE geomembranes are extrusion fillet welded, while PVC and CSPE-R geomembranes are usually bodied chemical seams (EPA, 1991). Careful visual inspection is necessary.

2. The soil support beneath the sumps and around the manhole risers of plastic pipes is critically important. The specification should reference ASTM D-2321 with only backfill types IA, IB and II being considered.

3. Riser pipes for primary and secondary leachate removal are generally not perforated, except for the lowest section of pipe which accepts the leachate.

4. Riser pipe joints for primary and secondary leachate removal require special visual attention since neither destructive nor nondestructive tests can usually be accommodated.

5. The sump, manholes and risers must be documented by the CQA engineer before acceptance and placement of solid waste.

8.3 Liner System Penetrations

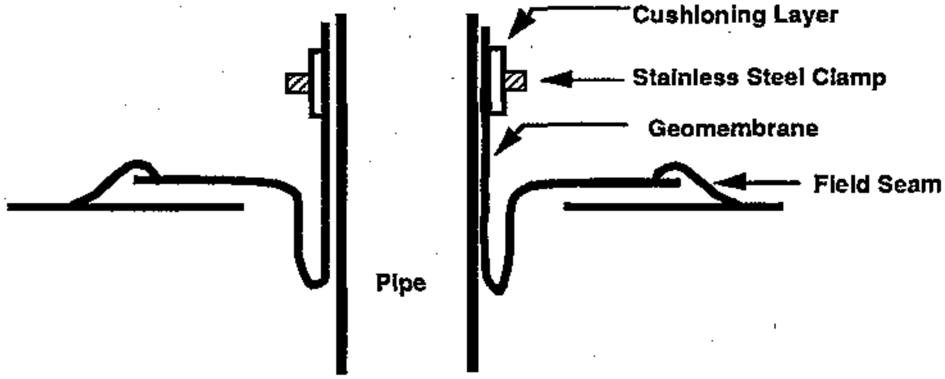
Although the intention of most designers of waste containment facilities is to avoid liner penetrations, leachate removal is inevitably required at some location(s) of the barrier system. Recall Fig. 8.7 where the cover is necessarily penetrated for primary leachate removal. For leak detection both the primary liner and the cover liner must be penetrated. It should also be recognized that the penetrations will include geomembranes, compacted clay liners and/or geosynthetic clay liners. Figure 8.8 illustrates some details of pipe penetrations through all three types of barrier materials.

The following recommendations are made for a specification or CQA document:

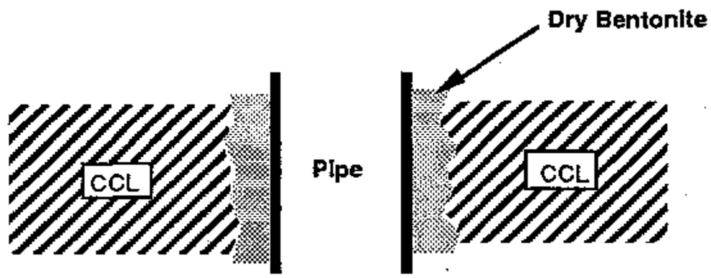
1. Geomembrane pipe boots are usually factory fabricated to a size which tightly fits the outside diameter of the penetrating pipe. Unique situations, however, will require field fabrication, e.g., when pipe penetration angles are unknown until final installation.

2. The skirt of the pipe boot which flares away from the pipe penetration should have at least 300 mm (12 in.) of geomembrane on all sides of the pipe.

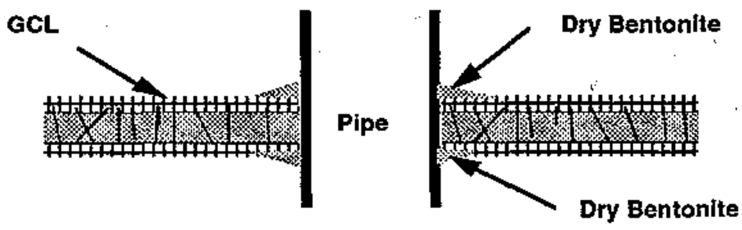
3. The skirt of the pipe boot should be seamed to the base geomembrane by extrusion fillet or bodied chemical seaming depending on the type of geomembrane (EPA, 1991).



(a) Geomembrane Penetration



(b) Compacted Clay Liner (CCL) Penetration



(c) Geosynthetic Clay Liner (GCL) Penetration

Figure 8.8 - Pipe Penetrations through Various Types of Barrier Materials

4. The nondestructive testing of the skirt of the pipe boot should be by vacuum box or air lance depending on the type of geomembrane. Refer to Section 3.6.2.

5. The pipe boot should be of the same type of geomembrane as that of the liner through which the penetration is being made.

6. Pipe penetrations should be positioned with sufficient clearance to allow for proper welding and inspection.

7. Stainless steel pipe clamps used to attach pipe boots to the penetrating pipes should be of an adequate size to allow for a cushion of compressible material to be placed between the inside surface of the clamp and that of the geomembrane portion of the pipe boot.

8. Location of pipe clamps should be as directed on the plans and specifications.

9. Pipe penetrations through compacted clay liners and geosynthetic clay liners should use an excess of hand placed dry bentonite clay as directed in the plans and specifications.

8.4 Anchor Trenches

Generally, the geosynthetics used to line or cover a waste facility end in an anchor trench around the individual cell or around the entire site.

8.4.1 Geomembranes

The termination of a geomembrane at the perimeter of landfill cells or at the perimeter of the entire facility generally ends in an anchor trench. As shown in Fig. 8.9, the variations are numerous. Such details should be specifically addressed in the construction plans and specifications.

Some general items that should be addressed in the specification or CQA documents regarding geomembrane termination in anchor trenches are as follows:

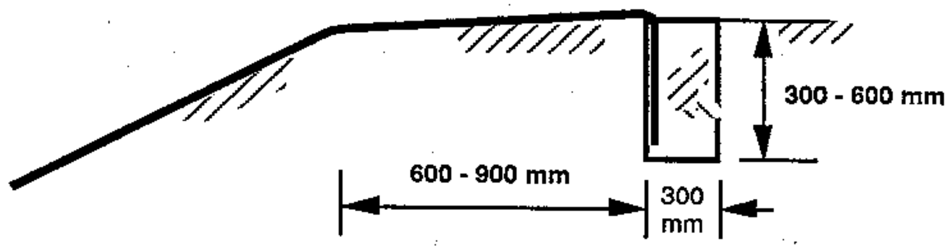
1. The seams of adjacent sheets of geomembranes should be continuous into the anchor trench to the full extent indicated in the plans and specifications.

2. Seaming of geomembranes within the anchor trench can be accomplished by temporarily supporting the adjacent sheets to be seamed on a wooden support platform in order that horizontal seaming can be accomplished continuously to the end of the geomembrane sheets. The temporary support is removed after the seam is complete and the geomembrane is then allowed to drop into the anchor trench.

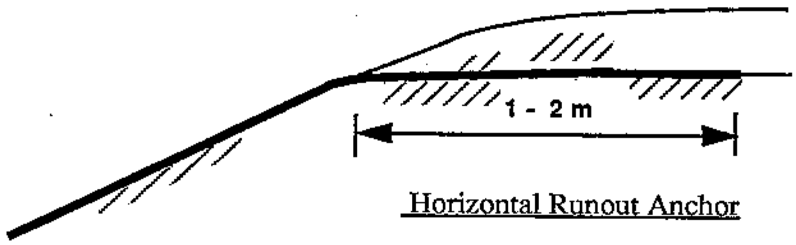
3. Destructive seam samples can be taken while the seamed geomembrane is temporarily supported in the horizontal position.

4. Nondestructive tests can also be performed while the seamed geomembrane is temporarily supported in the horizontal position.

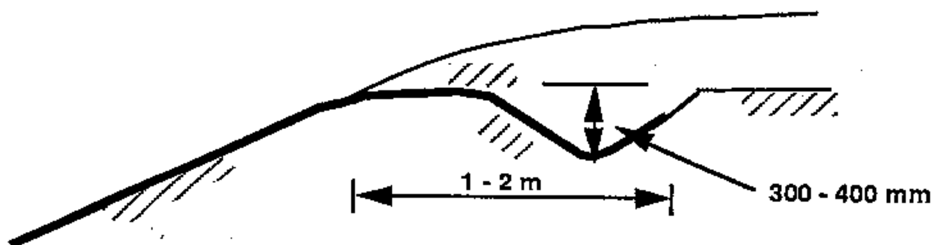
5. The anchor trench is generally backfilled after the geomembrane has been documented by the CQA engineer, but may be at a later date depending upon the site specific plans and specifications.



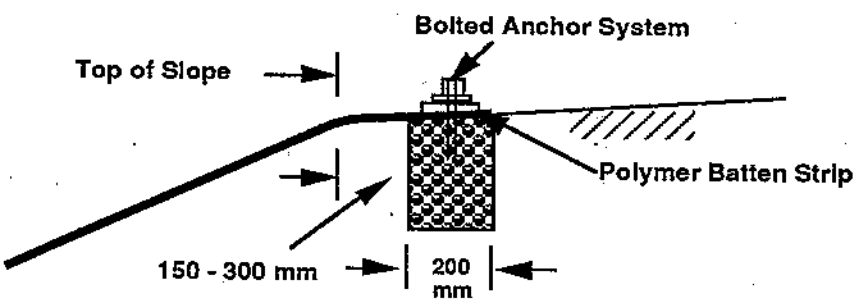
Typical Anchor Trench



Horizontal Runout Anchor



Shallow "V" Anchor Trench



Concrete Anchor Block

Figure 8.9 - Various Types of Geomembrane Anchors Trenches (Dimensions are Typical and for Example Only).

6. The anchor trench itself should be made with slightly rounded corners so as to avoid sharp bends in the geomembrane. Loose soil should not be allowed to underlie the geomembrane in the anchor trench.

7. The anchor trench should be adequately drained to prevent ponding of water or softening of the adjacent soils while the trench is open.

8. Backfilling in the anchor trench should be accomplished with approved backfill soils placed at their required moisture content and compacted to the required density.

9. The plans and specifications should provide detailed construction requirements for anchor trenches regardless if soils or other backfill materials are used.

8.4.2 Other Geosynthetics

Since all geosynthetics, not only geomembranes, need adequate termination, some additional comments are offered for plans, specifications or CQA documents.

1. Geotextiles, either beneath or above geomembranes, usually follow their associated geomembrane into the same type of anchor trenches as shown in Fig. 8.9.

2. Geonets may or may not terminate in the anchor trench. Water transmission from beyond the waste containment may be a concern when requiring termination of the geonet within the geomembrane's anchor trench or in a separate trench by itself. Thus termination of a geonet may be short of the associated geomembrane's anchor trench. This is obviously a design issue and must be clearly detailed in the contract plans and specifications.

3. When used by themselves, geosynthetic clay liners (GCLs) will generally terminate in a anchor trench in soil of the type shown in Fig. 8.9. When GCLs are with an associated geomembrane, as in a composite liner, each component will sometimes end in a separate anchor trench. These are design decisions.

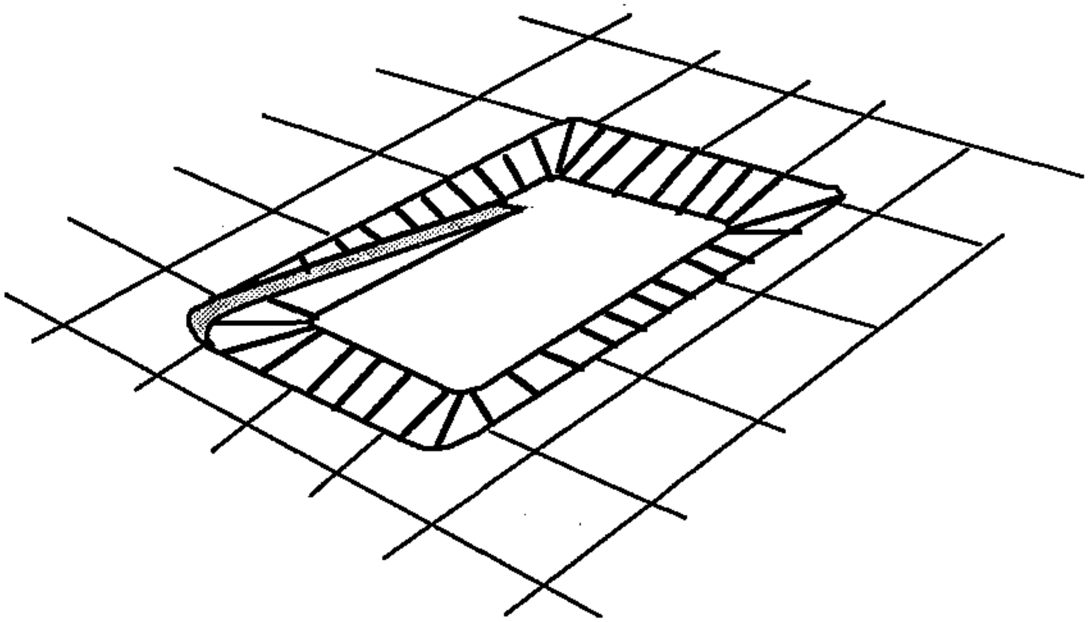
4. Double liner systems will generally have separate anchor trenches for primary and secondary liner systems. This is a design decision.

5. In all of the above cases, the plans and specifications should provide detailed dimensions and construction requirements for anchor trenches of all geosynthetic components.

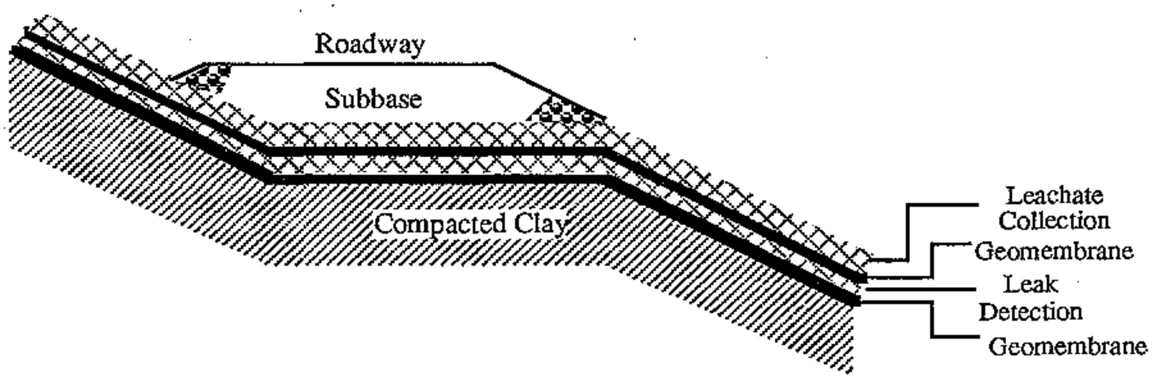
6. The plans and specifications should also show details of how natural soil components, e.g., compacted clay liners and sand or gravel drainage layers, terminate with respect to one another and with respect to the geosynthetic components.

8.5 Access Ramps

Heavily loaded vehicles must enter the landfill facility during construction activities and during placement of the solid waste. Typical access ramps will be up to 5.5 m (18 ft.) in width and have grades up to 12%. The general geometry of an access ramp is shown in Fig. 8.10(a).



(a) Geometry of a Typical Ramp



(b) Cross Section of Ramp Roadway

Figure 8.10 - Typical Access Ramp Geometry and Cross Section

The traffic loads on such a ramp can be extremely large and generally involve some degree of dynamic force due to the constant breaking action which drivers use when descending the steep grades. Note that the entire liner cross section must extend uninterrupted from the upper slope to the lower slope and in doing so must necessarily pass beneath the roadway base course. When working with a double lined facility this can involve numerous geosynthetic and natural soil layers. Further complicating the design issues is that drainage from the upper side slopes must communicate beneath the roadway base course layer or travel parallel to it and be contained accordingly. A reinforcing element (geotextile or geogrid) can be incorporated in the roadway base course material. This can serve several purposes; i.e., to protect long-term integrity of underlying systems, to minimize potential sliding failures, and to minimize potential rutting and bearing capacity failures. These are critical design issues and must be well defined in the plans and specifications.

Regarding recommendations for the contract specifications or CQA document, the following items apply:

1. Many facilities will limit the number of vehicles on the access ramp at a given time. Such stipulations should be strictly enforced.

2. Vehicle speeds on access ramps should be strictly enforced.

3. Regular inspection should be required to observe if tension cracks open in the roadway base coarse soils. This may indicate some degree of slippage of the soil and possible damage to the liner system.

4. Ponding of upper slope runoff water against the roadway profile should be observed for possible erosion effects and loss of base course material. If a drainage ditch or pipe system is indicated on the plans, it should be constructed as soon as possible after completion of the roadway subbase soils.

5. The roadway base course profile should be fully maintained for the active lifetime of the facility.

8.6 <u>Geosynthetic Reinforcement Materials</u>

For landfill and waste pile covers with slopes greater than 3 horizontal to 1 vertical (3H:1V), stability issues regarding downgradient sliding begin to be important. Additionally, the stability of primary leachate collection systems for landfill and waste pile liners with slopes greater than 3H : 1V is suspect at least until the solid waste material within the unit raises to a stabilizing level. Such issues, of course, must be considered during the design phase and the contract plans and specifications must be very clear on the method of reinforcement, if any. If reinforcement is necessary it can be accomplished by using geotextiles or geogrids within the layer contributing to the instability to offset some, or even all, of the gravitational stresses. Refer to Fig. 8.11(a) and (b) for the general orientation of such reinforcement, which is sometimes called "veneer reinforcement".

The concept of using geogrid or geotextile reinforcement to support a liner or liner system when a new landfill is built above, or adjacent to, an existing landfill has recently been developed. The technique has been referred to as "piggybacking" when vertical expansions are involved, see Fig. 8.11(c). The main focus of the reinforcement is to provide stability against differential settlement which can occur in the existing landfill.

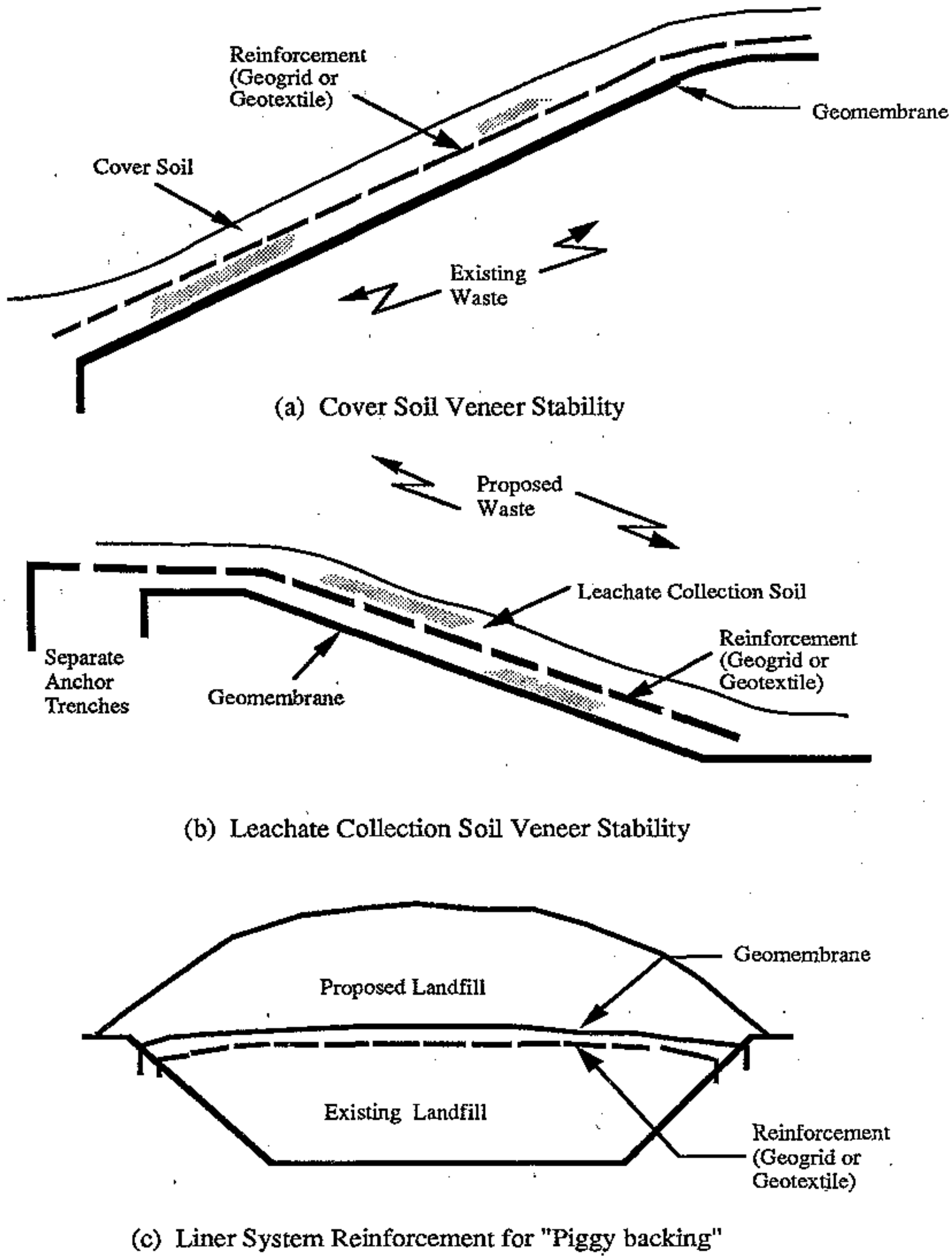


Figure 8.11 - Geogrid or Geotextile Reinforcement of (a) Cover Soil above Waste, (b) Leachate Collection Layer beneath Waste, and (c) Liner System Placed above Existing Waste ("Piggybacking")

Since geotextiles were described previously from a manufacturing standpoint and for separation and filtration applications, they will be discussed here only from their reinforcement perspective. Geogrids will be described from both their manufacturing and reinforcement perspectives.

8.6.1 Geotextiles for Reinforcement

The manufacturing of geotextiles was described in section 6.2 along with recommendations for MQC and MQA documents. Regarding CQC and CQA, the focus was on separation and filtration applications. Some specific recommendations regarding reinforcement geotextiles for a specification or CQA document are as follows:

1. A manufacturer's certification should be provided that the geotextile meets the property criteria specified for the geotextile that was approved for use on the project via the plans and specifications.

2. CQA personnel should check that the geotextile delivered to the job site is the proper and intended material. This is done by verifying the identification label and its coding and by visual identification of the product, its construction and other visual details.

3. Conformance samples of the geotextile supplied to the job site should be obtained as per ASTM D-4759. Typically, the outer wrap of the rolls are used for such sampling.

4. Conformance tests should be the following. Wide width tensile strength per ASTM D-4595, trapezoidal tear strength per ASTM D-4533 and puncture strength per ASTM D-4833. Additional conformance tests which may be considered are polymer identification via thermogravimetric analysis (TGA) and grab tensile strength, via ASTM D-4632.

5. Field placement of geotextiles should be at the locations indicated on the contract plans and in the specifications. Details of overlapping or seaming should be included.

6. Geotextile deployment is usually from the top of slope downward, so that the geotextile is taut before soil backfilling proceeds.

7. If the upper end of the geotextile should be anchored in an anchor trench, the details shown in the contract plans should be fulfilled.

8. Soil backfilling should proceed from the bottom of the slope upward, with a minimum backfill thickness of 220 mm (9 in.) of cover using light ground contact construction equipment of 40 kPa (6 lb/in^2) contact pressure or less.

9. Seams in geotextiles on side slopes are generally not allowed. If permitted, they should be located as close to the bottom of the slope as possible. Seams should be as approved by the CQA engineer. Test strips of seams should be requested for conformance tests in the CQA laboratory following ASTM D-4884.

8.6.2 Geogrids

Geogrids are reinforcement geosynthetics formed by intersecting and joining sets of longitudinal and transverse ribs with resulting open spaces called "apertures". Two different classes of geogrids are currently available, see Fig. 8.12(a). They are the following: (a) stiff, unitized, geogrids made from polyethylene or polypropylene sheet material which is cold worked into a post-yield state, and (b) flexible, textile-like geogrids made from high tenacity polyester yarns which are joined at their intersections and coated with a polymer or bitumen. Figure 8.12 (b) shows geogrids being used as veneer reinforcement.

Some recommended contract specification or CQA document items that should be addressed when using geogrids as reinforcement materials are as follows:

1. A manufacturer's certification should be provided that the geogrid meets the property criteria specified for the geogrid that was approved for use on the project per the plans and specifications.

2. CQA personnel should check that the geogrid delivered to the job site is the proper and intended material. This is done by verifying the identification label and its coding and by visual identification of the product, its rib joining, thickness and aperture size. If the geogrid has a primary strength direction it must be so indicated.

3. Conformance samples of the geogrid supplied to the job site should be obtained as per ASTM D-4759. Typically, the outer wrap of the rolls are used for such sampling.

4. Conformance tests should be the following. Aperture size by micrometer or caliper measurement, rib thickness and junction thickness by ASTM D-1777, and wide width tensile strength by ASTM D-4595 suitably modified for geogrids. Additional conformance tests which may be considered are polymer identification via thermal analysis methods and single rib tensile strength, via GRI GG1.

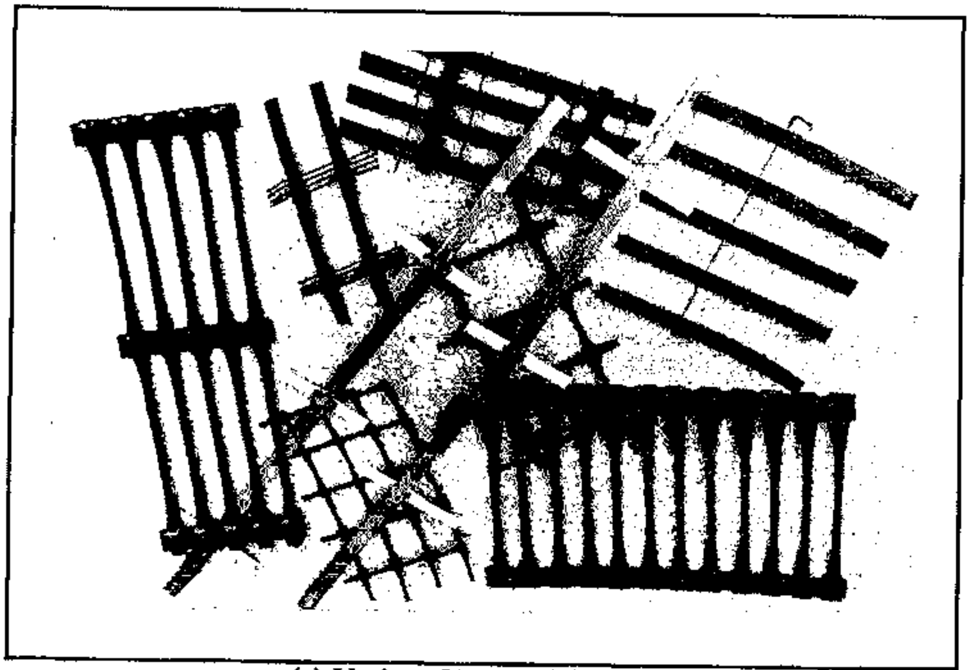
5. Field placement of geogrids should be at the locations indicated on the contract plans and in the specifications. Details of overlapping or seaming should be included.

6. Geogrid deployment is usually from the top of slope downward, so that the geogrid is taut before soil backfilling proceeds.

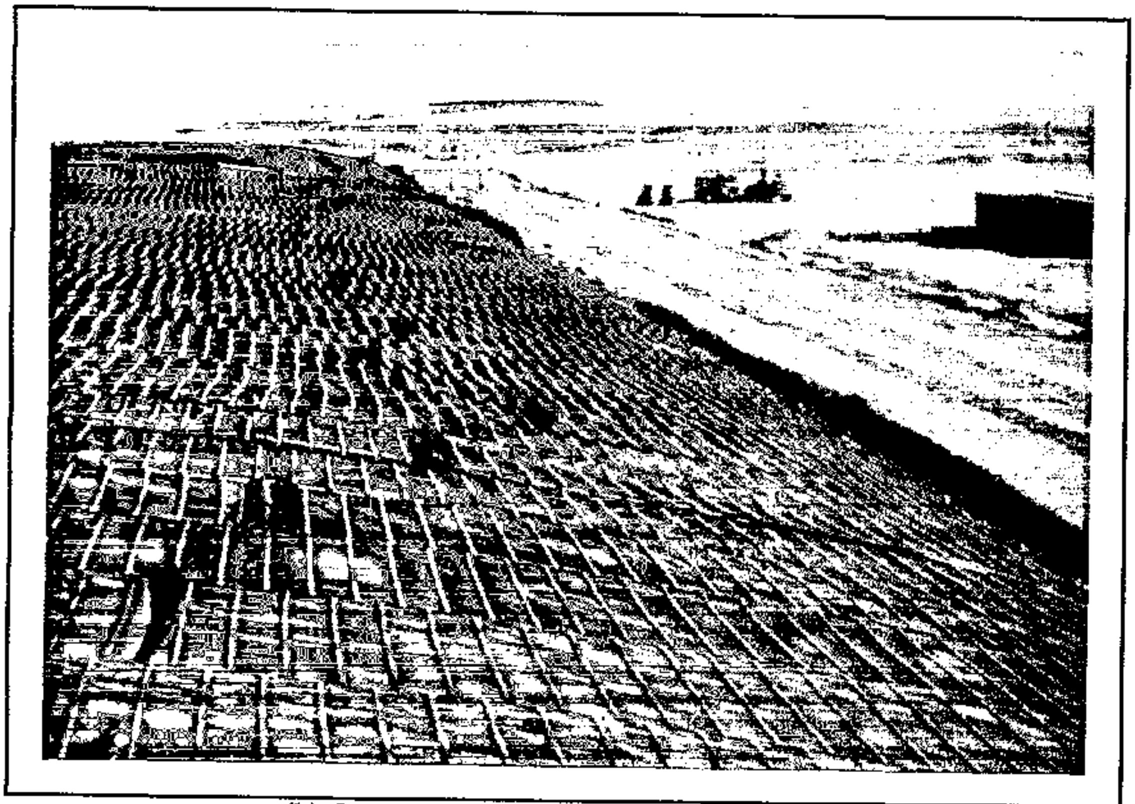
7. If the upper end of the geogrids are to be anchored in an anchor trench, the details shown in the contract plans should be fulfilled.

8. Soil backfilling should proceed from the bottom of the slope upward, with a minimum backfill thickness of 22 cm (9.0 in.) of cover using light ground contact construction equipment of 40 kPa (6 lb/in^2) contact pressure or less.

9. Connections of geogrid rolls on side slopes should generally be avoided. If permitted, they should be located as close to the bottom of the slope as possible. Connections should be as approved by the CQA engineer. Test strips of connections should be requested for conformance tests in the CQA laboratory following ASTM D-4884 (mod.) test method.



(a) Various Types of Geogrids



(b) Geogrids Used as Veneer Reinforcement

Figure 8.12 - Photographs of Geogrids Used as Soil (or Waste) Reinforcement Materials

8.7 Geosynthetic Erosion Control Materials

Often on sloping solid waste landfill covers soil loss in the form of rill, gully or sheet erosion occurs in the topsoil and sometimes extends down into the cover soil. This requires continuous maintenance until the phenomenon is halted and the long-term vegetative growth is established. Alternatively, the design may call for a temporary, or permanent, erosion control system to be deployed within or on top of the topsoil layer. Additional concerns regarding erosion control are on perimeter trenches, drainage ditches, and other surface water control structures associated with waste containment facilities. Listed below are a number of alternative erosion control systems ranging from the traditional hand distributed mulching to fully paved cover systems. They fall into two major groups; temporary degradable and permanent nondegradable.

Temporary Erosion Control and Revegetation Mats (TERMs)

- Mulches (hand or machine applied straw or hay)
- Mulches (hydraulically applied wood fibers or recycled paper)
- Jute Meshes
- Fiber Filled Containment Meshes
- Woven Geotextile Erosion Control Meshes
- Fiber Roving systems (continuous fiber systems)

Permanent Erosion Control and Revegetation Mats (PERMs)

- Geosynthetic Systems
    - turf reinforcement and revegetation mats (TRMs)
    - erosion control and revegetation mats (ECRMs)
    - geomatting systems
    - geocellular containment systems
- Hard Armor Systems
    - cobbles, with or without geotextiles
    - rip-rap, with or without geotextiles
    - articulated concrete blocks, with or without geotextiles
    - grout injected between geotextiles
    - partially or fully paved systems

Temporary degradable systems are used to enhance the establishment of vegetation and then degrade leaving the vegetation to provide the erosion protection required. Challenging sites that require protection above and beyond what vegetation can provide need to use a permanent nondegradation system, i.e., high flow channels, over steepened slopes etc. Of these various alternatives, jute meshes, containment meshes and geosynthetic systems are used regularly on landfill and waste pile cover systems, see Fig. 8.13.

Some items which are recommended for contract specifications or CQA document for these particular systems are as follows:

1. The CQA personnel should check the erosion control material upon delivery to see that the proper materials have been received.

2. Water and ultraviolet sensitive materials should be stored in dry conditions and protected from sunlight.

3. If the erosion control material has defects, tears, punctures, flaws, deterioration or damage incurred during manufacture, transportation or storage it should be rejected or suitably repaired to the satisfaction of the CQA personnel.

4. If the material is to be repaired, torn or punctured sections should be removed by cutting a cross section of the material out and replacing it with a section of undamaged material. The ends of the new section should overlap the damaged section by 30 cm (12 in.) and should be secured with ground anchors.

5. All ground surfaces should be prepared so that the material lies in complete contact with the underlying soil.

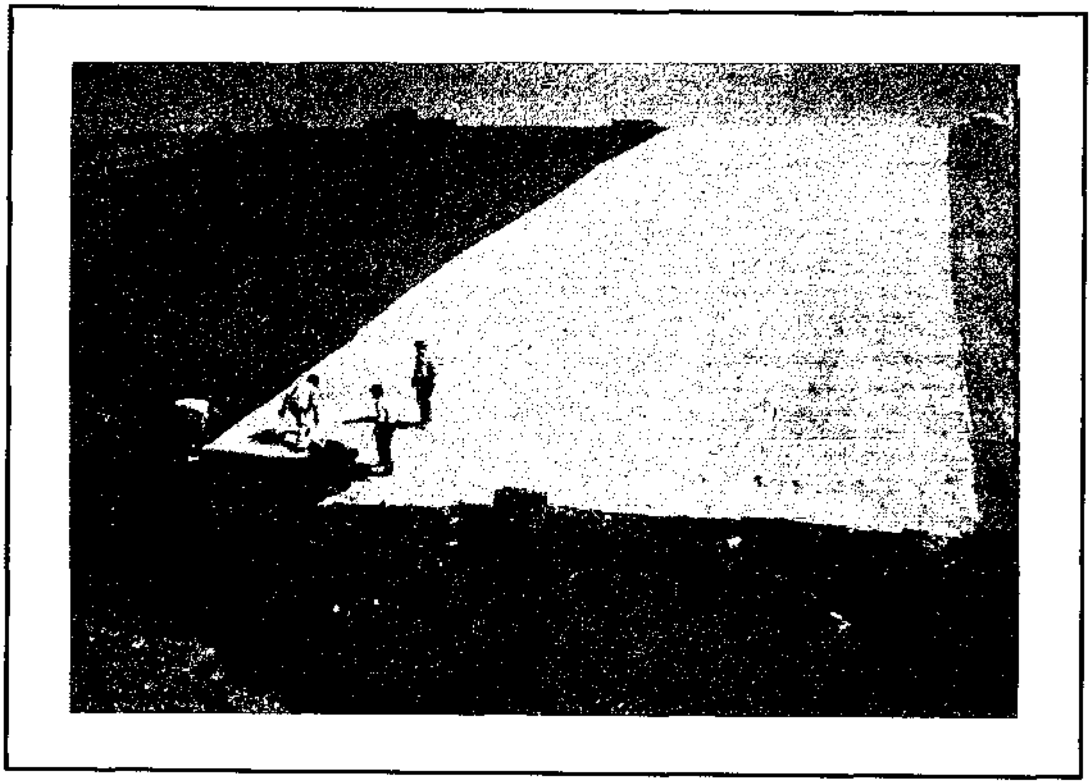
6. Ground anchors, called "pins", should be at least 30 cm (12 in.) long with an attached oversized washer 50 mm (2.0 in.) in diameter, or "staples" number 8 gauge "U" shaped wire at least 20 cm (8.0 in.) long. For less severe temporary applications e.g., TERMS's, one may consider 15 cm (6 in.) number 11 gauge "U" shaped wire staples.

7. Adjacent rolls of erosion control material shall be overlapped a minimum of 75 mm (3.0 in.). Staples should secure the overlaps at 75 cm (2.5 ft) intervals. The roll ends should overlap a minimum of 45 cm (18 in.) and be shingled downgradient. The end overlaps should be stapled at 45 cm (1.5 ft) intervals, or closer, or as recommended by the manufacturer.

8. If required on the plans and specifications, the erosion control material should be filled with topsoil, lightly raked or brushed into the mat to either fill it completely or to a maximum depth of 25 mm (1.0 in.).

9. For geosynthetic materials used in drainage ditches, their overlaps should always be shingled downgradient with overlaps as recommended by the manufacturer or plans and specifications whichever is the greatest.

10. If required by the plans and specifications, the manufacturer of the erosion control or drainage ditch material should provide a qualified and experienced representative on site to assist the installation contractor at the start of construction. After an acceptable routine is established, the representative should be available on an as-needed basis, at the CQA engineer's request.



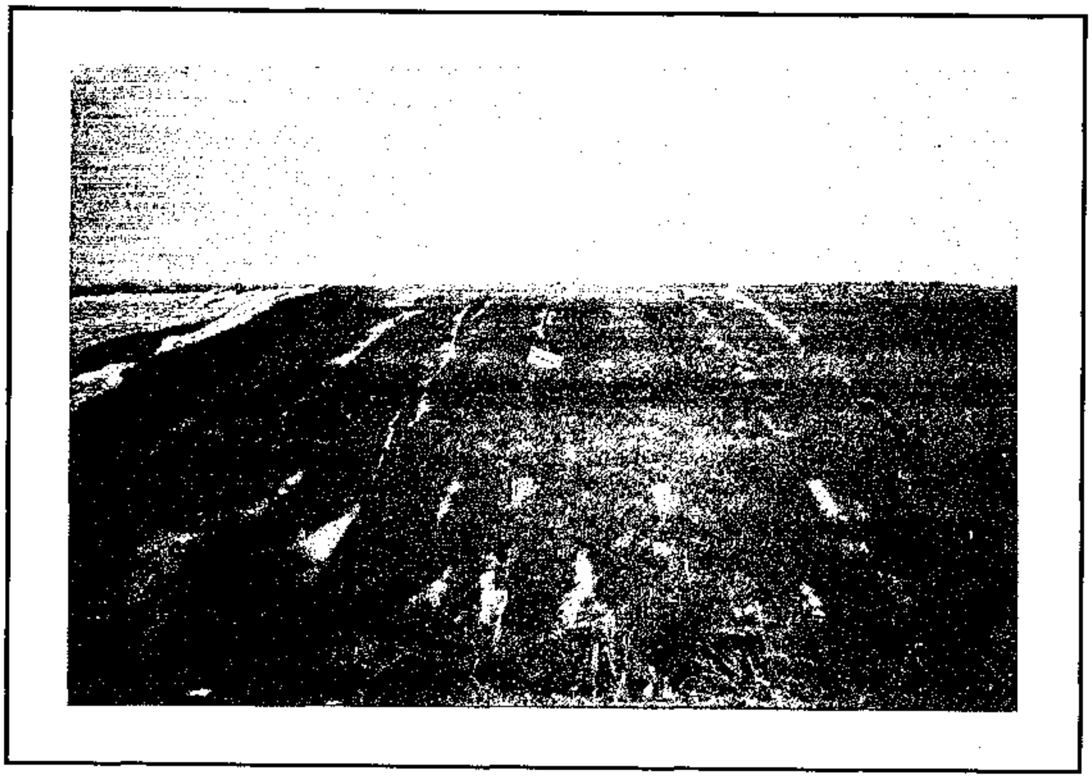


Figure 8.13 - Examples of Geosynthetic Erosion Control Systems

Figure 8.13 - Continued

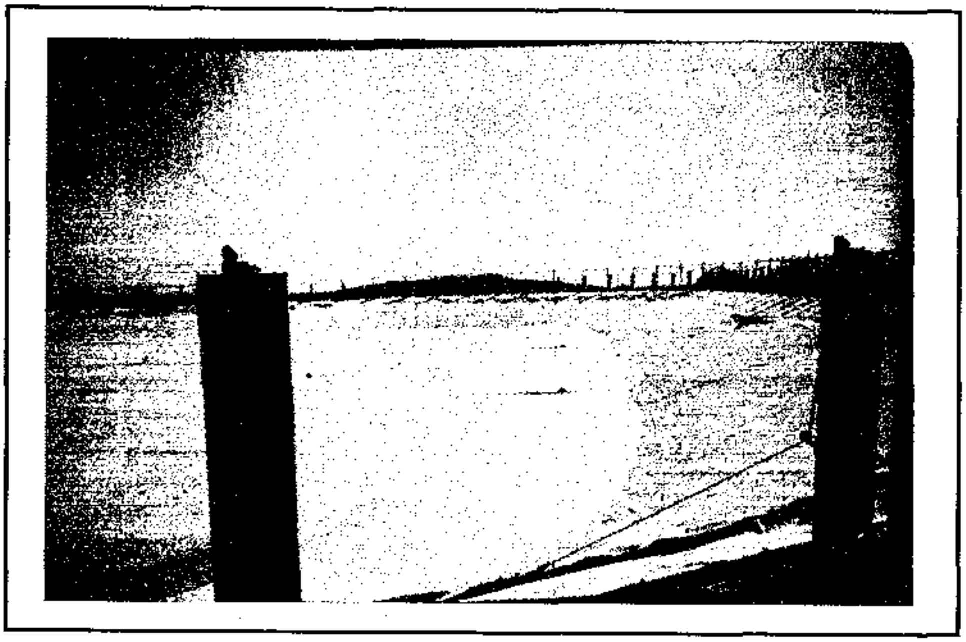
8.8 Floating Geomembrane Covers for Surface Impoundments

In concluding this Chapter, it was felt that a short section on geomembrane floating covers for liquid wastes contained in surface impoundments is appropriate. These floating covers are geomembranes of the types discussed in Chapter 3. Hence all details such as polymer type, production, conformance testing, etc., are applicable here as well. The uniqueness of the application is that the geomembrane is always exposed to the atmosphere, thus subject to sunlight, heat, damage, etc., and furthermore it must be rigidly anchored to a concrete anchor trench or other similar structure, surrounding the perimeter of the facility, see Fig. 8.14.

Some items in addition to those mentioned in Chapter 3 on geomembranes that are recommended for a contract specification or a CQA document are as follows:

1. Acceptance of the geomembrane should have some verification as to its weatherability characteristics. The tests most frequently referenced are ASTM D-4355 and ASTM G-26. There is also a growing body of data being developed under the ASTM G-53 test method.

2. Other conformance tests, e.g., physical and mechanical property tests, are product specific and have been described in Chapter 3.



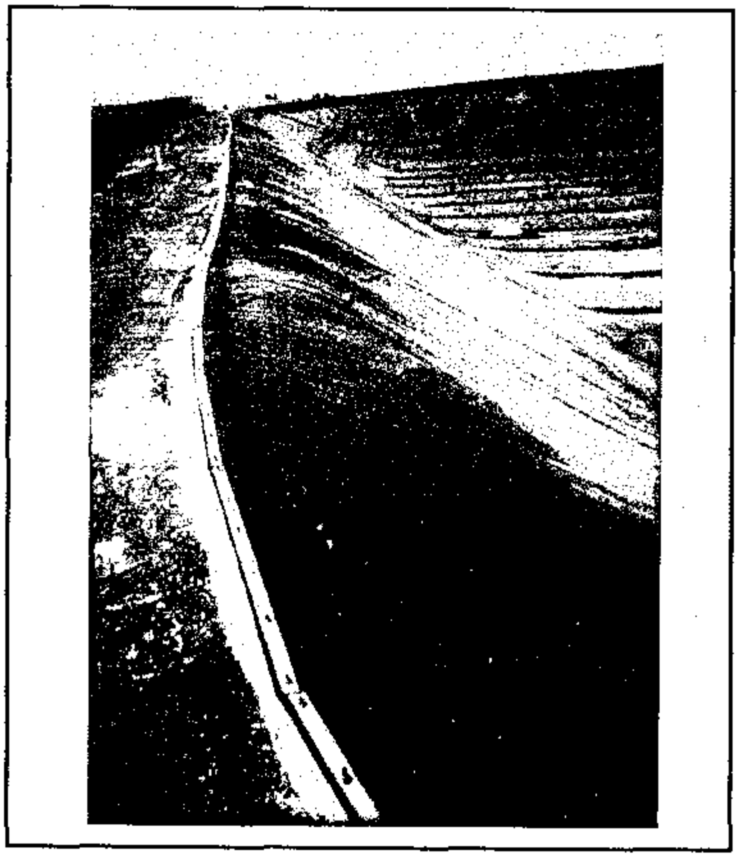


Figure 8.14 - Surface Impoundments with Geomembrane Floating Covers along with Typical Details of the Support System and/or Anchor Trench and Batten Strips

3. The anchorage detail for floating covers is critically important. Construction plans and specifications must be followed explicitly. To be noted is that there are very different anchorage schemes that are currently available. Some use concrete anchor blocks with embedded bolts which attach the geomembrane under a batten strip. Other anchorages are patented systems consisting of tensioned geomembranes attached to movable dead weights riding inside of stationary columns. Additional schemes are also possible. In each case the manufacturer's recommendations should be cited in the contract documents and must be followed completely.

4. The manufacturer/fabricator of the floating cover should provide a qualified and experienced representative on site to assist the installation contractor at the start of construction. After an initial start-up point, the representative should be available on an as needed basis, at the CQA engineer's request.

8.9 References

AASHTO M252-90, "Corrugated Polyethylene Drainage Tubing"

AASHTO M294-90, "Corrugated Polyethylene Pipe, 12- to 36-in. Diameter"

ASTM D-698, "Moisture Density Relations of Soils and Soil/Aggregate Mixtures"

ASTM D-792, "Specific Gravity and Density of Plastics by Displacement"

ASTM D-1238, "Flow Rates of Thermoplastics by Extrusion Plastomer"

ASTM D-1248, "Polyethylene Plastics and Extrusion Materials"

ASTM D-1505, "Density of Plastics by the Density-Gradient Technique"

ASTM D-1755, "Poly (Vinyl Chloride) (PVC) Resins"

ASTM D-1777, "Measuring Thickness of Textile Materials"

ASTM D-1785, "Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120"

ASTM D-2122, "Determining Dimensions of Thermoplastic Pipe and Fittings"

ASTM D-2241, "Poly (Vinyl Chloride) (PVC) Pressure Rated Pipe (SDR-Series)"

ASTM D-2321, "Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity - Flow Applications"

ASTM D-2412, "External Loading Properties of Plastic Pipe by Parallel Plate Loading"

ASTM D-2444, "Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)"

ASTM D-3034, "Type PSM Poly (Vinyl Chloride) (PVC) Sewer Pipe and Fittings"

ASTM D-4254, "Maximum Index Density of Soils and Calculation of Relative Density"

ASTM D-4355, "Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)

ASTM D-4533, "Trapezoidal Tearing Strength of Geotextiles"

ASTM D-4595, "Tensile Properties of Geotextiles by Wide Width Strip Method"

ASTM D-4632, "Breaking Load and Elongation of Geotextiles (Grab Method)"

ASTM D-4759, "Determining the Specification Conformance of Geosynthetics"

ASTM D-4833, "Index Puncture Resistance of Geotextiles, Geomembranes and Related Products"

ASTM D-4884, "Seam Strength of Sewn Geotextiles"

ASTM F-714, "Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter"

ASTM G-26, "Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials"

ASTM G-53, "Operating Light- and Water-Exposure Apparatus (Fluorescent UV - Condensation Type) for Exposure of Nonmetallic Materials"

GRI GG1, "Geogrid Rib Tensile Strength"

U.S. Environmental Protection Agency (1991), "Inspection Techniques for the Fabrication of Geomembrane Field Seams," Technical Resource Document, U.S. EPA, EPA/530/SW-91/051.

Appendix A

List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
ATV	All-Terrain Vehicle
CB	Cement-Bentonite
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CH	Fat Clay (ASTM D-2487)
CL	Lean Clay (ASTM D-2487)
CPE	Chlorinated Polyethylene
CQA	Construction Quality Assurance
CQC	Construction Quality Control
CSPE	Chlorosulfonated Polyethylene
CSPE-R	Chlorosulfonated Polyethylene (Scrim Reinforced)
ECRM	Erosion Control and Revegetation Mat
EIA	Ethylene Interpolymer Alloy
EIA-R	Ethylene Interpolymer Alloy - Reinforced
EPA	Environmental Protection Agency
EPDM	Ethylene Propylene Diene Monomer
FCEA	Fully Crosslinked Elastomeric Alloy
FML	Flexible Membrane Liner
FTB	Film Tear Bond
FTM	Federal Test Method
GCL	Geosynthetic Clay Liner
GRI	Geosynthetic Research Institute

HDPE	High Density Polyethylene
IFAI	Industrial Fabrics Association International
LL	Liquid Limit
LLDPE	Linear Low Density Polyethylene
MARV	Mimimum Average Roll Value
MQA	Manufacturing Quality Assurance
MQC	Manufacturing Quality Control
NDT	Nondestructive Testing
NICET	National Institute for Certification in Engineering Technologies
PE	Professional Engineer or Polyethylene
PERM	Permanent Erosion Control and Revegetation Mat
PI	Plasticity Index
PL	Plastic Limit
PP	Polypropylene
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
SB	Soil-Bentonite
SC	Clayey Sand (ASTM D-2487)
SCB	Soil-Cement-Bentonite
SDR	Standard Dimension Ratio
TERM	Temporary Erosion Control and Revegetation Mats
TGA	Thermogravimetric Analysis
TRM	Turf Reinforcement and Revegetation Mat
USCS	Unified Soil Classification System

USP	U.S. Pharmaceutical
VLDPE	Very Low Density Polyethylene

Appendix B

Glossary

Activity—Plasticity index (expressed as a percentage) divided by the clay content (expressed as a percentage and defined as material finer than 0.002 mm).

Adhesion—The state in which two surfaces are held together by interfacial forces which may consist of molecular forces or interlocking action or both: (a) measured in shear and peel modes for geomembranes, (b) measured by direct shear testing for geosynthetics-to-soil.

Adhesive—A chemical system used in the bonding of geomembranes. The adhesive residue results in an additional element in the seamed area. (Manufacturers and installers should be consulted for the various types of adhesives used with specific geomembranes).

Aeolian Deposit—Soil deposited by wind.

Air Lance—A commonly used nondestructive geomembrane test method performed with a stream of air forced through a nozzle at the end of a hollow metal tube to determine seam continuity and tightness of relatively thin, flexible geomembranes.

All-Terrain Vehicles (ATVs)—Mobile 3-, or 4-wheeled vehicles with low pressure balloon tires which are used to move small equipment and materials around project sites.

Anchor Trench—The terminus of most geosynthetic materials as they exit a waste containment facility usually consisting of a small trench where the geosynthetic is embedded and suitably backfilled.

Antioxidants—Primary types include phenols and amines that scavenge extraneous free radicals which cause degradation of geosynthetics. Secondary types include decomposed peroxides as a source of free radicals.

Anvil—In hot wedge seaming of geomembranes, the anvil is the wedge of metal above and below which the sheets to be joined must pass. The temperature controllers and thermocouples of most hot wedge devices are located within the anvil.

Apertures—The openings between adjacent sets of longitudinal and transverse ribs of geogrids and geonets.

Appurtenances—Detailed items related to the proper functioning of a waste containment facility, such as pipes, sumps, risers, manholes, vents, penetrations and related items.

Atterberg Limits—Liquid limit and plastic limit of a soil.

Basis Weight—A deprecated term for mass per unit area.

Bedding Soil—Compacted layer of soil immediately beneath a leachate collection pipe.

Bentonite—Any commercially processed clay material consisting primarily of the mineral group smectite.

Berm—The upper edge of an excavation which isolates one cell in a containment system from another. The ends of a geosynthetic are buried to hold them in place or to anchor the geosynthetics.

Blocking—Unintentional adhesion between geomembrane sheets or between a geomembrane and another surface usually occurring during storage or shipping.

Blown Film—An extrusion method for producing geomembranes whereby the molten polymer vertically exits a circular die in the form of a huge cylinder which is subsequently cut longitudinally, unfolded and rolled into cores.

Blow-Out—Geomembrane rolls or panels which have been unintentionally displaced from their correct position by wind.

Bodied Chemical Fusion Agent—A chemical fluid containing a portion of the parent geomembrane that, after the application of pressure and after the passage of a certain amount of time, results in the chemical fusion of two essentially similar geomembrane sheets, leaving behind only that portion of the parent material. (Manufacturers and installers should be consulted for the various types of chemical fluids used with specific geomembranes in order to inform workers and inspectors.)

Bodied Solvent Adhesive—An adhesive consisting of a solution of the liner compound used in the seaming of geomembranes.

Boot—A bellows-type covering of a penetration through a geomembrane to exclude dust, dirt, moisture, etc.

Borrow Material—Excavated material used to construct a component of a waste containment facility.

Borrow Pit—Excavation area adjacent to, or off-site, the waste containment facility from which soil will be taken for construction purposes.

Buffing—An inaccurate term often used to describe the grinding of polyethylene geomembranes to remove surface oxides and waxes in preparation of extrusion seaming.

Calender—A machine equipped with three or more heavy internally heated or cooled rolls, revolving in opposite direction. Used for preparation of continuous sheeting or plying up of rubber compounds and frictioning or coating of fabric with rubber or plastic compounds. [B. F. Goodrich Co. Akron, OH].

Chemical-Adhesive Fusion Agent—A chemical fluid that may or may not contain a portion of the parent geomembrane <u>and</u> an adhesive that, after the application of pressure and after passage of a certain amount of time, results in the chemical fusion of two geomembrane sheets, leaving behind an adhesive layer that is dissimilar from the parent liner material. (Manufacturers and installers should be consulted for the various types of chemical fluids used with specific geomembrane to inform workers and inspectors.)

Chemical Fusion—The chemically-induced reorganization in the polymeric structure of the surface of a polymer geomembrane that, after the application of pressure and the passage of a certain amount of time, results in the chemical fusion of two essentially similar geomembrane sheets being permanently joined together.

Chemical Fusion Agent—A chemical fluid that, after the application of the passage of a certain amount of time, results in the chemical fusion of two essentially similar geomembrane sheets without any other polymeric or adhesive additives. (Manufacturers and installers should be consulted for the various types of chemical fusion agents used with specific geomembranes to inform workers and inspectors.)

Chlorinated Polyethylene (CPE)—Family of polymers produced by the chemical reaction of chlorine with polyethylene. The resultant polymers presently contain 25-45% chlorine by weight and 0-25% crystallinity.

Chlorinated Polyethylene-Reinforced (CPE-R)—Sheets of CPE with an encapsulated fabric reinforcement layer, called a "scrim".

Chlorosulfonated Polyethylene (CSPE)—Family of polymers produced by the reaction of polyethylene with chlorine and sulphur dioxide. Present polymers contain 23 to 43% chlorine and 1.0 to 1.4% sulphur. A "low water absorption" grade is identified as significantly different from standard grades.

Chlorosulfonated Polyethylene-Reinforced (CSPE-R)—Sheets of CSPE with an encapsulated fabric reinforcement layer, called a "scrim".

Clay Content—The percentage of a material (dry weight basis) with an mean equivalent grain diameter smaller than a specified size (usually 0.002 or 0.005 mm).

Clod—Term referring to "chunks" of cohesive soil when used for compacted clay liners.

Coated Fabric—Fabric that has been impregnated and/or coated with a rubbery or plastic material in the form of a solution, dispersion, hot melt, or powder. The term also applies to materials resulting from the application of a pre-formed film to a fabric by means of calendering.

Coextrusion—A manufacturing process whereby multiple extruders eject molten polymer into a die for the purpose of distinguishing properties or materials across the thickness of the geosynthetic material, as in coextruded HDPE/VLDPE/HDPE geomembranes.

Compaction Curve—An experimentally obtained curve obtained by plotting dry unit weight versus molding water content, typically used with soil liners.

Composite Liner—A geomembrane placed directly on the surface of a compacted soil liner or geosynthetic clay liner.

Concentrate—Term commonly used for carbon black premixed with a carrier resin resulting in pellets which are added to the extruder in the manufacturing of geosynthetic materials.

Construction Quality Control (CQC)—A planned system of inspections that are used to directly monitor and control the quality of a construction project (EPA, 1986). Construction quality control is normally performed by the geosynthetics manufacturer or installer, or for natural soil materials by the earthwork contractor, and is necessary to achieve quality in the constructed or installed system. Construction quality control (CQC) refers to measures taken by the installer or contractor to determine compliance with the requirements for materials and workmanship as stated in the plans and specifications for the project.

Construction Quality Assurance (CQA)—A planned system of activities that provide assurance that the facility was constructed as specified in the design (EPA, 1986). Construction quality assurance includes inspections, verifications, audits, and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. Construction quality assurance (CQA) refers to measures taken by the CQA organization to assess if the installer or contractor is in compliance with the plans and specifications for a project.

Corrugated Pipe—Built-up sections of HDPE drainage pipe manufactured by methods of corrugation, profiling or spirally wrapping small pipe around an internal core.

CQC Personnel—Individuals who work for contractor whose job it is to ensure that construction is taking place in accord with the plans and specifications approved by the permitting agency.

Crystal Structure—The geometrical arrangement of the molecules that occupy the space lattice of the crystalline portion of a polymer.

Curing—The strength gain over time of a chemically fused, bodied chemically fused, or chemical adhesive geomembrane seam due primarily to evaporation of solvents or crosslinking of the organic phase of the mixture.

Curing Time—The time required for full curing as indicated by no further increase in strength over time.

Deltaic Deposit—Soil deposited in a river delta.

Denier—A unit used in the textile industry to indicate the fineness of continuous filaments as applies to geotextiles. Fineness in deniers equals the mass in grams of 9000-m length of the filament.

Density—(a) For geosynthetics, the mass per unit volume of a polymeric material (since there is no void space, per se); and (b) for soils, the mass per total unit volume, including void space (note: if the mass is the total mass, i.e., solids plus water, the density is the total density or bulk density; if the mass is just the dry mass of solids, the density is the dry density of the soil).

Desiccation—Drying that is sufficient to change the properties, such as hydraulic conductivity, of the material.

Design Engineer—An organization or person who designs a waste containment facility that fulfills the operational requirements of the owner/operator, complies with accepted design practices for waste containment facilities and meets or exceeds the minimum requirements of the permitting agency.

Destructive Tests—Tests performed on geomembrane seam samples cut out of a field installation or test strip to verify specification performance requirements, e.g., shear and peel tests of geomembrane seams during which the specimens are tested to failure.

Direction, Cross-Machine—The direction perpendicular to the long, machine or manufactured direction.

Direction, Machine—The direction parallel to the long, machine or manufactured direction (synonyms, lengthwise, or long direction).

Dispersion—A qualitative term used to identify the degree of mixing of one component of a formulation within the total mass, e.g., carbon black dispersion.

Drive Rollers—Knurled or rubber rollers which grip two geomembrane sheets to be joined via applied pressure and propel the seaming device at a controlled rate of travel.

Dumbbell Shaped—Geomembrane test specimens in the shape of a dumbbell or dogbone, for subsequent tensile testing.

Dwell Time—The time required for a chemical fusion, bodied chemical fusion or adhesive seam to take its initial "tack", enabling the two opposing geomembranes to be joined together.

Earthwork Contractor—The organization that is awarded the subcontract from the general contractor, or contract from the owner/operator, to construct the earthen components of the waste containment facility.

Embossing—A method of providing a textured, a roughened, surface to calendered geomembranes for the purpose of increasing its friction to adjacent materials.

Ethylene Interpolymer Alloy (EIA)—A blend of ethylene vinyl acetate and polyvinyl chloride resulting in a thermoplastic elastomer.

Ethylene Interpolymer Alloy-Reinforced (EIA-R)—Sheets of EIA with an encapsulated fabric reinforcement layer.

Extrudate—The molten polymer which is emitted from an extruder during seaming using either extrusion fillet or extrusion flat methods. The polymer is initially in the form of a ribbon, rod, bead or pellets.

Extruder—A machine with a driver screw for continuous forming of polymeric compounds by forcing through a die; two types are used in the manufacturing of geomembranes, flat die and blown film.

Extrusion Seams—A seam of two geomembrane sheets achieved by heat-extruding a polymer material between or over the overlap areas followed by the application of pressure.

Fabricator—The organization that factory assembles rolls of geosynthetic materials into large panels for subsequent field deployment.

Fabric, Composite—A textile structure produced by combining nonwoven, woven, or knit manufacturing methods.

Fabric, Knit—A textile structure produced by interloping one or more ends of yarn or comparable material.

Fabric, Nonwoven—For geotextiles, a planar and essentially random textile structure produced by bonding, interlocking of fibers, or both, accomplished by mechanical, chemical, thermal, or solvent means, and combinations thereof.

Fabric, Reinforcement—A fabric, scrim, and so on, used to add structural strength to a two-or more ply polymeric sheet. Such geomembranes are referred to as being supported.

Fabric, Woven—A planar textile structure produced by interlacing two or more sets of elements, such as yarns, fibers, roving, or filaments, where the elements pass each other, usually at right angles and one set of elements are parallel to the fabric axis.

Factory Seams—The seaming of geomembrane rolls together in a factory to make large panels to reduce the number of field seams.

Field Seams—The seaming of geomembrane rolls or panels together in the field thereby making a continuous liner system.

Filament Yarn—The yarn made from continuous filament fibers.

Fill—As used in textile technology refers to the threads or yarns in a fabric running at right angles to the warp. Also called filler threads.

Filling Direction—See Direction, cross-machine. Note: For use with woven geotextiles only.

Film Tear Bond (FTB)—Description of a destructive geomembrane seam test (shear or peel) wherein the sheet on either side of the seam fails rather than delamination of the seam itself.

Filter Cloth—A deprecated term for geotextile.

Fines—Material passing through the No. 200 sieve (opennings of 0.075 mm)

Fishmouth—The uneven mating of two geomembranes to be joined wherein the upper sheet has excessive length that prevents it from being bonded flat to the lower sheet. The resultant opening is often referred to as a "fishmouth".

Flashing—The molten extrudate or sheet material which is extruded beyond the die edge or molten edge of a thermally bonded geomembrane seam, also called "squeeze-out".

Flat Die—An extrusion method for producing geomembranes whereby the molten polymer horizontally exists a flat die in the form of a wide sheet which is subsequently rolled onto cores.

Flexible Membrane Liner (FML)—Name previously given in EPA literature for the more generic term of geomembrane. The latter is used exclusively in this manual.

Flood Coating—The generous application of a bodied chemical compound, or chemical adhesive compound to protect exposed yarns in scrim reinforced geomembranes.

Formulation—The blending of several components (resin plus additives) to make a mixture for subsequent processing into a geosynthetic material.

Fully Crosslinked Elastomeric Alloy (FCEA)—A thermoplastic elastomeric alloy of polypropylene (PP) and ethylene-propylene diene monomer (EPDM).

Gage—Deprecated term for the thickness of a geosynthetic material.

General Contractor—The organization that is awarded a contract from the owner/operator to construct a waste containment facility.

Geocell—A three-dimensional structure filled with soil, thereby forming a mattress for increased bearing capacity and maneuverability on loose or compressible subsoils.

Geocomposite—A manufactured material using geotextiles, geogrids, geonets, and/or geomembranes in laminated or composite form.

Geogrid—A geosynthetic used for reinforcement which is formed by a regular network of tensile elements with apertures of sufficient size to allow strike-through of surrounding soil, rock, or other geotechnical materials..

Geomembrane—An essentially impermeable geosynthetic composed of one or more synthetic sheets.

Geonet—A geosynthetic consisting of integrally connected parallel sets of ribs overlying similar sets at various angles for planar drainage of liquids and gases.

Geosynthetic Clay Liner (GCL)—Factory manufactured, hydraulic barrier typically consisting of bentonite clay or other very low permeability material, supported by geotextiles and/or geomembranes which are held together by needling, stitching and/or chemical adhesives.

Geosynthetics—The generic term for all synthetic materials used in geotechnical engineering applications; the term includes geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners and geocomposites.

Geotechnical Engineering—The engineering application of geotechnics.

Geotechnics—The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust to the solution of engineering problems; it embraces the field of soil mechanics, rock mechanics, and many of the engineering aspects of geology, geophysics, hydrology, and related sciences.

Geotextile—A permeable geosynthetic comprised solely of textiles. Current manufacturing techniques produce nonwoven fabrics, knitted (non-tubular) fabrics, and woven fabrics.

Glacial Till—A soil of varied grain sizes deposited by glacial action.

Gravel—Material that will not pass through the openings of a No. 4 sieve (4.76 mm openings)

Grinding—The removal of oxide layers and waxes from the surface of a polyethylene sheet in preparation of extrusion fillet or extrusion flat seaming.

Gun—Synonymous term for hand held extrusion fillet device or hand held hot air device.

Haunch Area—The location of a buried pipe which extends for the lower 180° around the bottom outside of the pipe.

Heat Bonded—See Melt-bonded.

Heat-Seaming—The process of joining two or more thermoplastic geomembranes by heating areas in contract with each other to the temperature at which fusion occurs. The process is usually aided by a controlled pressure. In dielectric seaming the heat is induced by means of radio-frequency waves.

High Density Polyethylene (HDPE)—A polymer prepared by low-pressure polymerization of ethylene as the principal monomer and having the characteristics of ASTM D-1348 Type III and IV polyethylene. Such polymer resins have density greater than or equal to 0.941 g/cc as noted in ASTM D-1248.

Hook Blade—A shielded knife blade confined in such a way that the blade cuts upward or is drawn toward the person doing the cutting to avoid damage to underlying sheets.

Hydraulic Conductivity—The rate of discharge of water under laminar flow conditions through a unit cross-sectional area of a porous medium under a unit hydraulic gradient and standard temperature conditions (20°C).

Initial Reaction Time—(See dwell time).

Installation Contractor—The organization that is awarded a subcontract from the general contractor or owner/operator, to install geosynthetic materials in the waste containment facility.

Kneading Compaction—Compaction of a soil liner whereby a foot or prong is repeatedly passed into and through a lift of soil.

Lacustrine Deposit—A soil deposited in a stagnent body of water, e.g., lake.

Lapped Seam—A seam made by placing one surface to be joined partly over another surface and bonding the overlapping portions.

Leachate—Liquid that has percolated through or drained from solid waste or other man-emplaced materials and contains soluble, partially soluble, or miscible components removed from such waste.

Let-Down—Term used for the addition of carbon black powder or concentrated pellets into an extruder in the manufacture of geosynthetic materials.

Lift—Term applied to the construction of a discrete layer of a soil liner, usually 150 to 225 mm (6 to 9 in.) in thickness.

Liner—A layer of emplaced materials beneath a surface impoundment or landfill which serves to restrict the escape of waste or its constituents from the impoundment or landfill. The term can apply to soil liners, geomembranes or geosynthetic clay liners.

Linear Low Density Polyethylene (LLDPE)—A polyethylene material produced by a low pressure polymerization process with random incorporation of comonomers to produce a density of 0.915 to 0.930 g/cc.

Liquid Limit (LL)—The water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil .

Manhole—A vertical pipe rising from a sump area through the waste mass and eventually penetrating the cover for the purpose of leachate removal.

Manufacturer—The organization that manufactures geosynthetic materials used at a waste containment facility.

Manufacturing Quality Assurance (MQA)—A planned system of activities that provide assurance that the materials were constructed as specified in the certification documents and contract plans. MQA includes manufacturing facility inspections, verifications, audits and evaluation of raw materials and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract plans for a project.

Manufacturing Quality Control (MQC)—A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factor originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract plans.

Mass Per Unit Area—The proper term to represent and compare the amount of material per unit area (units are oz./yd.^{2} or g/m^2). Often called "weight" or "basis weight".

Medium Density Polyethylene (MDPE)—A polymer prepared by low-pressure polymerization of ethylene as the principal monomer and having the characteristics of ASTM D-1348 Type II polyethylene. Such polymer resins have density less than 0.941 g/cc as noted in ASTM D-1248.

Melt-Bonded—Thermally bonded by melting the fibers to form weld points.

Membrane—A continuous sheet of material, whether prefabricated as a geomembrane or sprayed or coated in the field, as a sprayed-on asphalt/polymer mixture.

Minimum Average Roll Value (MARV)—A statistical value of a particular test property which embraces the 95% confidence level of all possible values of that property. For a normally distributed set of data it is approximately the mean value plus and minus two standard deviations.

Modified Compaction—A laboratory technique that produces maximum dry unit weights approximately equal to field dry units weights for soils that are well compacted using the heaviest compaction equipment available (ASTM D-1557).

Mouse—Synonymous term for hot wedge, or hot shoe, seaming device.

MQA/CQA Certifying Engineer—The individual who is responsible for certifying to the owner/operator and permitting agency that, in his or her opinion, the facility has been constructed in accord with the plans and specifications and MQA/CQA document approved by the permitting agency.

MQA/CQA Engineer—The individual who has overall responsibility for manufacturing quality assurance and construction quality assurance.

MQA/CQA Personnel—Those individuals responsible for making observations and performing field tests to ensure that the facility is constructed in accord with the plans and specifications approved by the permitting agency.

MQA/CQA Plan—A written plan, or document, prepared on behalf of the owner/operator which includes a detailed description of all MQA/CQA activities that will be used during materials manufacturing and construction to manage the installed quality of the facility.

Needle-Punched—A nonwoven geotextile which is mechanically bonded by needling with barbed needles.

NICET—An acronym for the National Institute for Certification in Engineering Technologies, an organization who administers examinations for geosynthetic and earthen materials for waste containment facilities. [NICET, 1420 King Street, Alexandria, VA 22314]

Nondestructive Test—A test method which does not require the removal of samples from, nor damage to, the installed liner system. The evaluation is done in an in-situ manner. The results do not indicate the seam's mechanical strength but are performed for examination for the seam's continuity.

Nonwoven—See Fabric, nonwoven.

Normal Direction—For geotextiles, the direction perpendicular to the plane of a geotextile.

Outliers—Experimental data points which do not fit into the anticipated and/or required maxima, or minima, specified values.

Owner/Operator—The organization that will own and operate the disposal unit.

Owner's Representative—The official representative who is responsible for coordinating schedules, meetings and field activities.

Oxide Layer—The reacting of atmospheric oxygen with the surface of a polymer geomembrane.

Padfoot Roller—Footed, or padded, roller typically consisting of 4.0 in. long pads used to compact soil liners.

Panels—The factory fabrication of geomembrane rolls into relatively large sections, or panels, so as to reduce the number of field seams.

Peel Test—A geomembrane seam test wherein the seam is placed in a tension state as the geomembrane ends are pulled apart.

Permeability—(1) The capacity of a porous medium to conduct or transmit fluid; (2) the amount of liquid moving through a barrier in a unit time, unit area, and unit gradient not normalized for, but directly related to, thickness. See Hydraulic Conductivity.

Permitting Agency—Often a state regulatory agency but may include local or regional agencies and/or other federal agencies.

Permittivity—For a geotextile, the volumetric flow rate of water per unit cross-section area, per unit head, under laminar flow conditions, in the normal direction through the fabric.

pH—A measure of the acidity or alkalinity of a solution; numerically equal to the logarithm of the reciprocal of the hydrogen ion concentration in gram equivalents per liter of solution. pH is represented on a scale of 0 to 14; 7 represents a neutral state; 0 represents the most acid, and 14 the most alkaline.

Pinholes—Very small imperfections in geomembranes which may allow for escape of the contained liquid.

Piping—The phenomenon of soil fines migrating out of a soil mass by flow of liquid leaving a small channel, or pipe, in the upstream soil mass.

Plastic—A material that contains as an essential ingredient one or more organic polymeric substances of large molecular weight which is solid in its finished state and at some stage in its manufacture or processing into finished articles can be shaped by flow [ASTM].

Plastic Index (PI)—The numerical difference between liquid and plastic limits, i.e., LL-PL.

Plastic Limit (PL)—The water content corresponding to the arbitrary limit between the plastic and solid states of consistency of a soil .

Plasticizer—A plasticizer is a material, frequently "solventlike," incorporated in a plastic or a rubber to increase its ease of workability, its flexibility, or distensibility. Adding the plasticizer may lower the melt viscosity, the temperature of the second-order transition, or the elastic modulus of the polymer. Plasticizers may be monomeric liquids (phthalate esters), low-molecular-weight liquid polymers (polyesters), or rubbery high polymers (EVA). The most important use of plasticizers in geosynthetics is with PVC geomembranes, where the choice of plasticizer will dictate under what conditions the liner may be used.

Plugging—The phenomenon of soil fines migrating into and clogging the voids of larger particle sized soils within a soil mass or geotextile filter.

Ply—Individual layer of material, usually sheet of geomembrane, which is laminated to another, or several, layers to form the complete geomembrane.

Ply Adhesion—The bonding force required to break the adhesive bond of one layer, or material, to another. It is usually evaluated by some type of tension peel test.

Polyester Fiber—Generic name for a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of an ester of a dihydric alcohol and terephthalic acid.

Polyethylene (PE)—A polyolefin formed by bulk polymerization (for low density) or solution polymerization (for high density) where the ethylene monomer is placed in a reactor under high pressure and temperature. The oxygen produces free radicals which initiate the chain polymerization. For solution polymerization the monomer is first dissolved in an inert solvent. Catalysts are sometimes required to initiate the reaction.

Polymer—A macromolecular material formed by the chemical combination of monomers having either the same or different chemical composition. Plastics, rubbers, and textile fibers are all high-molecular-weight polymers.

Polymeric Liner—Plastic or rubber sheeting used to line disposal sites, pits, ponds, lagoons, canals, and so on.

Polyolefin—A family of polymeric materials that includes polypropylene and polyethylene, the former being very common in geotextiles, the latter in geomembranes. Many variations of each exist.

Polypropylene—A polyolefin formed by solution polymerization as was described for high density polyethylene.

Polyvinyl Chloride (PVC)—A synthetic thermoplastic polymer prepared from vinylchloride. PVC can be compounded into flexible and rigid forms through the use of plasticizers, stabilizers, fillers, and other modifiers; rigid forms used in pipes and well screens: flexible forms used in manufacture of geomembranes.

Pressure Rollers—Rollers accompanying a seaming technique which apply pressure to the opposing geomembrane sheets to be joined. They closely follow the actual melting process and are self-contained within the seaming device.

Pressurized Dual Seam—A thermal fusion method of making a geomembrane whereby a unbonded space is left between two parallel bonded tracks. The unbonded space is subsequently used for a nondestructive air pressure test.

Proctor Test—The tests utilized to obtain a laboratory compaction curve. Synonymous to compaction test.

Puckering—A heat related sign of localized strain caused by improper seaming using extrusion or fusion methods. It often occurs on the bottom of the lower geomembrane and in the shape of a shallow inverted "V".

Pugmill—A mechanical device used for mixing of dry soil materials.

Quality Assurance (QA)—A planned system of activities that provide assurance that the facility was constructed as specified in the design.

Quality Control (QC)—A planned system of inspections that are used to directly monitor and control the quality of a construction project.

Reclaim—Small pieces, or chips, of previously used polymer materials which are entered into the processing of a geosynthetic material,. Synonymous with "reprocess" and "recycle".

Record Drawings—Drawings which document the actual lines and grades and conditions of each component of the disposal unit. Synonymous with "as-built" drawings.

Regrind—Small pieces, or chips, of previously fabricated geosynthetic material which are re-entered into the processing of the same type of geosynthetic material, synonymous with "rework".

Residual Soil—Soil formed in place from weathering of parent rock.

Risers—Pipelines extending from primary or secondary leachate collection sumps up the sideslope of the facility and exiting to a shed or manhole.

Rolling Bank—A charge of molten polymer used in the calendering production method of geomembranes for the purpose of directing the flow of polymer in the desired roll direction.

Scrim Designation—The weight of number of yarns of fabric reinforcement per inch of length and width, e.g., a 10 × 10 scrim has 10 yarns per inch in both the machine and cross machine directions.

Scrim (or Fabric) Reinforcement—The fabric reinforcement layer used with some geomembranes for the purpose of increased strength and dimensional stability.

Sealant—A viscous chemical used to seal the exposed edges of scrim reinforced geomembranes. (Manufacturers and installers should be consulted for the various types of sealant used with specific geomembranes).

Sealed Double Ring Infiltrometer (SDRI)—A device used for measuring in-situ hydraulic conductivity of a test pad for a soil liner.

Seam Strength—Strength of a seam of liner material measured either in shear or peel modes. Strength of the seams is reported either in absolute units (e.g., pounds per inch of width) or as a percent of the strength of the geomembrane.

Seaming Boards—Smooth wooden planks placed beneath the area to be seamed to provide a uniform resistance to applied roller pressure in the fabrication of geomembrane seams.

Selvage—The longitudinal edges of woven geotextile in which the weft yarns fold back upon themselves. In fabric reinforced geomembranes selvage refers to edge of the rolls where no scrim is present.

Shear Test—A geomembrane seam test wherein the seam is placed in a shear state as the geomembrane ends are pulled apart.

Sheepsfoot Roller—Footed, or pronged, roller typically consisting of 8.0 in. long feet used to compact soil liners.

Sheeting—A form of plastic or rubber in which the thickness is very small in proportion to length and width and in which the polymer compound is present as a continuous phase throughout, with or without fabric, synonymous with geomembrane.

Shielded Blade—A knife within a housing which protects the blade from being used in an open fashion, i.e., a protected knife.

Slope—Deviation of a surface from the horizontal expressed as a percentage, by a ratio, or in degrees. In engineering, usually expressed as a percentage of vertical to horizontal change [EPA].

Slurry Wall—A construction technique whereby a vertical sided trench is supported by means of the hydrostatic pressure of a clay-water suspension ("slurry") placed within it.

Smectite—A group of expandable clay minerals with a very large ratio of surface area to mass, a large negative surface charge, a high cation exchange capacity, and a high shrink-swell potential.

Soil Liners—Low-hydraulic-conductivity materials constructed of earthen materials that usually contain a significant amount of clay.

Solvent, Bodied Solvent and Solvent Adhesive—See Chemical Fusion, Bodied Chemical Fusion and Chemical Adhesive.

Spotting—The final placement, or positioning, of a geomembrane roll or panel prior to field seaming.

Spread-Coating—A manufactured process whereby a polymeric material is spread in a continuous fashion on a geotextile substrate thereby forming a reinforced geomembrane composite.

Squeeze-Out—See "flashing".

Standard Compaction—A laboratory technique which produces maximum dry unit weights approximately equal to field dry unit weights for soil that are well compacted using modest-sized compaction equipment.

Staple—Short fibers in the range 0.5 to 3.0 in. (1 cm to 8 cm) long.

Staple Yarn—Yarn made from staple fibers.

Stinger—A long steel rod on the end of a front end loader or fork lift which is inserted into the core of a roll of geosynthetic material for the purpose of lifting and maneuvering.

Stress Crack— An external or internal crack in a plastic caused by tensile stresses less than its short-time mechanical strength. Note: The development of such cracks is frequently accelerated by the environment to which the plastic is exposed. The stresses which cause cracking may be present internally or externally or may be combinations of these stresses.

Strike-through—The penetration of one material into and/or through the openings of an adjacent planar material.

Substrate—The layer, or unit, that is immediately beneath the layer under consideration.

Sumps—A low area in a waste facility which gravitationally collects leachate from either the primary or secondary leachate collection system.

Superstrate—The layer, or unit, that is immediately above the layer under consideration.

Support Sheeting—See Fabric reinforcement.

Tack—Stickiness of a geomembrane or the temporarily welding of geomembranes together.

Tenacity—The fiber strength on a grams per denier basis.

Tensiometer—A field measuring device containing a set of opposing grips used to place a geomembrane sheet or seam in tension for evaluating its strength.

Testing Laboratory—The testing laboratory(s) providing testing services to verify physical, mechanical, hydraulic or endurance properties of the materials used to construct the waste containment facility.

Test Pads—Prototype layer or layers of soil materials constructed for the purpose of simulating construction conditions and/or measuring performance characteristics. Test pads are most frequently used to verify that the materials and methods of construction proposed for a soil liner will lead to development of the desired low hydraulic conductivity.

Test Strips—Trial sections of seamed geomembranes used (1) to establish machine settings of temperature, pressure and travel rate for a specific geomembrane under a specific set of atmospheric conditions for machine-assisted seaming and (2) to establish methods and materials for chemical and chemical adhesive seams under a specific set of atmospheric conditions.

Test Welds—See "test strips".

Tex—Denier multiplied by 9 and is the weight in grams of 1000 m of yarn.

Textured Sheet—Polyethylene geomembranes which are produced with a roughened surface via coextrusion, impingement or lamination so as to create a high friction surface(s).

Thermal Fusion—The temporary, thermally-induced reorganization in the polymeric make-up of the surface of a polymeric geomembrane that, after the application of pressure and the passage of a certain amount of time, results in the two geomembranes being permanently joined together.

Thermoplastic Polymer—A polymer that can be heated to a softening point, shaped by pressure, and cooled to retain that shape. The process can be done repeatedly.

Thermoset Polymer—A polymer that can be heated to a softening point, shaped by pressure, and, if desired, removed from the hot mold without cooling. The process cannot be repeated since the polymer cannot be resoftened by the application of heat.

Trampolining—The lifting of a geomembrane off of its subbase material due to thermal contraction and inadequate slack which can occur at the toe of slope or in corners of a facility.

Transmissivity—For a geotextile, the volumetric flow rate per unit thickness under laminar flow conditions, within the in-plane direction of the fabric.

Transverse Direction—A deprecated term for cross-machine direction.

Tremie—A method of hydraulic placement of soil, or other material, under a head of water.

Ultraviolet Degradation—The breakdown of polymeric structure when exposed to natural light.

Unsupported Geomembrane—A polymeric geomembrane consisting of one or more piles without a reinforcing-fabric layer or scrim.

Vacuum Box—A commonly used type of nondestructive test method which develops a vacuum in a localized region of a geomembrane seam in order to evaluate the seam's tightness and suitability.

Veneer Reinforcement—Geogrid or geotextile reinforcement layer(s) which placed in the soil covering a geomembrane for the purpose of side slope stabilization.

Very Low Density Polyethylene (VLDPE)—A linear polymer of ethylene with other alpha-olefins with a density of 0.890 to 0.912 g/cc.

Virgin Ingredients—Components of a geosynthetic formulation which have never been used in a prior formulation or product.

Warp—In textiles, the lengthwise yarns in a woven fabric.

Waxes—The low molecular weight components of some polyethylene compounds which migrate to the surface over time and must be removed by grinding (for polyethylene) or be mixed into the melt zone using thermal seaming methods.

Weft—A deprecated term for cross-machine direction.

Wicking—The phenomenon of liquid transmission within the fabric yarns of reinforced geomembranes via capillary action.

Width—For a geotextile, the cross-direction edge-to-edge measurement of a fabric in a relaxed condition on a flat surface.

Woof—A deprecated term for cross-machine direction.

Woven—See Fabric, woven.

Woven, Monofilament—The woven geotextile produced with monofilament yarns.

Woven, Multifilament—The woven geotextile produced with multifilament yarns.

Woven, Slit-Film—The woven fabric produced with yarns produced from slit film.

Woven, Split-Film—See Woven, slit-film.

Yarn—A generic term for continuous strands of textile fibers or filaments in a form suitable for knitting, weaving, or otherwise intertwining to form a textile fabric. Yarn may refer to (1) a number of fibers twisted together, (2) a number of filaments laid together without twist (a zero-twist yarn), (3) a number of filaments laid together with more or less twist, or (4) a single filament with or without twist (a monofilament).

Zero Air Voids Curve—A curve that relates dry unit weight to water content for a saturated soil that contains no air.

Appendix C

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*U.S. GOVERNMENT PRINTING OFFICE 1993 -750 -002 /80296

Available Companion Document of Standards

To

Quality Control and Quality Assurance for Waste Containment Facilities,
EPA/600/R-93/182

A compilation of standards referenced in this document (*Quality Control and Quality Assurance for Waste Containment Facilities*, EPA/600/R-93/182) is available from The American Society for Testing and Materials (ASTM). It is intended as a companion for this document and for engineers and researchers who are involved with quality assurance and quality control practices concerning all components of waste containment.

The ASTM document is entitled *ASTM and other Specifications and Test Methods on the Quality Assurance of Landfill Liner Systems*, and is identified by the following numbers:

Publication Code Number (PCN): 03-435193-38
International Standard Book Number (ISBN): 0-8031-1784-1

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R2070, October, 1993

EXHIBIT 3
Part 3

ATTACHMENT E

Eco-profiles of the European Plastics Industry
High Density Polyethylene (HDPE)

PlasticsEurope
Association of Plastics Manufacturers

Eco-profiles of the European Plastics Industry

HIGH DENSITY POLYETHYLENE (HDPE)

A report by

I Boustead

for

Plastics*Europe*

Data last calculated

March 2005

IMPORTANT NOTE

Before using the data contained in this report, you are strongly recommended to look at the following documents:

1. Methodology

This provides information about the analysis technique used and gives advice on the meaning of the results.

2. Data sources

This gives information about the number of plants examined, the date when the data were collected and information about up-stream operations.

In addition, you can also download data sets for most of the upstream operations used in this report. All of these documents can be found at: www.plasticseurope.org.

Plastics*Europe* may be contacted at

Ave E van Nieuwenhuyse 4
Box 3
B-1160 Brussels

Telephone: 32-2-672-8259
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OLEFIN POLYMERS

High density polyethylene (HDPE) is one of the olefin polymers and it is useful to examine briefly the four major olefin polymers because it highlights the differences between them and indicates why these different polymers are produced. The polymers are shown in Table 1.

Table 1
Large tonnage polyolefins produced in Europe in 1999.

Polymer	Acronym	Production ('000 tonne)[1]
Low density polyethylene	LDPE	4793
High density polyethylene	HDPE	4308
Linear low density polyethylene	LLDPE	1934
Polypropylene	PP	7395

The polyolefins are chemically the simplest of all polymer structures. They can be produced commercially from olefin (alkene) monomers because the olefins contain a reactive double bond. Schematically the process of converting monomer to polymer is illustrated in Figure 1 for ethylene. Essentially the double bond in the ethylene molecule is opened to form a reactive *radical,* which then attaches itself to another radical. The process repeats itself to produce a long chain molecule or polymer terminating only when the propagating radical attaches itself to an unreactive species.[2] The starting material, ethylene, is called the *monomer* and the final compound consisting of many thousands of ethylene units is called the *polymer*.[3]

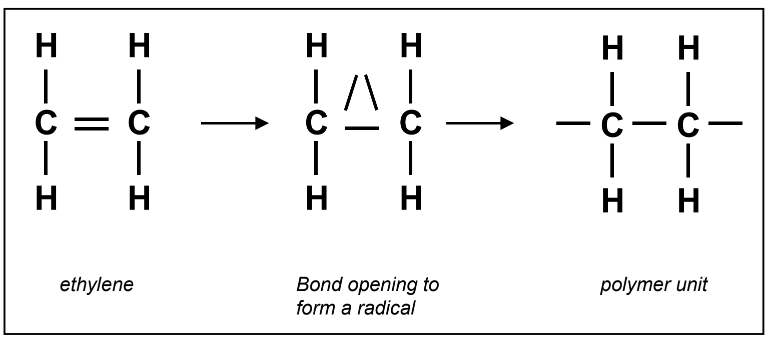


Figure 1
Schematic diagram of the formation of polyethylene.

[1] APME Annual Report 2001.
[2] The actual polymerisation process is somewhat more complex than this but the concept of opening the double bond is a useful way to think of addition polymerisation.
[3] The terms *monomer* and *polymer* are due to Berzelius (1830) from the Greek: poly = many; meros = part; mono = single or alone

Such polymers are often referred to as *addition polymers* because they are formed by continually adding further monomer units to the growing polymer chain and the polymerisation mechanism is known as *free radical polymerisation*.[4]

CHARACTERISTICS OF OLEFIN POLYMERS

All olefin polymers have an unbroken carbon backbone and in its simplest form the structure of polyethylene is schematically of the form shown in Figure 2. (Polyethylene with this highly linear structure is often referred to as polymethylene).

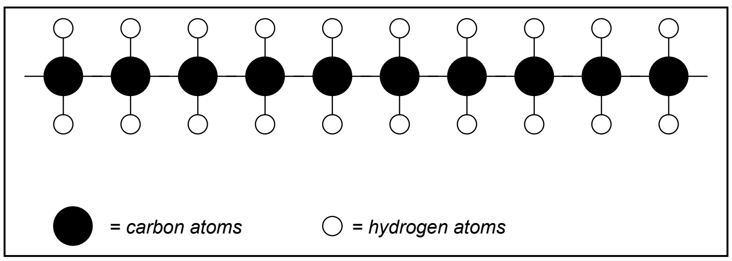


Figure 2
Schematic structure of linear polyethylene

When a highly regular polymer such as that shown in Figure 2 is cooled from the melt, the polymer chains do not remain as a random tangle. Instead they tend to fold and lie alongside each other as shown in Figure 3.

These ordered regions inside polymer solids behave as crystalline regions. However, unlike atomic crystals, the whole of the long molecules cannot be incorporated into these ordered regions and so there will always be regions where the molecules are randomly arranged. These are amorphous regions. Because of the closer packing in the crystalline regions, their density is higher (~ 1000 kg m^{-3}) than the amorphous regions (~850 kg m^{-3}). Thus the higher the density of a specified polymer type, the greater the crystallinity.

The amount of crystallinity in a polymer directly affects the properties because the crystalline regions exhibit superior mechanical properties and for most applications the higher the crystallinity the better.

[4] All addition polymers rely on the opening of a double bond to form the polymer backbone and this concept presents a useful way of determining polymer structures once the structural formula of the monomer is known.

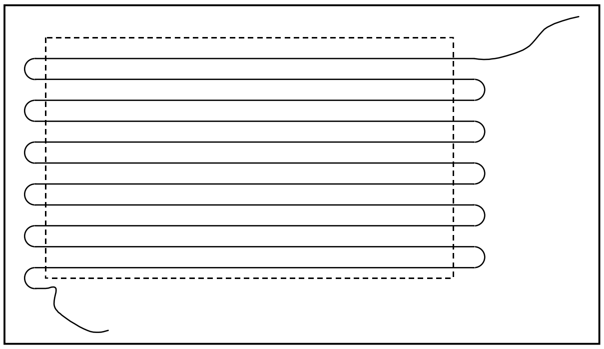


Figure 3
Chain folding in regular polymers. The region inside the broken line is regarded as a polymer crystal.

A critical factor in promoting the formation of crystalline regions in polymers is the regularity of the polymer chains. In practice, when ethylene is polymerised it does not form a simple linear chain of the type shown in Figure 2. Instead, it grows side branches. These side branches may be short (up to 8 carbon atoms) or very long (up to several thousand carbon atoms). Short, irregularly positioned side branches of different length tend to inhibit crystal formation but long side branches can usually be incorporated into the crystalline regions. The production technology determines the number, positioning and length of the side branches.

HISTORICAL BACKGROUND

The first record of polyolefin production was in 1898 when von Pechmann in Germany produced the first polymethylene structure in the laboratory. It was not, however, until 1935 that Perrin at ICI showed that it was possible to produce large quantities of low density polyethylene by subjecting ethylene to pressures up to 350 MPa and temperatures up to 350°C. This process was developed commercially and production of LDPE started in 1938 in the UK.

In 1950, Hogan and Bank at Phillips Petroleum Co invented a catalyst containing chromium oxide on silica that allowed polymerisation at lower pressures (3 – 4 MPa) and temperatures (70 - 100°C). These Phillips catalysts were used to produce the first HDPE.

In 1953, Ziegler in Germany developed catalysts containing titanium halides and alkylaluminium which promoted polymerisation at atmospheric pressure and temperatures of 50 - 100°C. By adjusting the precise composition of the catalyst, he found that it was possible to obtain a wide range of polyethylenes that could be used in different applications. In 1954, Natta at Montecatini modified the Ziegler catalysts to produce isotactic polypropylene and commercial production of polypropylene started in 1957.

During the period 1956-1976 considerable research by Phillips, Solvay, Montedison and Mitsui Petrochemical went into different catalyst systems with the aim of obtaining high yield isotactic polypropylene.

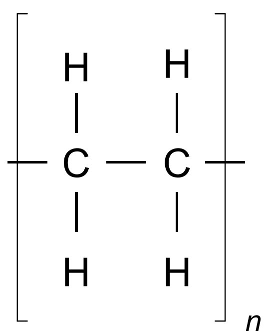
In 1976, Kaminsky and Sunn developed a new family of catalysts which allowed the production of ethylene polymers and copolymers and controlled the regularity of the chain branching. These were the catalysts that allowed the first commercial production of LLDPE.

As this brief history shows, most of the research in this area has been concerned with catalysts which achieve two main factors: obtaining more benign production conditions and producing polymers with more controlled structures.

POLYETHYLENE

Low density polyethylene

The repeat unit of polyethylene is:



Low density polyethylene (LDPE) has traditionally been defined as polyethylene with a density less than 940 kg m^{-3}. It is produced by a high pressure process and so is often referred to as high pressure polyethylene. The polymer contains both long and short chain side branching with the number of branches being from 2 and 50 per 1000 carbon atoms on the carbon backbone. LDPE can be produced with chain lengths ranging from 50,000 to 100,000 repeat units, with crystallinities in the range 35 to 75% and with densities in the range 915 to 940 kg m^{-3}.

High density polyethylene

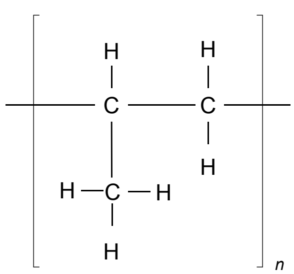
High density polyethylene (HDPE) has the same repeat unit as LDPE and is usually regarded as polyethylene with a density greater than 940 kg m^{-3}. It is produced in low pressure reactors and so is often referred to as low pressure polyethylene. It differs from LDPE in that it contains fewer side branches at 5 to 10 per 1000 carbon atoms on the backbone. Most of the side branches are short with long side branches being rare. Molecular weights are similar to low density polyethylene but crystallinities are usually high (50 – 85%) and densities range from 940 to 960 kg m^{-3}.

Linear low density polyethylene

Linear low density polyethylene (LLDPE) is a copolymer of ethylene with another short chain olefin. The most common co-monomers are 1-butene, 1-hexene, 4-methyl-1-pentene and 1-octene. The comonomer is usually present in concentrations of 2.5 to 3.5% and this results in densities in the range 915 to 925 kg m^{-3} with crystallinities of 30 to 45%. The range of molecular weights of LLDPE are considerably narrower than for LDPE and HDPE; typically they lie in the range 50,000 to 200,000.

POLYPROPYLENE

The repeat unit for polypropylene is:



The CH_3 side group can be arranged in three different ways in polypropylene and the three possibilities are shown in Figure 4. In *isotactic polypropylene*, the methyl side groups all lie on the same side of the polymer chain. In three dimensions, the polymer chain forms a helix and can fold to form crystalline regions similar to Figure 3. These crystalline regions have a density of 936 kg m^{-3} In *syndiotactic polypropylene*, the methyl side groups are arranged regularly on alternate side of the polymer chain. In three dimensions, syndiotactic polypropylene also forms a helical structure although it is more open that the isotactic form and so, although it too can fold to form crystalline regions, the crystal density is lower at 910 kg m^{-3}. In *atactic polypropylene*, the methyl side groups are randomly arranged on either side of the chain. The resultant structure is amorphous. Of the three forms, isotactic has the most superior properties and so manufacture aims to maximise this form. Some atactic polymer is invariably produced in small quantities and this is often used as a waterproof mastic.

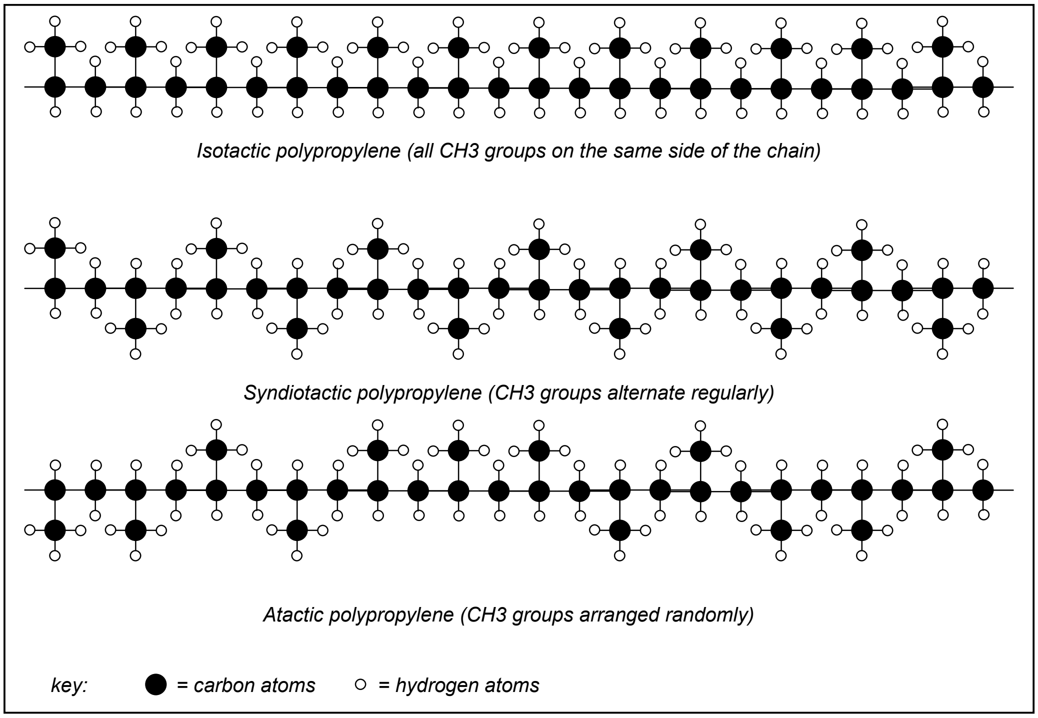


Figure 4
Different types of polypropylene depending on the arrangement of the methyl side group.

PRODUCTION PROCESSES

Three main techniques are employed in the production of polyolefins: high pressure technology, solution or slurry processes and gas phase polymerisation.

High pressure technology

When monomer is held at high pressures and temperatures above the polymer melting point, the monomer/polymer mixture can act as a polymerisation medium. Initiators and catalysts can be added to this medium. This technology is used only for LDPE and employs pressures up to 300 MPa[5] and temperatures up to 300°C.

There are two major problems with this type of technology. The first is the obvious one of handling materials under such high pressures and the second is that of temperature control. Two types of reactor are used to solve these problems. The *stirred autoclave* is essentially a cylindrical, thick-walled reaction vessel stirred by paddles. Because of the very thick walls needed to withstand the pressure, external heat extraction is not possible and temperature is controlled using the monomer as a heat sink. The residence time is usually less than a minute and the conversion per pass is usually less than 20%. Unreacted monomer is cooled and reused. In the *tubular reactor*, the monomer is passed along the inner of a pair of concentric tubes. Coolant passes between the inner and outer tubes. Conversion rates per pass are up to 35% and again, unreacted monomer is recovered for reuse.

Solution/slurry polymerisation

Many low molecular weight, saturated hydrocarbons will dissolve polyolefins. If the temperature is higher than the melting point of the polymer and the concentration of the polymer is low, the polymer will remain as a true solution. However, at lower temperatures and higher concentrations, the polymer will form a suspension or mobile slurry. Using solutions or slurries as the polymerisation medium requires relatively low temperatures (70 - 110°C) and relatively low pressures (1 – 5 MPa).

Reaction vessels can be either stirred tank reactors using solvents such as hexane or closed loop, cooled pipe reactors using solvents such as isopentane. In slurry reactors, the slurry concentration is usually maintained at ~25% and settling chambers at the base of the reactor allow polymer to be removed continuously. The recovered solvent is reused and conversions can be as high as 98%.

Gas phase polymerisation

A gas phase reactor is essentially a fluidised bed of dry polymer particles maintained either by stirring or by passing gas at high speeds through it. Pressures are usually relatively low at ~2MPa and temperatures are usually in the range 70 - 110°C. A variety of different configurations are used mainly to obtain an acceptable particle size and shape in the final product. Gas phase polymerisation is used for HDPE, PP and LLDPE.

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[5] To put these pressures in perspective, 1 atmosphere pressure is approximately 0.101MPa

ECO-PROFILE OF HIGH DENSITY POLYETHYLENE

Data have been obtained for the production of 3.87 million tonnes of HDPE. This represents 89.7% of all West European production. The average gross energy required to produce 1 kg of high density polyethylene is 76 MJ with a range extending from 56 MJ to 91 MJ. Table 2 shows the breakdown of this gross energy and Table 3 gives these same data expressed in terms of primary fuels. Table 4 shows the energy data expressed as masses of fuels. Table 5 shows the raw materials requirements and Table 6 shows the demand for water. Table 7 shows the gross air emissions and Table 8 shows the corresponding carbon dioxide equivalents of these air emissions. Table 9 gives the emissions to water. Table 10 shows the gross solid waste generated and Table 11 gives this solid waste in EU format.

Table 2
Gross energy required to produce 1 kg of high density polyethylene. (Totals may not agree because of rounding)

Fuel type	Fuel prod'n & delivery energy (MJ)	Energy content of delivered fuel (MJ)	Energy use in transport (MJ)	Feedstock energy (MJ)	Total energy (MJ)
Electricity	5.96	2.45	0.58	-	8.98
Oil fuels	0.24	7.39	0.11	32.09	39.82
Other fuels	0.26	5.39	0.02	22.23	27.91
Totals	6.47	15.22	0.70	54.32	76.71

Table 3
Gross primary fuels required to produce 1 kg of high density polyethylene. (Totals may not agree because of rounding)

Fuel type	Fuel prod'n & delivery energy (MJ)	Energy content of delivered fuel (MJ)	Fuel use in transport (MJ)	Feedstock energy (MJ)	Total energy (MJ)
Coal	1.48	1.24	0.19	<0.01	2.90
Oil	0.88	7.66	0.20	32.09	40.83
Gas	1.52	6.46	0.17	22.23	30.39
Hydro	0.33	0.25	<0.01	-	0.58
Nuclear	2.07	0.93	0.13	-	3.13
Lignite	<0.01	<0.01	<0.01	-	<0.01
Wood	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur	<0.01	<0.01	<0.01	<0.01	<0.01
Biomass (solid)	0.05	0.03	<0.01	<0.01	0.09
Hydrogen	<0.01	<0.01	<0.01	-	<0.01
Recovered energy	<0.01	-1.40	<0.01	-	-1.40
Unspecified	<0.01	<0.01	<0.01	-	<0.01
Peat	0.01	0.01	<0.01	-	0.02
Geothermal	0.02	0.01	<0.01	-	0.03
Solar	<0.01	<0.01	<0.01	-	<0.01
Wave/tidal	<0.01	<0.01	<0.01	-	<0.01
Biomass (liquid/gas)	0.03	0.01	0.01	-	0.05
Industrial waste	0.02	0.01	<0.01	-	0.03
Municipal Waste	0.04	0.02	<0.01	-	0.06
Wind	0.01	0.01	<0.01	-	0.02
Totals	6.47	15.22	0.70	54.32	76.71

Table 4
Gross primary fuels used to produce 1 kg of high density polyethylene expressed as mass.

Fuel type	Input in mg
Crude oil	910000
Gas/condensate	580000
Coal	100000
Metallurgical coal	70
Lignite	3
Peat	1900
Wood	2

Table 5
Gross raw materials required to produce 1 kg of high density polyethylene.

Raw material	Input in mg
Air	260000
Animal matter	<1
Barytes	<1
Bauxite	5
Bentonite	33
Biomass (including water)	16000
Calcium sulphate (CaSO4)	3
Chalk (CaCO3)	<1
Clay	<1
Cr	<1
Cu	<1
Dolomite	2
Fe	170
Feldspar	<1
Ferromanganese	<1
Fluorspar	<1
Granite	<1
Gravel	1
Hg	<1
Limestone (CaCO3)	130
Mg	<1
N2	170000
Ni	<1
O2	3
Olivine	2
Pb	1
Phosphate as P2O5	<1
Potassium chloride (KCl)	<1
Quartz (SiO2)	<1
Rutile	<1
S (bonded)	<1
S (elemental)	52
Sand (SiO2)	84
Shale	9
Sodium chloride (NaCl)	350
Sodium nitrate (NaNO3)	<1
Talc	<1
Unspecified	<1
Zn	15

Table 6
Gross water consumption required for the production of 1 kg of high density polyethylene. (Totals may not agree because of rounding)

Source	Use for processing (mg)	Use for cooling (mg)	Totals (mg)
Public supply	1800000	160000	1900000
River canal	970000	59000	1000000
Sea	130000	11000000	11000000
Well	95000	<1	95000
Unspecified	430000	17000000	18000000
Totals	3400000	29000000	32000000

Table 7
Gross air emissions associated with the production of 1 kg of high density polyethylene. (Totals may not agree because of rounding)

Emission	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	From biomass (mg)	From fugitive (mg)	Totals (mg)
dust (PM10)	310	74	2	250	-	-	640
CO	1300	11000	21	490	-	-	12000
CO2	420000	950000	8800	190000	-2	-	1600000
SOX as SO2	2100	1400	140	510	-	-	4100
H2S	<1	-	<1	<1	-	-	<1
mercaptan	<1	<1	<1	<1	-	-	<1
NOX as NO2	1500	1500	56	170	-	-	3200
NH3	<1	-	<1	<1	-	-	<1
Cl2	<1	<1	<1	<1	-	-	<1
HCl	42	20	<1	<1	-	-	62
F2	<1	<1	<1	<1	-	-	<1
HF	2	<1	<1	<1	-	-	2
hydrocarbons not specified	740	83	17	3300	-	<1	4100
aldehyde (-CHO)	<1	-	<1	<1	-	-	<1
organics	<1	<1	<1	60	-	-	60
Pb+compounds as Pb	<1	<1	<1	<1	-	-	<1
Hg+compounds as Hg	<1	-	<1	<1	-	-	<1
metals not specified elsewhere	<1	1	<1	1	-	-	2
H2SO4	<1	-	<1	<1	-	-	<1
N2O	<1	<1	<1	<1	-	-	<1
H2	40	<1	<1	2	-	-	41
dichloroethane (DCE) C2H4Cl2	<1	-	<1	<1	-	<1	<1
vinyl chloride monomer (VCM)	<1	-	<1	<1	-	<1	<1
CFC/HCFC/HFC not specified	<1	-	<1	1	-	-	1
organo-chlorine not specified	<1	-	<1	<1	-	-	<1
HCN	<1	-	<1	<1	-	-	<1
CH4	9900	240	<1	4100	-	<1	14000
aromatic HC not specified elsewhere	<1	-	<1	85	-	<1	86
polycyclic hydrocarbons (PAH)	<1	<1	<1	<1	-	-	<1
NMVOC	<1	-	<1	150	-	-	150
CS2	<1	-	<1	<1	-	-	<1
methylene chloride CH2Cl2	<1	-	<1	<1	-	-	<1
Cu+compounds as Cu	<1	<1	<1	<1	-	-	<1
As+compounds as As	-	-	-	<1	-	-	<1
Cd+compounds as Cd	<1	-	<1	<1	-	-	<1
Ag+compounds as Ag	-	-	-	<1	-	-	<1
Zn+compounds as Zn	<1	-	<1	<1	-	-	<1
Cr+compounds as Cr	<1	<1	<1	<1	-	-	<1
Se+compounds as Se	-	-	-	<1	-	-	<1
Ni+compounds as Ni	<1	<1	<1	<1	-	-	<1
Sb+compounds as Sb	-	-	<1	<1	-	-	<1
ethylene C2H4	-	-	<1	2	-	-	2
oxygen	-	-	-	<1	-	-	<1
asbestos	-	-	-	<1	-	-	<1
dioxin/furan as Teq	-	-	-	<1	-	-	<1
benzene C6H6	-	-	-	<1	-	<1	<1
toluene C7H8	-	-	-	<1	-	<1	<1
xylenes C8H10	-	-	-	<1	-	<1	<1
ethylbenzene C8H10	-	-	-	<1	-	<1	<1
styrene	-	-	-	<1	-	<1	<1
propylene	-	-	-	1	-	-	1

Table 8
Carbon dioxide equivalents corresponding to the gross air emissions for the production of 1 kg of high density polyethylene. (Totals may not agree because of rounding)

Type	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	From biomass (mg)	From fugitive (mg)	Totals (mg)
20 year equiv	1000000	990000	8900	450000	-2	<1	2500000
100 year equiv	650000	980000	8900	290000	-2	<1	1900000
500 year equiv	490000	970000	8900	230000	-2	<1	1700000

Table 9

Gross emissions to water arising from the production of 1 kg of high density polyethylene. (Totals may not agree because of rounding).

Emission	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	Totals (mg)
COD	1	-	<1	190	190
BOD	<1	-	<1	21	21
Pb+compounds as Pb	<1	-	<1	<1	<1
Fe+compounds as Fe	<1	-	<1	<1	<1
Na+compounds as Na	<1	-	<1	77	77
acid as H+	1	-	<1	1	2
NO3-	<1	-	<1	2	2
Hg+compounds as Hg	<1	-	<1	<1	<1
metals not specified elsewhere	<1	-	<1	7	7
ammonium compounds as NH4+	1	-	<1	2	3
Cl-	<1	-	<1	160	160
CN-	<1	-	<1	<1	<1
F-	<1	-	<1	<1	<1
S+sulphides as S	<1	-	<1	<1	<1
dissolved organics (non-	<1	-	<1	10	10
suspended solids	26	-	3	170	200
detergent/oil	<1	-	<1	6	6
hydrocarbons not specified	4	<1	<1	<1	4
organo-chlorine not specified	<1	-	<1	<1	<1
dissolved chlorine	<1	-	<1	<1	<1
phenols	<1	-	<1	2	2
dissolved solids not specified	<1	-	<1	21	21
P+compounds as P	<1	-	<1	<1	<1
other nitrogen as N	<1	-	<1	1	1
other organics not specified	<1	-	<1	<1	<1
SO4--	<1	-	<1	830	830
dichloroethane (DCE)	<1	-	<1	<1	<1
vinyl chloride monomer (VCM)	<1	-	<1	<1	<1
K+compounds as K	<1	-	<1	1	1
Ca+compounds as Ca	<1	-	<1	3	3
Mg+compounds as Mg	<1	-	<1	<1	<1
Cr+compounds as Cr	<1	-	<1	<1	<1
ClO3--	<1	-	<1	<1	<1
BrO3--	<1	-	<1	<1	<1
TOC	<1	-	<1	11	11
AOX	<1	-	<1	<1	<1
Al+compounds as Al	<1	-	<1	1	1
Zn+compounds as Zn	<1	-	<1	<1	<1
Cu+compounds as Cu	<1	-	<1	<1	<1
Ni+compounds as Ni	<1	-	<1	<1	<1
CO3--	-	-	<1	29	29
As+compounds as As	-	-	<1	<1	<1
Cd+compounds as Cd	-	-	<1	<1	<1
Mn+compounds as Mn	-	-	<1	<1	<1
organo-tin as Sn	-	-	<1	<1	<1
Sr+compounds as Sr	-	-	<1	<1	<1
organo-silicon	-	-	-	<1	<1
benzene	-	-	-	<1	<1
dioxin/furan as Teq	-	-	<1	<1	<1

Table 10
Gross solid waste associated with the production of 1 kg of high density polyethylene. (Totals may not agree because of rounding)

Emission	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	Totals (mg)
Plastic containers	<1	-	<1	<1	<1
Paper	<1	-	<1	<1	<1
Plastics	<1	-	<1	630	630
Metals	<1	-	<1	<1	<1
Putrescibles	<1	-	<1	<1	<1
Unspecified refuse	990	-	<1	<1	990
Mineral waste	24	-	33	140	190
Slags & ash	7600	850	13	840	9400
Mixed industrial	-270	-	1	1100	860
Regulated chemicals	1200	-	<1	820	2000
Unregulated chemicals	910	-	<1	2000	2900
Construction waste	<1	-	<1	<1	<1
Waste to incinerator	<1	-	<1	870	870
Inert chemical	<1	-	<1	720	720
Wood waste	<1	-	<1	<1	<1
Wooden pallets	<1	-	<1	<1	<1
Waste to recycling	<1	-	<1	4500	4500
Waste returned to mine	20000	-	1	51	20000
Tailings	1	-	1	60	62
Municipal solid waste	-5500	-	-	<1	-5500

Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.

Table 11

Gross solid waste in EU format associated with the production of 1 kg of high density polyethylene. Entries marked with an asterisk (*) are considered hazardous as defined by EU Directive 91/689/EEC

Emission	Totals (mg)
010101 metallic min'l excav'n waste	140
010102 non-metal min'l excav'n waste	20000
010306 non 010304/010305 tailings	2
010308 non-010307 powdery wastes	2
010399 unspecified met. min'l wastes	1
010408 non-010407 gravel/crushed rock	<1
010410 non-010407 powdery wastes	<1
010411 non-010407 potash/rock salt	1
010499 unsp'd non-met. waste	<1
010505*oil-bearing drilling mud/waste	1200
010508 non-010504/010505 chloride mud	910
010599 unspecified drilling mud/waste	990
020107 wastes from forestry	<1
050106*oil ind. oily maint'e sludges	3
050107*oil industry acid tars	210
050199 unspecified oil industry waste	190
050699 coal pyrolysis unsp'd waste	16
060101*H2SO4/H2SO3 MFSU waste	<1
060102*HCl MFSU waste	<1
060106*other acidic MFSU waste	<1
060199 unsp'd acid MFSU waste	<1
060204*NaOH/KOH MFSU waste	<1
060299 unsp'd base MFSU waste	<1
060313*h. metal salt/sol'n MFSU waste	1
060314 other salt/sol'n MFSU waste	<1
060399 unsp'd salt/sol'n MFSU waste	3
060404*Hg MSFU waste	<1
060405*other h. metal MFSU waste	<1
060499 unsp'd metallic MFSU waste	<1
060602*dangerous sulphide MFSU waste	<1
060603 non-060602 sulphide MFSU waste	<1
060701*halogen electrol. asbestos waste	<1
060702*Cl pr. activated C waste	<1
060703*BaSO4 sludge with Hg	<1
060704*halogen pr. acids and sol'ns	<1
060799 unsp'd halogen pr. waste	<1
061002*N ind. dangerous sub. waste	<1
061099 unsp'd N industry waste	<1
070101*organic chem. aqueous washes	<1
070103*org. halogenated solv'ts/washes	<1
070107*hal'd still bottoms/residues	<1
070108*other still bottoms/residues	7
070111*org. chem. dan. eff. sludge	<1
070112 non-070111 effluent sludge	<1
070199 unsp'd organic chem. waste	13
070204*polymer ind. other washes	<1

continued over …..

Table 11 - continued
Gross solid waste in EU format associated with the production of 1 kg of high density polyethylene. Entries marked with an asterisk (*) are considered hazardous as defined by EU Directive 91/689/EEC

070207*polymer ind. hal'd still waste	<1
070208*polymer ind. other still waste	3000
070209*polymer ind. hal'd fil. cakes	<1
070213 polymer ind. waste plastic	3800
070214*polymer ind. dan. additives	1400
070215 non-0702130 additive waste	130
070216 polymer ind. silicone wastes	<1
070299 unsp'd polymer ind. waste	1200
080199 unspecified paint/varnish waste	<1
100101 non-100104 ash, slag & dust	8200
100102 coal fly ash	1000
100104*oil fly ash and boiler dust	<1
100105 FGD Ca-based reac. solid waste	<1
100113*emulsified hyrdocarbon fly ash	<1
100114*dangerous co-incin'n ash/slag	46
100115 non-100115 co-incin'n ash/slag	3
100116*dangerous co-incin'n fly ash	<1
100199 unsp'd themal process waste	<1
100202 unprocessed iron/steel slag	52
100210 iron/steel mill scales	4
100399 unspecified aluminium waste	<1
100501 primary/secondary zinc slags	<1
100504 zinc pr. other dust	<1
100511 non-100511 Zn pr. skimmings	<1
101304 lime calcin'n/hydration waste	5
130208*other engine/gear/lub. oil	<1
150101 paper and cardboard packaging	<1
150102 plastic packaging	<1
150103 wooden packaging	<1
150106 mixed packaging	<1
170107 non-170106 con'e/brick/tile mix	<1
170904 non-170901/2/3 con./dem'n waste	<1
190199 unspecified incin'n/pyro waste	<1
190905 sat./spent ion exchange resins	720
200101 paper and cardboard	<1
200108 biodeg. kitchen/canteen waste	<1
200138 non-200137 wood	<1
200139 plastics	<1
200140 metals	<1
200199 other separately coll. frac'ns	-1300
200301 mixed municipal waste	1
200399 unspecified municipal wastes	-4400
Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.	

ATTACHMENT F

Annual and Quarterly Groundwater Monitoring Report
Joliet #29 Generating Station
January 21, 2021

ANNUAL and QUARTERLY GROUNDWATER MONITORING REPORT
JOLIET #29 GENERATING STATION

January 21, 2021

Ms. Andrea Rhodes
Illinois Environmental Protection Agency
Division of Public Water Supplies
MC#19
1021 North Grand Avenue East
Springfield, IL 62794-9276

VIA FEDEX

Re: Annual and Quarterly Groundwater Monitoring Results – Fourth Quarter 2020
Joliet #29 Generating Station – Former Ash Impoundments
Compliance Commitment Agreement VN W-2012-00059; ID# 6284

Dear Ms. Rhodes:

The fourth quarterly groundwater sampling for 2020 has been completed for the former ash pond monitoring wells located at the Midwest Generation, LLC (Midwest Generation) Joliet #29 Generating Station in accordance with the signed Compliance Commitment Agreement (CCA) with Illinois Environmental Protection Agency (IEPA) dated October 24, 2012. This Quarterly Monitoring Report is being submitted summarizing the results of the monitoring event. This report is also intended to serve as the Annual Report and includes historical data analysis/summaries.

Well Inspection and Sampling Procedures

The groundwater monitoring network around the existing ponds at this facility consists of eleven wells (MW-01 through MW-11) as shown on Figure 1. As part of sampling procedures, the integrity of all monitoring wells was inspected and water levels were obtained using an electronic water level meter (see summary of water level discussion below). All wells were generally found in good condition with locked protector casings and the concrete surface seals were intact.

Groundwater samples at well locations MW-03 through MW-08, MW-10 and MW-11 were collected using the low-flow sampling technique. Based on historical water levels at monitoring well locations MW-01 and MW-02, it was determined that there was not enough water column within these wells (generally less than two feet of water column within each well) to allow for the placement of dedicated pumping systems. Instead, at these two well locations, sample collection is completed using a peristaltic pump when sufficient water is available for sampling. During this sampling event, there was not enough water volume within both of these wells to allow for sample collection. The dedicated pump for MW-09 was found to be nonoperational during the fourth quarter, therefore a bailer was used to obtain groundwater samples at well location MW-09 during the most recent round of groundwater sampling. A new bladder pump has been ordered for this well and will be replaced prior to the next round of sampling.

One duplicate sample was collected at well MW-04. In addition, a de-ionized water trip blank accompanied the groundwater samples bottles from and back to the laboratory. The groundwater monitoring samples and the duplicate sample were analyzed for the compounds listed in Illinois Administrative Code (IAC) 620.410(a), 620.410(d) and 620.410(e), excluding radium 226/228. The trip blank was analyzed for the volatile organic compounds (VOCs) listed in IAC 620.410(d).

Groundwater Flow Evaluation

Water level data from the most recent round of sampling along with historical water levels obtained from each well are summarized in Table 1. The water levels were used to generate a groundwater flow map which is provided on Figure 2. It is noted that the water level at well MW-04 appeared slightly elevated relative to surrounding wells and is believed to be an anomalous measurement. The water elevation data indicates a general southeasterly flow. The flow conditions observed during this sampling are consistent with historical conditions reported for the site. Relative to an annual evaluation of groundwater levels, a historical hydrograph is presented in Attachment 1.

Summary of Analytical Data

A copy of the analytical data package is provided in Attachment 2. The field parameter and analytical data from the most recent sampling, along with the previous eight quarters of data, are summarized in Table 2. It is noted that some elevated metals concentrations were detected at well MW-09 relative to previous concentration (e.g., arsenic and lead) and may be reflective of the previously noted change in sample collection method due to dedicated pump failure. Subsequent sampling will determine the nature of these detections.

All duplicate values were within an acceptable range (+/- 30%). All wells for which the sampling data reports a value above groundwater comparison standards are located within the area of the approved Groundwater Management Zone (GMZ).

Relative to an annual evaluation of the water chemistry data, time versus concentration curves are provided for each parameter analyzed in Attachment 3. The curves include the Class I drinking water standard for reference, where applicable.

As noted previously, all wells for which the sampling data reports a value above one or more applicable groundwater standards are located within the area of the approved GMZ.

If there are any questions, please contact either Sharene Shealey of NRG Energy at 724-255-3220 or Richard Gnat of KPRG and Associates, Inc. at 262-781-0475.

Sincerely,

William Naglosky
Station Manager

cc: Mike Summers/Lynn Dunaway, IEPA
Peter O'Day, Midwest Generation, LLC
Sharene Shealey, NRG Energy
Richard Gnat, KPRG and Associates, Inc.

FIGURES

NOTE:
BACKGROUND MAP RETRIEVED FROM GOOGLE MAPS 2013

N

0 250'
APPROXIMATE SCALE

ENVIRONMENTAL CONSULTATION & REMEDIATION

KPRG

KPRG and Associates, inc.

14665 West Lisbon Road, Suite 1A Brookfield, Wisconsin 53005 Telephone 262-781-0475 Facsimile 262-781-0478

414 Plaza Drive, Suite 106 Westmont, Illinois 60559 Telephone 630-325-1300 Facsimile 630-325-1593

SITE MAP

JOLIET #29 GENERATING STATION
JOLIET, ILLINOIS

Scale: 1" = 250'	Date: January 23, 2019
KPRG Project No. 12313.0	FIGURE 1

ENVIRONMENTAL CONSULTATION & REMEDIATION

KPRG

KPRG and Associates, inc.

14665 West Lisbon Road, Suite 1A Brookfield, Wisconsin 53005 Telephone 262-781-0475 Facsimile 262-781-0478

414 Plaza Drive, Suite 106 Westmont, Illinois 60559 Telephone 630-325-1300 Facsimile 630-325-1593

GROUNDWATER CONTOUR MAP 10/2020

JOLIET #29 GENERATING STATION
JOLIET, ILLINOIS

Scale: 1" = 250'	Date: October 31, 2020
KPRG Project No. 12313.0	FIGURE 2

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TABLES

Table 1. Groundwater Elevations - Midwest Generation, LLC, Joliet Station #29, Joliet, IL

Well ID	Date	Top of Casing (TOC) Elevation (ft above MSL)	Ground Elevation (ft above MSL)	Groundwater Elevation (ft above MSL)	Sampling Groundwater Elevation (ft above MSL)	Bottom of Well Elevation (ft above MSL)	Depth to Groundwater (ft below TOC)	Sampling Depth to Groundwater (ft below TOC)	Depth to Bottom of Well (ft below TOC)
MW-01	02/10/15	534.76	531.46	NM	NM	504.88	NM	NM	29.88
	05/27/15	534.76	531.46	NM	NM	504.88	NM	NM	29.88
	08/04/15	534.76	531.46	NM	NM	504.88	NM	NM	29.88
	10/27/15	534.76	531.46	NM	NM	504.88	NM	NM	29.88
	02/09/16	534.03	531.56	NM	NM	505.50	NM	NM	28.53
	05/10/16	534.03	531.56	505.90	506.18	505.50	28.13	27.85	28.53
	08/30/16	534.03	531.56	506.85	506.91	505.50	27.18	27.12	28.53
	11/01/16	534.03	531.56	505.89	505.53	505.50	28.14	28.50	28.53
	02/06/17	534.03	531.56	NM	NM	505.50	NM	NM	28.53
	04/25/17	534.03	531.56	NM	NM	505.50	NM	NM	28.53
	08/01/17	534.03	531.56	506.59	506.53	505.50	27.44	27.50	28.53
	10/17/17	534.03	531.56	508.87	508.85	505.50	25.16	25.18	28.53
	02/21/18	534.03	531.56	506.37	509.54	505.50	27.66	24.49	28.53
	04/25/18	534.03	531.56	505.89	505.58	505.50	28.14	28.45	28.53
	07/31/18	534.03	531.56	505.75	505.50	505.50	28.28	28.53	28.53
	10/16/18	534.03	531.56	506.22	505.93	505.50	27.81	28.10	28.53
	02/04/19	534.03	531.56	505.73	NM	505.50	28.30	NM	28.53
	05/06/19	534.03	531.56	509.00	509.00	505.50	25.03	25.03	28.53
	08/06/19	534.03	531.56	505.88	NM	505.50	28.15	NM	28.53
	11/06/19	534.03	531.56	507.38	NM	505.50	26.65	NM	28.53
	02/12/20	534.03	531.56	505.69	NM	505.50	28.34	NM	28.53
	05/21/20	534.03	531.56	511.60	NM	505.50	22.43	NM	28.53
	07/30/20	534.03	531.56	505.74	NM	505.50	28.29	NM	28.53
	10/21/20	534.03	531.56	505.73	NM	505.50	28.30	NM	28.53
MW-02	02/10/15	534.28	531.19	505.17	510.69	504.05	29.11	23.59	30.23
	05/27/15	534.28	531.19	505.34	505.32	504.05	28.94	28.96	30.23
	08/04/15	534.28	531.19	505.14	505.13	504.05	29.14	29.15	30.23
	10/27/15	534.28	531.19	504.89	505.09	504.05	29.39	29.19	30.23
	02/09/16	534.30	531.17	505.59	505.57	504.07	28.71	28.73	30.23
	05/10/16	534.30	531.17	505.89	506.09	504.07	28.41	28.21	30.23
	08/30/16	534.30	531.17	506.83	506.97	504.07	27.47	27.33	30.23
	11/01/16	534.30	531.17	505.90	505.89	504.07	28.40	28.41	30.23
	02/06/17	534.30	531.17	505.46	505.74	504.07	28.84	28.56	30.23
	04/25/17	534.30	531.17	505.69	505.70	504.07	28.61	28.60	30.23
	08/01/17	534.30	531.17	506.59	506.52	504.07	27.71	27.78	30.23
	10/17/17	534.30	531.17	508.82	508.82	504.07	25.48	25.48	30.23
	02/21/18	534.30	531.17	506.35	509.65	504.07	27.95	24.65	30.23
	04/25/18	534.30	531.17	505.87	505.81	504.07	28.43	28.49	30.23
	08/01/18	534.30	531.17	505.22	505.14	504.07	29.08	29.16	30.23
	10/16/18	534.30	531.17	506.17	506.11	504.07	28.13	28.19	30.23
	02/04/19	534.30	531.17	505.68	505.65	504.07	28.62	28.65	30.23
	05/06/19	534.30	531.17	508.95	508.29	504.07	25.35	26.01	30.23
	08/06/19	534.30	531.17	505.16	NM	504.07	29.14	NM	30.23
	11/06/19	534.30	531.17	507.27	NM	504.07	27.03	NM	30.23
	02/12/20	534.30	531.17	505.49	NM	504.07	28.81	NM	30.23
	05/21/20	534.30	531.17	510.37	NM	504.07	23.93	23.94	30.23
	07/30/20	534.30	531.17	504.98	NM	504.07	29.32	NM	30.23
	10/21/20	534.30	531.17	505.25	NM	504.07	29.05	NM	30.23
MW-03	02/10/15	538.78	535.54	505.19	505.20	494.68	33.59	33.58	44.10
	05/27/15	538.78	535.54	505.36	505.35	494.68	33.42	33.43	44.10
	08/04/15	538.78	535.54	505.22	505.22	494.68	33.56	33.56	44.10
	10/27/15	538.78	535.54	504.91	505.04	494.68	33.87	33.74	44.10
	02/09/16	538.79	535.53	505.62	505.51	494.68	33.17	33.28	44.10
	05/10/16	538.79	535.53	505.97	505.99	494.68	32.82	32.80	44.10
	08/30/16	538.79	535.53	506.91	507.22	494.68	31.88	31.57	44.10
	11/01/16	538.79	535.53	505.91	505.94	494.68	32.88	32.85	44.10
	02/06/17	538.79	535.53	505.54	505.54	494.68	33.25	33.25	44.10
	04/26/17	538.79	535.53	505.73	505.78	494.68	33.06	33.01	44.10
	08/01/17	538.79	535.53	506.43	506.44	494.68	32.36	32.35	44.10
	10/18/17	538.79	535.53	508.76	508.54	494.68	30.03	30.25	44.10
	02/20/18	538.79	535.53	506.38	506.56	494.68	32.41	32.23	44.10
	04/24/18	538.79	535.53	505.96	505.96	494.68	32.83	32.83	44.10
	07/31/18	538.79	535.53	505.23	505.25	494.68	33.56	33.54	44.10
	10/17/18	538.79	535.53	506.21	506.09	494.68	32.58	32.70	44.10
	02/04/19	538.79	535.53	505.74	505.81	494.68	33.05	32.98	44.10
	05/06/19	538.79	535.53	508.84	508.61	494.68	29.95	30.18	44.10
	08/06/19	538.79	535.53	505.26	505.29	494.68	33.53	33.50	44.10
	11/06/19	538.79	535.53	505.41	505.29	494.68	33.38	33.50	44.10
	02/12/20	538.79	535.53	505.61	505.29	494.68	33.18	33.50	44.10
	05/20/20	538.79	535.53	511.66	511.66	494.68	27.13	27.13	44.10
	07/30/20	538.79	535.53	505.06	505.04	494.68	33.73	33.75	44.10
	10/21/20	538.79	535.53	505.27	505.46	494.68	33.52	33.33	44.10

Table 1. Groundwater Elevations - Midwest Generation, LLC, Joliet Station #29, Joliet, IL

Well ID	Date	Top of Casing (TOC) Elevation (ft above MSL)	Ground Elevation (ft above MSL)	Groundwater Elevation (ft above MSL)	Sampling Groundwater Elevation (ft above MSL)	Bottom of Well Elevation (ft above MSL)	Depth to Groundwater (ft below TOC)	Sampling Depth to Groundwater (ft below TOC)	Depth to Bottom of Well (ft below TOC)
MW-04	02/10/15	539.03	535.80	505.19	505.18	496.13	33.84	33.85	42.90
	05/27/15	539.03	535.80	505.39	505.37	496.13	33.64	33.66	42.90
	08/04/15	539.03	535.80	505.19	505.19	496.13	33.84	33.84	42.90
	10/27/15	539.03	535.80	504.98	505.00	496.13	34.05	34.03	42.90
	02/09/16	539.01	535.83	505.59	505.44	496.11	33.42	33.57	42.90
	05/10/16	539.01	535.83	505.94	505.95	496.11	33.07	33.06	42.90
	08/30/16	539.01	535.83	506.93	507.19	496.11	32.08	31.82	42.90
	11/01/16	539.01	535.83	505.85	505.87	496.11	33.16	33.14	42.90
	02/06/17	539.01	535.83	505.50	505.52	496.11	33.51	33.49	42.90
	04/26/17	539.01	535.83	505.72	505.74	496.11	33.29	33.27	42.90
	08/01/17	539.01	535.83	506.92	506.39	496.11	32.09	32.62	42.90
	10/18/17	539.01	535.83	508.73	508.50	496.11	30.28	30.51	42.90
	02/20/18	539.01	535.83	505.37	506.69	496.11	33.64	32.32	42.90
	04/24/18	539.01	535.83	505.91	505.92	496.11	33.10	33.09	42.90
	07/31/18	539.01	535.83	505.20	505.22	496.11	33.81	33.79	42.90
	10/17/18	539.01	535.83	506.16	506.03	496.11	32.85	32.98	42.90
	02/04/19	539.01	535.83	505.72	505.72	496.11	33.29	33.29	42.90
	05/06/19	539.01	535.83	509.18	508.57	496.11	29.83	30.44	42.90
	08/06/19	539.01	535.83	505.22	505.21	496.11	33.79	33.80	42.90
	11/06/19	539.01	535.83	507.36	505.21	496.11	31.65	33.80	42.90
	02/12/20	539.01	535.83	505.56	505.26	496.11	33.45	33.75	42.90
	05/20/20	539.01	535.83	511.61	511.61	496.11	27.40	27.40	42.90
	07/30/20	539.01	535.83	505.01	505.04	496.11	34.00	33.97	42.90
	10/21/20	539.01	535.83	505.53	505.46	496.11	33.48	33.55	42.90
MW-05	02/11/15	539.69	536.43	505.12	505.12	494.64	34.57	34.57	45.05
	05/27/15	539.69	536.43	505.26	505.25	494.64	34.43	34.44	45.05
	08/04/15	539.69	536.43	505.14	505.14	494.64	34.55	34.55	45.05
	10/27/15	539.69	536.43	504.78	504.95	494.64	34.91	34.74	45.05
	02/09/16	539.64	536.36	505.46	505.33	494.59	34.18	34.31	45.05
	05/10/16	539.64	536.36	505.83	505.86	494.59	33.81	33.78	45.05
	08/30/16	539.64	536.36	506.82	507.09	494.59	32.82	32.55	45.05
	11/01/16	539.64	536.36	505.74	505.74	494.59	33.90	33.90	45.05
	02/06/17	539.64	536.36	505.41	505.40	494.59	34.23	34.24	45.05
	04/26/17	539.64	536.36	505.60	505.66	494.59	34.04	33.98	45.05
	08/01/17	539.64	536.36	506.52	506.24	494.59	33.12	33.40	45.05
	10/18/17	539.64	536.36	508.61	508.59	494.59	31.03	31.05	45.05
	02/20/18	539.64	536.36	506.35	506.74	494.59	33.29	32.90	45.05
	04/24/18	539.64	536.36	505.85	505.82	494.59	33.79	33.82	45.05
	07/31/18	539.64	536.36	505.10	505.11	494.59	34.54	34.53	45.05
	10/17/18	539.64	536.36	506.03	505.91	494.59	33.61	33.73	45.05
	02/04/19	539.64	536.36	505.97	505.96	494.59	33.67	33.68	45.05
	05/06/19	539.64	536.36	509.09	508.98	494.59	30.55	30.66	45.05
	08/06/19	539.64	536.36	505.09	505.09	494.59	34.55	34.55	45.05
	11/06/19	539.64	536.36	507.24	505.09	494.59	32.40	34.55	45.05
	02/12/20	539.64	536.36	505.48	504.59	494.59	34.16	35.05	45.05
	05/20/20	539.64	536.36	511.48	511.48	494.59	28.16	28.16	45.05
	07/30/20	539.64	536.36	504.87	504.88	494.59	34.77	34.76	45.05
	10/21/20	539.64	536.36	505.12	506.09	494.59	34.52	33.55	45.05
MW-06	02/10/15	539.06	535.86	505.23	505.23	496.86	33.83	33.83	42.20
	05/28/15	539.06	535.86	505.46	505.45	496.86	33.60	33.61	42.20
	08/05/15	539.06	535.86	505.11	505.12	496.86	33.95	33.94	42.20
	10/27/15	539.06	535.86	504.88	504.93	496.86	34.18	34.13	42.20
	02/09/16	539.05	535.89	505.61	505.46	496.85	33.44	33.59	42.20
	05/10/16	539.05	535.89	506.00	506.94	496.85	33.05	32.11	42.20
	08/30/16	539.05	535.89	506.96	507.36	496.85	32.09	31.69	42.20
	11/01/16	539.05	535.89	505.88	505.91	496.85	33.17	33.14	42.20
	02/06/17	539.05	535.89	505.56	505.57	496.85	33.49	33.48	42.20
	04/27/17	539.05	535.89	505.74	505.77	496.85	33.31	33.28	42.20
	08/01/17	539.05	535.89	506.65	506.28	496.85	32.40	32.77	42.20
	10/19/17	539.05	535.89	508.74	508.14	496.85	30.31	30.91	42.20
	02/21/18	539.05	535.89	506.57	509.45	496.85	32.48	29.60	42.20
	04/25/18	539.05	535.89	505.94	505.86	496.85	33.11	33.19	42.20
	07/31/18	539.05	535.89	505.27	505.25	496.85	33.78	33.80	42.20
	10/18/18	539.05	535.89	506.16	506.00	496.85	32.89	33.05	42.20
	02/04/19	539.05	535.89	506.12	506.12	496.85	32.93	32.93	42.20
	05/06/19	539.05	535.89	509.19	508.22	496.85	29.86	30.83	42.20
	08/06/19	539.05	535.89	505.26	505.33	496.85	33.79	33.72	42.20
	11/06/19	539.05	535.89	507.36	505.33	496.85	31.69	33.72	42.20
	02/12/20	539.05	535.89	505.63	505.60	496.85	33.42	33.45	42.20
	05/21/20	539.05	535.89	511.51	511.45	496.85	27.54	27.60	42.20
	07/30/20	539.05	535.89	505.08	505.08	496.85	33.97	33.97	42.20
	10/21/20	539.05	535.89	505.30	505.37	496.85	33.75	33.68	42.20
MW-07	02/10/15	539.35	535.86	505.24	505.24	496.12	34.11	34.11	43.23
	05/28/15	539.35	535.86	505.50	505.50	496.12	33.85	33.85	43.23
	08/05/15	539.35	535.86	505.18	505.17	496.12	34.17	34.18	43.23
	10/27/15	539.35	535.86	504.93	505.00	496.12	34.42	34.35	43.23
	02/09/16	539.35	535.87	505.66	505.51	496.12	33.69	33.84	43.23
	05/10/16	539.35	535.87	506.34	507.02	496.12	33.01	32.33	43.23
	08/30/16	539.35	535.87	507.04	507.41	496.12	32.31	31.94	43.23
	11/01/16	539.35	535.87	505.91	505.93	496.12	33.44	33.42	43.23
	02/06/17	539.35	535.87	505.59	505.62	496.12	33.76	33.73	43.23
	04/27/17	539.35	535.87	505.77	505.82	496.12	33.58	33.53	43.23
	08/01/17	539.35	535.87	506.68	506.30	496.12	32.67	33.05	43.23
	10/19/17	539.35	535.87	508.76	508.07	496.12	30.59	31.28	43.23
	02/21/18	539.35	535.87	506.67	509.64	496.12	32.68	29.71	43.23
	04/25/18	539.35	535.87	505.98	505.89	496.12	33.37	33.46	43.23
	08/01/18	539.35	535.87	505.30	505.31	496.12	34.05	34.04	43.23
	10/18/18	539.35	535.87	506.17	506.03	496.12	33.18	33.32	43.23
	02/04/19	539.35	535.87	506.19	506.19	496.12	33.16	33.16	43.23
	05/06/19	539.35	535.87	509.22	508.51	496.12	30.13	30.84	43.23
	08/06/19	539.35	535.87	505.33	505.33	496.12	34.02	34.02	43.23
	11/06/19	539.35	535.87	507.40	505.33	496.12	31.95	34.02	43.23
	02/12/20	539.35	535.87	505.65	505.65	496.12	33.70	33.70	43.23
	05/21/20	539.35	535.87	511.53	511.53	496.12	27.82	27.82	43.23
	07/30/20	539.35	535.87	505.14	505.14	496.12	34.21	34.21	43.23
	10/21/20	539.35	535.87	505.32	505.65	496.12	34.03	33.70	43.23

Table 1. Groundwater Elevations - Midwest Generation, LLC, Joliet Station #29, Joliet, IL

Well ID	Date	Top of Casing (TOC) Elevation (ft above MSL)	Ground Elevation (ft above MSL)	Groundwater Elevation (ft above MSL)	Sampling Groundwater Elevation (ft above MSL)	Bottom of Well Elevation (ft above MSL)	Depth to Groundwater (ft below TOC)	Sampling Depth to Groundwater (ft below TOC)	Depth to Bottom of Well (ft below TOC)
MW-08	02/10/15	536.87	533.72	505.18	505.19	498.81	31.69	31.68	38.06
	05/27/15	536.87	533.72	505.36	505.38	498.81	31.51	31.49	38.06
	08/04/15	536.87	533.72	505.19	505.20	498.81	31.68	31.67	38.06
	10/27/15	536.87	533.72	504.93	504.98	498.81	31.94	31.89	38.06
	02/09/16	536.96	533.77	505.72	505.72	498.90	31.24	31.24	38.06
	05/10/16	536.96	533.77	498.00	498.24	498.90	38.96	38.72	38.06
	08/30/16	536.96	533.77	507.05	507.09	498.90	29.91	29.87	38.06
	11/01/16	536.96	533.77	506.01	506.03	498.90	30.95	30.93	38.06
	02/06/17	536.96	533.77	505.58	505.62	498.90	31.38	31.34	38.06
	04/25/17	536.96	533.77	505.74	505.79	498.90	31.22	31.17	38.06
	08/01/17	536.96	533.77	506.78	506.76	498.90	30.18	30.20	38.06
	10/17/17	536.96	533.77	509.02	508.99	498.90	27.94	27.97	38.06
	02/20/18	536.96	533.77	506.00	506.55	498.90	30.96	30.41	38.06
	08/01/18	536.96	533.77	505.23	505.26	498.90	31.73	31.70	38.06
	10/16/18	536.96	533.77	506.36	506.35	498.90	30.60	30.61	38.06
	02/04/19	536.96	533.77	506.04	506.04	498.90	30.92	30.92	38.06
	05/06/19	536.96	533.77	509.22	509.13	498.90	27.74	27.83	38.06
	08/06/19	536.96	533.77	505.27	505.27	498.90	31.69	31.69	38.06
	11/06/19	536.96	533.77	507.54	507.16	498.90	29.42	29.80	38.06
	02/12/20	536.96	533.77	505.56	505.56	498.90	31.40	31.40	38.06
	05/20/20	536.96	533.77	511.82	511.63	498.90	25.14	25.33	38.06
	07/30/20	536.96	533.77	505.13	505.12	498.90	31.83	31.84	38.06
	10/28/20	536.96	533.77	505.29	505.41	498.90	31.67	31.55	38.06
MW-09	02/10/15	534.44	531.13	505.22	504.70	496.29	29.22	29.74	38.15
	05/27/15	534.44	531.13	505.37	504.98	496.29	29.07	29.46	38.15
	08/04/15	534.44	531.13	505.22	504.91	496.29	29.22	29.53	38.15
	10/27/15	534.44	531.13	504.96	504.83	496.29	29.48	29.61	38.15
	02/09/16	534.41	531.08	505.64	505.49	496.26	28.77	28.92	38.15
	05/10/16	534.41	531.08	505.90	506.39	496.26	28.51	28.02	38.15
	08/30/16	534.41	531.08	506.98	506.94	496.26	27.43	27.47	38.15
	11/01/16	534.41	531.08	505.89	505.32	496.26	28.52	29.09	38.15
	02/06/17	534.41	531.08	505.51	505.66	496.26	28.90	28.75	38.15
	04/25/17	534.41	531.08	505.66	505.54	496.26	28.75	28.87	38.15
	08/01/17	534.41	531.08	506.64	506.27	496.26	27.77	28.14	38.15
	10/17/17	534.41	531.08	508.89	508.73	496.26	25.52	25.68	38.15
	02/20/18	534.41	531.08	506.39	506.99	496.26	28.02	27.42	38.15
	04/26/18	534.41	531.08	505.89	505.58	496.26	28.52	28.83	38.15
	08/01/18	534.41	531.08	505.18	505.05	496.26	29.23	29.36	38.15
	10/16/18	534.41	531.08	506.23	506.12	496.26	28.18	28.29	38.15
	02/04/19	534.41	531.08	506.02	505.99	496.26	28.39	28.42	38.15
	05/06/19	534.41	531.08	509.08	508.09	496.26	25.33	26.32	38.15
	08/06/19	534.41	531.08	505.23	504.61	496.26	29.18	29.80	38.15
	11/06/19	534.41	531.08	507.42	504.61	496.26	26.99	29.80	38.15
	02/12/20	534.41	531.08	505.53	504.89	496.26	28.88	29.52	38.15
	05/20/20	534.41	531.08	511.06	510.76	496.26	23.35	23.65	38.15
	07/30/20	534.41	531.08	505.02	505.05	496.26	29.39	29.36	38.15
	10/21/20	534.41	531.08	505.28	505.05	496.26	29.13	29.36	38.15
MW-10	02/11/15	540.03	536.95	505.27	505.27	496.10	34.76	34.76	43.93
	05/28/15	540.03	536.95	505.48	505.48	496.10	34.55	34.55	43.93
	08/04/15	540.03	536.95	505.29	505.30	496.10	34.74	34.73	43.93
	10/27/15	540.03	536.95	504.93	505.07	496.10	35.10	34.96	43.93
	02/09/16	540.02	536.98	505.70	505.61	496.09	34.32	34.41	43.93
	05/10/16	540.02	536.98	506.00	506.66	496.09	34.02	33.36	43.93
	08/30/16	540.02	536.98	507.05	507.38	496.09	32.97	32.64	43.93
	11/01/16	540.02	536.98	505.98	505.97	496.09	34.04	34.05	43.93
	02/06/17	540.02	536.98	505.60	505.62	496.09	34.42	34.40	43.93
	04/26/17	540.02	536.98	505.80	505.84	496.09	34.22	34.18	43.93
	08/01/17	540.02	536.98	506.84	506.50	496.09	33.18	33.52	43.93
	10/18/17	540.02	536.98	508.89	508.61	496.09	31.13	31.41	43.93
	02/21/18	540.02	536.98	506.19	509.42	496.09	33.83	30.60	43.93
	04/24/18	540.02	536.98	506.05	506.02	496.09	33.97	34.00	43.93
	08/01/18	540.02	536.98	505.27	505.27	496.09	34.75	34.75	43.93
	10/17/18	540.02	536.98	506.29	506.14	496.09	33.73	33.88	43.93
	02/04/19	540.02	536.98	506.11	506.10	496.09	33.91	33.92	43.93
	05/06/19	540.02	536.98	509.44	508.82	496.09	30.58	31.20	43.93
	08/06/19	540.02	536.98	505.32	505.32	496.09	34.70	34.70	43.93
	11/06/19	540.02	536.98	507.60	505.32	496.09	32.42	34.70	43.93
	02/12/20	540.02	536.98	505.67	505.67	496.09	34.35	34.35	43.93
	05/20/20	540.02	536.98	511.83	511.86	496.09	28.19	28.16	43.93
	07/30/20	540.02	536.98	505.14	505.12	496.09	34.88	34.90	43.93
	10/21/20	540.02	536.98	505.30	505.30	496.09	34.72	34.72	43.93
MW-11	02/11/15	539.47	536.52	505.49	505.49	497.14	33.98	33.98	42.33
	05/28/15	539.47	536.52	505.96	505.97	497.14	33.51	33.50	42.33
	08/04/15	539.47	536.52	505.65	505.64	497.14	33.82	33.83	42.33
	10/27/15	539.47	536.52	505.16	505.32	497.14	34.31	34.15	42.33
	02/09/16	539.41	536.62	506.10	505.88	497.08	33.31	33.53	42.33
	05/10/16	539.41	536.62	507.33	506.60	497.08	32.08	32.81	42.33
	08/30/16	539.41	536.62	508.27	508.85	497.08	31.14	30.56	42.33
	11/01/16	539.41	536.62	506.32	506.28	497.08	33.09	33.13	42.33
	02/06/17	539.41	536.62	505.90	505.92	497.08	33.51	33.49	42.33
	04/26/17	539.41	536.62	506.17	506.17	497.08	33.24	33.24	42.33
	08/01/17	539.41	536.62	507.47	507.38	497.08	31.94	32.03	42.33
	10/19/17	539.41	536.62	509.61	509.16	497.08	29.8	30.25	42.33
	02/21/18	539.41	536.62	506.45	509.85	497.08	32.96	29.56	42.33
	04/25/18	539.41	536.62	505.48	506.40	497.08	33.93	33.01	42.33
	08/01/18	539.41	536.62	505.53	505.54	497.08	33.88	33.87	42.33
	10/17/18	539.41	536.62	506.63	506.51	497.08	32.78	32.90	42.33
	02/04/19	539.41	536.62	506.19	506.19	497.08	33.22	33.22	42.33
	05/06/19	539.41	536.62	510.58	509.98	497.08	28.83	29.43	42.33
	08/06/19	539.41	536.62	505.66	505.66	497.08	33.75	33.75	42.33
	11/06/19	539.41	536.62	508.26	505.66	497.08	31.15	33.75	42.33
	02/12/20	539.41	536.62	505.88	505.81	497.08	33.53	33.60	42.33
	05/20/20	539.41	536.62	512.83	512.81	497.08	26.58	26.60	42.33
	07/30/20	539.41	536.62	505.53	505.48	497.08	33.88	33.93	42.33
	10/21/20	539.41	536.62	505.39	505.39	497.08	34.02	34.02	42.33

Note: Values for Depth to Bottom of Well are from prior to the installation of the dedicated pumps.

NM - Not Measured

Table 2. Groundwater Analytical Results - Midwest Generation LLC, Joliet Station #29, Joliet, IL

Sample: MW-01	Date	8/1/2018		10/17/2018		2/4/2019		5/7/2019		8/6/2019		11/7/2019		2/13/2020		5/21/2020		7/30/2020		10/22/2020	
Parameter	Standards	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result
Antimony	0.006	NS	NS	0.003	ND	0.003	NS	0.003	ND	0.003	NS	0.003	ND	0.003	NS	0.003	0.0066	NS	NS	NS	NS
Arsenic	0.01	NS	NS	0.001	ND	0.001	NS	0.001	ND	0.001	NS	0.001	ND	0.001	NS	0.001	0.0012	NS	NS	NS	NS
Barium	2	NS	NS	0.0025	0.12	0.0025	NS	0.0025	0.054	0.0025	NS	0.0025	0.051	0.0025	NS	0.0025	0.076	NS	NS	NS	NS
Beryllium	0.004	NS	NS	0.001	ND^	0.001	NS	0.001	ND ^	0.001	NS	0.001	ND	0.001	NS	0.001	ND ^	NS	NS	NS	NS
Boron	2	NS	NS	0.05	0.23	0.05	NS	0.05	0.22	0.05	NS	0.05	0.22	0.05	NS	0.05	0.35	NS	NS	NS	NS
Cadmium	0.005	NS	NS	0.0005	ND	0.0005	NS	0.0005	ND	0.0005	NS	0.0005	ND	0.0005	NS	0.0005	ND	NS	NS	NS	NS
Chloride	200	NS	NS	10	130	10	NS	10	280	10	NS	10	60	10	NS	10	140	NS	NS	NS	NS
Chromium	0.1	NS	NS	0.005	ND	0.005	NS	0.005	ND	0.005	NS	0.005	ND	0.005	NS	0.005	ND	NS	NS	NS	NS
Cobalt	1	NS	NS	0.001	ND	0.001	NS	0.001	ND	0.001	NS	0.001	ND	0.001	NS	0.001	0.0011	NS	NS	NS	NS
Copper	0.65	NS	NS	0.002	ND	0.002	NS	0.002	ND	0.002	NS	0.002	ND	0.002	NS	0.002	ND	NS	NS	NS	NS
Cyanide	0.2	NS	NS	0.01	ND	0.01	NS	0.01	ND	0.01	NS	0.01	ND	0.01	NS	0.01	ND	NS	NS	NS	NS
Fluoride	4	NS	NS	0.1	0.36	0.1	NS	0.1	0.42	0.1	NS	0.1	0.34	0.1	NS	0.1	0.4	NS	NS	NS	NS
Iron	5	NS	NS	0.1	ND	0.1	NS	0.1	0.1	0.1	NS	0.1	ND	0.1	NS	0.1	ND	NS	NS	NS	NS
Lead	0.0075	NS	NS	0.0005	ND	0.0005	NS	0.0005	ND	0.0005	NS	0.0005	ND	0.0005	NS	0.0005	ND	NS	NS	NS	NS
Manganese	0.15	NS	NS	0.0025	ND	0.0025	NS	0.0025	ND	0.0025	NS	0.0025	ND	0.0025	NS	0.0025	ND	NS	NS	NS	NS
Mercury	0.002	NS	NS	0.0002	ND	0.0002	NS	0.0002	ND	0.0002	NS	0.0002	ND	0.0002	NS	0.0002	ND	NS	NS	NS	NS
Nickel	0.1	NS	NS	0.002	ND	0.002	NS	0.002	ND	0.002	NS	0.002	ND	0.002	NS	0.002	0.0023	NS	NS	NS	NS
Nitrogen/Nitrate	10	NS	NS	0.1	1.8	0.1	NS	0.1	2.9	0.1	NS	0.1	1.6	0.1	NS	0.1	2.1	NS	NS	NS	NS
Nitrogen/Nitrate, Nitrite	NA	NS	NS	0.1	1.8	0.1	NS	0.1	2.9	0.1	NS	0.1	1.6	0.1	NS	0.1	2.1	NS	NS	NS	NS
Nitrogen/Nitrite	NA	NS	NS	0.02	ND	0.02	NS	0.02	ND	0.02	NS	0.02	ND	0.02	NS	0.02	ND	NS	NS	NS	NS
Perchlorate	0.0049	NS	NS	0.004	ND	0.004	NS	0.004	ND	0.004	NS	0.004	ND	0.004	NS	0.004	ND	NS	NS	NS	NS
Selenium	0.05	NS	NS	0.0025	0.0071	0.0025	NS	0.0025	0.016	0.0025	NS	0.0025	ND	0.0025	NS	0.0025	0.0075	NS	NS	NS	NS
Silver	0.05	NS	NS	0.0005	ND	0.0005	NS	0.0005	ND	0.0005	NS	0.0005	ND	0.0005	NS	0.0005	ND	NS	NS	NS	NS
Sulfate	400	NS	NS	20	56	20	NS	20	84	20	NS	20	42	20	NS	20	120	NS	NS	NS	NS
Thallium	0.002	NS	NS	0.002	ND	0.002	NS	0.002	ND	0.002	NS	0.002	ND	0.002	NS	0.002	ND	NS	NS	NS	NS
Total Dissolved Solids	1,200	NS	NS	10	720	10	NS	10	940	10	NS	10	510	10	NS	10	730	NS	NS	NS	NS
Vanadium	0.049	NS	NS	0.005	ND^	0.005	NS	0.005	ND	0.005	NS	0.005	ND	0.005	NS	0.005	0.005	NS	NS	NS	NS
Zinc	5	NS	NS	0.02	ND	0.02	NS	0.02	ND ^	0.02	NS	0.02	ND	0.02	NS	0.02	ND	NS	NS	NS	NS
Benzene	0.005	NS	NS	0.0005	ND	0.0005	NS	0.0005	ND	0.0005	NS	0.0005	ND	0.0005	NS	0.0005	ND	NS	NS	NS	NS
BETX	11.705	NS	NS	0.0025	ND	0.0025	NS	0.0025	ND	0.0025	NS	0.0025	ND	0.0025	NS	0.0025	ND	NS	NS	NS	NS
pH	6.5 - 9.0	NS	NS	NA	7.20	NA	NS	NA	7.42	NA	NS	NA	7.9	NA	NS	NA	7.01	NS	NS	NS	NS
Temperature	NA	NS	NS	NA	13.12	NA	NS	NA	14.8	NA	NS	NA	11.25	NA	NS	NA	12.7	NS	NS	NS	NS
Conductivity	NA	NS	NS	NA	0.91	NA	NS	NA	2.25	NA	NS	NA	90.6	NA	NS	NA	1.226	NS	NS	NS	NS
Dissolved Oxygen	NA	NS	NS	NA	9.88	NA	NS	NA	8.62	NA	NS	NA	12.51	NA	NS	NA	8.61	NS	NS	NS	NS
ORP	NA	NS	NS	NA	30.4	NA	NS	NA	-246.5	NA	NS	NA	-29.4	NA	NS	NA	87.6	NS	NS	NS	NS

Notes: Standards obtained from IAC, Title 35, Chapter I, Part 620, Subpart D, Section 620.410 - Groundwater Quality Standards for Class I: Potable Resource Groundwater

All values are in mg/L (ppm) unless otherwise noted.

Temperature	°C	degrees Celsius
Conductivity	ms/cm^c	millisiemens/centimeters
Dissolved Oxygen	mg/L	milligrams/liter
Oxygen Reduction Potential (ORP)	mV	millivolts

DL - Detection limit
NA - Not Applicable
ND - Not Detected
NS - Not Sampled

^ - Instrument related QC outside limit.
F1- MS and/or MSD recovery exceeds control limits.
J- Estimated concentration. Less than RL but at or above MDL.

Table 2. Groundwater Analytical Results - Midwest Generation LLC, Joliet Station #29, Joliet, IL

Sample: MW-02	Date	8/1/2018		10/16/2018		2/4/2019		5/7/2019		8/6/2019		11/7/2019		2/13/2020		5/21/2020		7/30/2020		10/22/2020	
Parameter	Standards	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result
Antimony	0.006	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	NS	0.003	ND	0.003	NS	0.003	ND	NS	NS	NS	NS
Arsenic	0.01	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	NS	0.001	ND	0.001	NS	0.001	ND	NS	NS	NS	NS
Barium	2	0.0025	0.071	0.0025	0.063	0.0025	0.071	0.0025	0.11	0.0025	NS	0.0025	0.065	0.0025	NS	0.0025	0.089	NS	NS	NS	NS
Beryllium	0.004	0.001	ND	0.001	ND^	0.001	ND	0.001	ND	0.001	NS	0.001	ND	0.001	NS	0.001	ND ^	NS	NS	NS	NS
Boron	2	0.05	0.14	0.05	0.15	0.05	0.14	0.05	0.15	0.05	NS	0.05	0.18	0.05	NS	0.05	0.24	NS	NS	NS	NS
Cadmium	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	NS	0.0005	ND	0.0005	NS	0.0005	ND	NS	NS	NS	NS
Chloride	200	10	200	10	120	10	150	10	500	10	NS	10	100	10	NS	10	260	NS	NS	NS	NS
Chromium	0.1	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	NS	0.005	ND	0.005	NS	0.005	ND	NS	NS	NS	NS
Cobalt	1	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	NS	0.001	ND	0.001	NS	0.001	ND	NS	NS	NS	NS
Copper	0.65	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	NS	0.002	ND	0.002	NS	0.002	ND	NS	NS	NS	NS
Cyanide	0.2	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	NS	0.01	ND	0.01	NS	0.01	ND	NS	NS	NS	NS
Fluoride	4	0.1	0.4	0.1	0.43	0.1	0.39	0.1	0.41	0.1	NS	0.1	0.38	0.1	NS	0.1	0.41	NS	NS	NS	NS
Iron	5	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	NS	0.1	ND	0.1	NS	0.1	ND	NS	NS	NS	NS
Lead	0.0075	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	NS	0.0005	ND	0.0005	NS	0.0005	ND	NS	NS	NS	NS
Manganese	0.15	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	NS	0.0025	ND	0.0025	NS	0.0025	ND	NS	NS	NS	NS
Mercury	0.002	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	NS	0.0002	ND	0.0002	NS	0.0002	ND	NS	NS	NS	NS
Nickel	0.1	0.002	0.003	0.002	ND	0.002	0.0027	0.002	0.0034	0.002	NS	0.002	0.0021	0.002	NS	0.002	0.0046	NS	NS	NS	NS
Nitrogen/Nitrate	10	0.1	0.81	0.1	0.68	0.1	1.0	0.1	1.8	0.1	NS	0.1	1.2	0.1	NS	0.1	2.9	NS	NS	NS	NS
Nitrogen/Nitrate, Nitrite	NA	0.1	0.81	0.1	0.68	0.1	1.0	0.1	1.8	0.1	NS	0.1	1.2	0.1	NS	0.1	2.9	NS	NS	NS	NS
Nitrogen/Nitrite	NA	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	NS	0.02	ND	0.02	NS	0.02	ND	NS	NS	NS	NS
Perchlorate	0.0049	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	NS	0.004	ND	0.004	NS	0.004	ND	NS	NS	NS	NS
Selenium	0.05	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	NS	0.0025	ND	0.0025	NS	0.0025	0.0045	NS	NS	NS	NS
Silver	0.05	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	NS	0.0005	ND	0.0005	NS	0.0005	ND	NS	NS	NS	NS
Sulfate	400	20	76	20	45	20	71	20	73	20	NS	20	34	20	NS	20	160	NS	NS	NS	NS
Thallium	0.002	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	NS	0.002	ND	0.002	NS	0.002	ND	NS	NS	NS	NS
Total Dissolved Solids	1,200	10	760	10	520	10	690	10	1,100	10	NS	10	580	10	NS	10	910	NS	NS	NS	NS
Vanadium	0.049	0.005	ND	0.005	ND^	0.005	ND	0.005	ND	0.005	NS	0.005	ND	0.005	NS	0.005	ND	NS	NS	NS	NS
Zinc	5	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	NS	0.02	ND	0.02	NS	0.02	ND	NS	NS	NS	NS
Benzene	0.005	0.0005	0.001	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	NS	0.0005	ND	0.0005	NS	0.0005	ND	NS	NS	NS	NS
BETX	11.705	0.0025	0.0142	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	NS	0.0025	ND	0.0025	NS	0.0025	ND	NS	NS	NS	NS
pH	6.5 - 9.0	NA	7.36	NA	7.70	NA	7.32	NA	7.3	NA	NS	NA	7.16	NA	NS	NA	6.99	NS	NS	NS	NS
Temperature	NA	NA	17.40	NA	14.68	NA	13.4	NA	19.3	NA	NS	NA	12.61	NA	NS	NA	14.5	NS	NS	NS	NS
Conductivity	NA	NA	0.961	NA	0.735	NA	1.1	NA	3.0	NA	NS	NA	9.67	NA	NS	NA	1.577	NS	NS	NS	NS
Dissolved Oxygen	NA	NA	5.36	NA	6.25	NA	6.20	NA	6.98	NA	NS	NA	9.1	NA	NS	NA	7.77	NS	NS	NS	NS
ORP	NA	NA	85.9	NA	36.6	NA	125.6	NA	NA	NA	NS	NA	-10.5	NA	NS	NA	82.1	NS	NS	NS	NS

Notes: Standards obtained from IAC, Title 35, Chapter I, Part 620, Subpart D, Section 620.410 - Groundwater Quality Standards for Class I: Potable Resource Groundwater

All values are in mg/L (ppm) unless otherwise noted.

Temperature °C degrees Celsius
Conductivity ms/cm^c millisiemens/centimeters
Dissolved Oxygen mg/L milligrams/liter
Oxygen Reduction Potential (ORP) mV millivolts

DL - Detection limit
NA - Not Applicable
ND - Not Detected
NS - Not Sampled

^ - Instrument related QC outside limit.
F1- MS and/or MSD recovery exceeds control limits.
J- Estimated concentration. Less than RL but at or above MDL.

Table 2. Groundwater Analytical Results - Midwest Generation LLC, Joliet Station #29, Joliet, IL

Sample: MW-03	Date	7/31/2018		10/17/2018		2/4/2019		5/7/2019		8/7/2019		11/7/2019		2/17/2020		5/20/2020		7/30/2020		10/22/2020	
Parameter	Standards	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result
Antimony	0.006	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND
Arsenic	0.01	0.001	0.0012	0.001	0.001	0.001	0.0011	0.001	0.001	0.001	ND	0.001	0.0012	0.001	0.0015	0.001	0.0015	0.001	0.001	0.001	ND
Barium	2	0.0025	0.099	0.0025	0.1	0.0025	0.089	0.0025	0.11	0.0025	0.088	0.0025	0.081	0.0025	0.09	0.0025	0.11	0.0025	0.093	0.0025	0.1
Beryllium	0.004	0.001	ND	0.001	ND^	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND ^	0.001	ND	0.001	ND
Boron	2	0.05	0.33	0.05	0.22	0.05	0.36	0.05	0.41	0.05	0.36	0.05	0.32	0.05	0.33	0.05	0.36	0.05	0.28	0.05	0.29
Cadmium	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Chloride	200	10	260	10	250	10	160	10	270 F1	10	220	10	150	10	130	10	230	10	170	10	180
Chromium	0.1	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Cobalt	1	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND
Copper	0.65	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Cyanide	0.2	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.005	0.0062	0.01	ND
Fluoride	4	0.1	0.42	0.1	0.4	0.1	0.43	0.1	0.41	0.1	0.39	0.1	0.41	0.1	0.46	0.1	0.42	0.1	0.45	0.1	0.44
Iron	5	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND
Lead	0.0075	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Manganese	0.15	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.0035	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
Mercury	0.002	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND
Nickel	0.1	0.002	0.0025	0.002	0.0049	0.002	0.0033	0.002	0.0035	0.002	ND	0.002	0.0028	0.002	ND	0.002	ND	0.002	ND	0.002	0.0031
Nitrogen/Nitrate	10	0.1	1.4	0.1	0.94	0.1	1.0	0.1	2.1	0.1	2.7	0.1	1.8	0.1	1.7	0.1	2.1	0.1	3	0.1	2.8
Nitrogen/Nitrate, Nitrite	NA	0.1	1.4	0.1	0.94	0.1	1.0	0.1	2.1	0.1	2.7	0.1	1.8	0.1	1.7	0.1	2.1	0.5	3	0.5	2.8
Nitrogen/Nitrite	NA	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Perchlorate	0.0049	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND
Selenium	0.05	0.0025	0.0038	0.0025	ND	0.0025	0.0032	0.0025	0.0056	0.0025	0.0037	0.0025	0.0025	0.0025	0.0025	0.0025	0.0039	0.0025	0.0028	0.0025	ND
Silver	0.05	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Sulfate	400	25	110	25	84	25	100	25	160	25	71	25	73	25	65	25	100	25	77	15	91
Thallium	0.002	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Total Dissolved Solids	1,200	10	920	10	860	10	770	10	900	10	760	10	740	10	610	10	910	30	680	30	760
Vanadium	0.049	0.005	ND	0.005	ND^	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Zinc	5	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Benzene	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
BETX	11.705	0.0025	0.001	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
pH	6.5 - 9.0	NA	7.22	NA	7.04	NA	7.44	NA	7.27	NA	7.34	NA	7.32	NA	7.31	NA	7.56	NA	7.1	NA	7.23
Temperature	NA	NA	20.13	NA	11.69	NA	11.00	NA	12.00	NA	13.00	NA	11.86	NA	12.00	NA	11.50	NA	12.50	NA	12.60
Conductivity	NA	NA	1.206	NA	1.070	NA	123.700	NA	2.35	NA	1.37	NA	11.87	NA	9.37	NA	9.92	NA	1.36	NA	1.35
Dissolved Oxygen	NA	NA	6.75	NA	9.38	NA	7.10	NA	6.48	NA	6.09	NA	8.23	NA	5.7	NA	3.98	NA	7.65	NA	4.22
ORP	NA	NA	142.0	NA	101.7	NA	194.7	NA	-237.9	NA	157.7	NA	-9.8	NA	154.4	NA	160.7	NA	157.4	NA	180.0

Notes: Standards obtained from IAC, Title 35, Chapter I, Part 620, Subpart D, Section 620.410 - Groundwater Quality Standards for Class I: Potable Resource Groundwater

All values are in mg/L (ppm) unless otherwise noted.

Temperature	°C	degrees Celsius
Conductivity	ms/cm^c	millisiemens/centimeters
Dissolved Oxygen	mg/L	milligrams/liter
Oxygen Reduction Potential (ORP)	mV	millivolts

DL - Detection limit
NA - Not Applicable
ND - Not Detected
NS - Not Sampled

^ - Instrument related QC outside limit.
F1- MS and/or MSD recovery exceeds control limits.
J- Estimated concentration. Less than RL but at or above MDL.

Table 2. Groundwater Analytical Results - Midwest Generation LLC, Joliet Station #29, Joliet, IL

Sample: MW-04	Date	7/31/2018		10/17/2018		2/4/2019		5/7/2019		8/6/2019		11/6/2019		2/17/2020		5/20/2020		7/31/2020		10/22/2020	
Parameter	Standards	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result
Antimony	0.006	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND
Arsenic	0.01	0.001	0.0011	0.001	0.001	0.001	0.0012	0.001	0.001	0.001	ND	0.001	0.001	0.001	0.0014	0.001	0.0014	0.001	ND	0.001	ND
Barium	2	0.0025	0.089	0.0025	0.093	0.0025	0.085	0.0025	0.091	0.0025	0.08	0.0025	0.082	0.0025	0.085	0.0025	0.085	0.0025	0.082	0.0025	0.09
Beryllium	0.004	0.001	ND	0.001	ND^	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND
Boron	2	0.05	0.35	0.05	0.29	0.05	0.44	0.05	0.77	0.05	0.26	0.05	0.28	0.05	0.25	0.05	0.25	0.05	0.23	0.05	0.29
Cadmium	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Chloride	200	10	250	10	210	10	190	10	310	10	220	10	140	10	160	10	160	10	170	10	190
Chromium	0.1	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Cobalt	1	0.001	0.008	0.001	ND	0.001	0.0046	0.001	ND	0.001	0.0057	0.001	0.0016	0.001	0.0071	0.001	0.0071	0.001	0.0031	0.001	0.0041
Copper	0.65	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Cyanide	0.2	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.005	0.0057	0.01	ND
Fluoride	4	0.1	0.43	0.1	0.46	0.1	0.46	0.1	0.43	0.1	0.39	0.1	0.42	0.1	0.46	0.1	0.46	0.1	0.47	0.1	0.49
Iron	5	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND
Lead	0.0075	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Manganese	0.15	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
Mercury	0.002	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND
Nickel	0.1	0.002	ND	0.002	0.0021	0.002	0.0022	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Nitrogen/Nitrate	10	0.1	1.7	0.1	1.4	0.1	1.4	0.1	2.5	0.1	2.5	0.1	1.8	0.1	1.6	0.1	1.6	0.1	2.7	0.1	3.4
Nitrogen/Nitrate, Nitrite	NA	0.1	1.7	0.1	1.4	0.1	1.4	0.1	2.5	0.1	2.5	0.1	1.8	0.1	1.6	0.1	1.6	0.5	2.7	0.5	3.4
Nitrogen/Nitrite	NA	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Perchlorate	0.0049	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND
Selenium	0.05	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.0076	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
Silver	0.05	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Sulfate	400	50	110	25	91	25	130	25	150	25	74	25	53	25	94	25	94	25	75	15	82
Thallium	0.002	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Total Dissolved Solids	1,200	10	1000	10	790	10	840	10	980	10	770	10	690	10	710	10	710	30	700	30	760
Vanadium	0.049	0.005	ND	0.005	ND^	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Zinc	5	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Benzene	0.005	0.0005	0.0024	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
BETX	11.705	0.0025	0.0082	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
pH	6.5 - 9.0	NA	7.58	NA	7.20	NA	7.41	NA	7.27	NA	7.31	NA	7.33	NA	7.26	NA	7.26	NA	7.23	NA	7.15
Temperature	NA	NA	16.54	NA	12.53	NA	11.30	NA	11.60	NA	12.70	NA	11.72	NA	11.20	NA	11.20	NA	14.20	NA	14.40
Conductivity	NA	NA	1.125	NA	1.086	NA	1.336	NA	2.520	NA	1.440	NA	1.080	NA	1.016	NA	1.016	NA	1.428	NA	0.292
Dissolved Oxygen	NA	NA	7.54	NA	8.36	NA	6.32	NA	7.10	NA	52.40	NA	6.65	NA	6.23	NA	6.23	NA	7.32	NA	5.33
ORP	NA	NA	96.5	NA	58.0	NA	163.9	NA	-233.6	NA	182.3	NA	192.0	NA	167.2	NA	167.2	NA	128.4	NA	178.4

Notes: Standards obtained from IAC, Title 35, Chapter I, Part 620, Subpart D, Section 620.410 - Groundwater Quality Standards for Class I: Potable Resource Groundwater

All values are in mg/L (ppm) unless otherwise noted.

Temperature °C degrees Celsius
Conductivity ms/cm^c millisiemens/centimeters
Dissolved Oxygen mg/L milligrams/liter
Oxygen Reduction Potential (ORP) mV millivolts

DL - Detection limit
NA - Not Applicable
ND - Not Detected
NS - Not Sampled

^ - Instrument related QC outside limit.
F1- MS and/or MSD recovery exceeds control limits.
J- Estimated concentration. Less than RL but at or above MDL.

Table 2. Groundwater Analytical Results - Midwest Generation LLC, Joliet Station #29, Joliet, IL

Sample: MW-05	Date	7/31/2018		10/17/2018		2/5/2019		5/6/2019		8/6/2019		11/7/2019		2/13/2020		5/20/2020		7/31/2020		10/22/2020	
Parameter	Standards	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result
Antimony	0.006	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND
Arsenic	0.01	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	0.0033	0.001	ND	0.001	0.0011	0.001	ND	0.001	ND
Barium	2	0.0025	0.061	0.0025	0.067	0.0025	0.076	0.0025	0.094	0.0025	0.062	0.0025	0.062	0.0025	0.072	0.0025	0.074	0.0025	0.054	0.0025	0.07
Beryllium	0.004	0.001	ND	0.001	ND^	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND ^	0.001	ND	0.001	ND
Boron	2	0.05	0.58	0.05	0.31	0.05	0.28	0.05	0.34	0.05	0.5	0.05	0.32	0.05	0.43	0.05	0.29	0.05	0.47	0.05	0.47
Cadmium	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Chloride	200	10	120	10	200	10	180	10	470	10	120	10	130	10	170	10	280	10	180	10	180
Chromium	0.1	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	0.0053	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Cobalt	1	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	0.0015	0.001	ND	0.001	ND	0.001	ND	0.001	ND
Copper	0.65	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	0.0063	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Cyanide	0.2	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.005	ND	0.01	ND
Fluoride	4	0.1	0.38	0.1	0.33	0.1	0.33	0.1	0.31	0.1	0.31	0.1	0.31	0.1	0.36	0.1	0.37	0.1	0.38	0.1	0.38
Iron	5	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	4.1	0.1	ND	0.1	0.11	0.1	ND	0.1	ND
Lead	0.0075	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	0.0033	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Manganese	0.15	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.14	0.0025	ND	0.0025	0.0025	0.0025	ND	0.0025	ND
Mercury	0.002	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND
Nickel	0.1	0.002	0.0034	0.002	ND	0.002	ND	0.002	ND	0.002	0.0024	0.002	0.0072	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Nitrogen/Nitrate	10	0.1	1.7	0.1	1.3	0.1	0.92	0.1	1.8	0.1	1.3	0.1	1.2	0.1	1.2	0.1	1.4	0.1	1.3	0.1	0.99
Nitrogen/Nitrate, Nitrite	NA	0.1	1.7	0.1	1.3	0.1	0.92	0.1	1.8	0.1	1.3	0.1	1.2	0.1	1.2	0.1	1.4	0.1	1.3	0.1	0.99
Nitrogen/Nitrite	NA	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Perchlorate	0.0049	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND
Selenium	0.05	0.0025	0.023	0.0025	0.0028	0.0025	ND	0.0025	ND	0.0025	0.011	0.0025	ND	0.0025	0.0025	0.0025	0.0048	0.0025	0.0029	0.0025	0.0032
Silver	0.05	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Sulfate	400	50	190	25	110	25	110	25	90	25	180	25	68	25	ND	25	190	25	79	15	84
Thallium	0.002	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Total Dissolved Solids	1,200	10	1000	10	800	10	720	10	1,400	10	770	10	630	10	700	10	920	30	680	30	690
Vanadium	0.049	0.005	0.0077	0.005	ND^	0.005	ND	0.005	ND	0.005	ND	0.005	0.012	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Zinc	5	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	0.027	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Benzene	0.005	0.0005	0.00096	0.0005	ND	0.0005	ND	0.0005	0.0007	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
BETX	11.705	0.0025	0.00396	0.0025	ND	0.0025	ND	0.0025	0.0007	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
pH	6.5 - 9.0	NA	7.61	NA	7.29	NA	7.40	NA	7.11	NA	7.03	NA	7.44	NA	7.02	NA	7.03	NA	7.28	NA	7.16
Temperature	NA	NA	18.49	NA	14.72	NA	10.70	NA	13	NA	14.2	NA	10.34	NA	13.2	NA	12.8	NA	13.7	NA	14.5
Conductivity	NA	NA	1.122	NA	1.050	NA	1.116	NA	2.95	NA	1.28	NA	10.56	NA	1.058	NA	1.534	NA	1.381	NA	0.278
Dissolved Oxygen	NA	NA	5.67	NA	7.68	NA	5.97	NA	4.48	NA	3.53	NA	7.84	NA	6.2	NA	6.85	NA	5.7	NA	4.34
ORP	NA	NA	77.8	NA	42.1	NA	150.3	NA	-281.1	NA	170.6	NA	-11.9	NA	136.4	NA	142.8	NA	119.9	NA	161.3

Notes: Standards obtained from IAC, Title 35, Chapter I, Part 620, Subpart D, Section 620.410 - Groundwater Quality Standards for Class I: Potable Resource Groundwater

All values are in mg/L (ppm) unless otherwise noted.

Temperature	°C	degrees Celsius
Conductivity	ms/cm^c	millisiemens/centimeters
Dissolved Oxygen	mg/L	milligrams/liter
Oxygen Reduction Potential (ORP)	mV	millivolts

DL - Detection limit
NA - Not Applicable
ND - Not Detected
NS - Not Sampled

^ - Instrument related QC outside limit.
F1- MS and/or MSD recovery exceeds control limits.
J- Estimated concentration. Less than RL but at or above MDL.

Table 2. Groundwater Analytical Results - Midwest Generation LLC, Joliet Station #29, Joliet, IL

Sample: MW-06	Date	7/31/2018		10/18/2018		2/5/2019		5/6/2019		8/7/2019		11/7/2019		2/13/2020		5/21/2020		7/31/2020		10/22/2020	
Parameter	Standards	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result
Antimony	0.006	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND
Arsenic	0.01	0.001	0.0012	0.001	0.001	0.001	0.0011	0.001	0.0014	0.001	ND	0.001	0.0011	0.001	0.0014	0.001	0.0017	0.001	0.001	0.001	ND
Barium	2	0.0025	0.1	0.0025	0.13	0.0025	0.12	0.0025	0.15	0.0025	0.11	0.0025	0.13	0.0025	0.14	0.0025	0.14	0.0025	0.13	0.0025	0.13
Beryllium	0.004	0.001	ND	0.001	ND^	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND ^	0.001	ND	0.001	ND
Boron	2	0.05	0.21	0.05	0.22	0.05	0.24	0.05	0.3	0.05	0.21	0.05	0.24	0.05	0.2	0.05	0.49	0.05	0.18	0.05	0.23
Cadmium	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Chloride	200	10	140	10	150	10	170 F1	10	420	10	130	10	99	10	150	10	180	10	160	10	160
Chromium	0.1	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Cobalt	1	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND
Copper	0.65	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Cyanide	0.2	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.005	0.0051	0.01	ND
Fluoride	4	0.1	0.31	0.1	0.34	0.1	0.33	0.1	0.34	0.1	0.26	0.1	0.3	0.1	0.37	0.1	0.37	0.1	0.32	0.1	0.31
Iron	5	0.1	ND	0.1	ND	0.1	ND	0.1	0.26	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND
Lead	0.0075	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Manganese	0.15	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.017	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
Mercury	0.002	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND
Nickel	0.1	0.002	ND	0.002	ND	0.002	ND	0.002	0.0024	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Nitrogen/Nitrate	10	0.1	0.43	0.1	0.34	0.1	2.2	0.1	1.7	0.1	0.47	0.1	0.61	0.1	0.75	0.1	1.9	0.1	0.66	0.1	0.56
Nitrogen/Nitrate, Nitrite	NA	0.1	0.43	0.1	0.34	0.1	2.2	0.1	1.7	0.1	0.47	0.1	0.61	0.1	0.75	0.1	1.9	0.1	0.66	0.1	0.56
Nitrogen/Nitrite	NA	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Perchlorate	0.0049	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND
Selenium	0.05	0.0025	ND	0.0025	0.0034	0.0025	0.0026	0.0025	0.026	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.053	0.0025	ND	0.0025	ND
Silver	0.05	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND F1	0.0005	ND	0.0005	ND	0.0005	ND
Sulfate	400	25	76	20	89	20	130	20	110	20	7.8	20	78	20	130	20	160	25	110	15	83
Thallium	0.002	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Total Dissolved Solids	1,200	10	620	10	640	10	720	10	1,200	10	620	10	620	10	710	10	830	30	650	30	640
Vanadium	0.049	0.005	ND	0.005	ND^	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	0.0056	0.005	ND	0.005	ND
Zinc	5	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Benzene	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
BETX	11.705	0.0025	0.0023	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
pH	6.5 - 9.0	NA	7.54	NA	7.63	NA	7.62	NA	7.42	NA	7.39	NA	7.27	NA	7.42	NA	7.06	NA	7.44	NA	6.95
Temperature	NA	NA	19.68	NA	12.51	NA	13.1	NA	11.7	NA	12.8	NA	13.84	NA	13.2	NA	12.5	NA	13.2	NA	17.1
Conductivity	NA	NA	1.265	NA	0.825	NA	1159	NA	2.83	NA	1.06	NA	9.34	NA	0.983	NA	1.141	NA	1.306	NA	1.2
Dissolved Oxygen	NA	NA	7.19	NA	10.56	NA	5.93	NA	5.82	NA	51.00	NA	9.01	NA	7.71	NA	7.98	NA	7.06	NA	3.67
ORP	NA	NA	71.6	NA	2.2	NA	112.0	NA	-265.1	NA	187.4	NA	-11.6	NA	157.2	NA	224.6	NA	152.0	NA	157.4

Notes: Standards obtained from IAC, Title 35, Chapter I, Part 620, Subpart D, Section 620.410 - Groundwater Quality Standards for Class I: Potable Resource Groundwater

All values are in mg/L (ppm) unless otherwise noted.

Temperature	°C	degrees Celsius
Conductivity	ms/cm^c	millisiemens/centimeters
Dissolved Oxygen	mg/L	milligrams/liter
Oxygen Reduction Potential (ORP)	mV	millivolts

DL - Detection limit
NA - Not Applicable
ND - Not Detected
NS - Not Sampled

^ - Instrument related QC outside limit.
F1- MS and/or MSD recovery exceeds control limits.
J- Estimated concentration. Less than RL but at or above MDL.

Table 2. Groundwater Analytical Results - Midwest Generation LLC, Joliet Station #29, Joliet, IL

Sample: MW-07	Date	8/1/2018		10/18/2018		2/5/2019		5/6/2019		8/6/2019		11/7/2019		2/13/2020		5/21/2020		7/31/2020		10/22/2020	
Parameter	Standards	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result
Antimony	0.006	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND
Arsenic	0.01	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	0.0011	0.001	ND	0.001	ND	0.001	ND
Barium	2	0.0025	0.093	0.0025	0.12	0.0025	0.13	0.0025	0.1	0.0025	0.11	0.0025	0.11	0.0025	0.14	0.0025	0.095	0.0025	0.11	0.0025	0.13
Beryllium	0.004	0.001	ND	0.001	ND^	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND ^	0.001	ND	0.001	ND
Boron	2	0.05	0.18	0.05	0.25	0.05	0.19	0.05	0.24	0.05	0.23	0.05	0.19	0.05	0.23	0.05	0.38	0.05	0.19	0.05	0.34
Cadmium	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Chloride	200	10	130	10	140	10	180	10	400 F1	10	130	10	87	10	190	10	190	10	210	10	150
Chromium	0.1	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Cobalt	1	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND
Copper	0.65	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Cyanide	0.2	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.005	ND	0.01	ND
Fluoride	4	0.1	0.29	0.1	0.26	0.1	0.26	0.1	0.3	0.1	0.24	0.1	0.26	0.1	0.3	0.1	0.33	0.1	0.29	0.1	0.28
Iron	5	0.1	ND	0.1	0.58	0.1	0.45	0.1	0.2	0.1	0.16	0.1	ND	0.1	0.13	0.1	ND	0.1	ND	0.1	ND
Lead	0.0075	0.0005	ND	0.0005	ND	0.0005	0.0005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Manganese	0.15	0.0025	0.0026	0.0025	0.015	0.0025	0.017	0.0025	0.0068	0.0025	0.0063	0.0025	ND	0.0025	0.004	0.0025	ND	0.0025	0.0041	0.0025	ND
Mercury	0.002	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND
Nickel	0.1	0.002	ND	0.002	0.0021	0.002	0.0022	0.002	0.0022	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Nitrogen/Nitrate	10	0.1	0.29	0.1	0.29	0.1	0.85	0.1	1.6	0.1	0.23	0.1	0.68	0.1	0.88	0.1	1.4	0.1	0.54	0.1	0.93
Nitrogen/Nitrate, Nitrite	NA	0.1	0.29	0.1	0.29	0.1	0.85	0.1	1.6	0.1	0.23	0.1	0.68	0.1	0.88	0.1	1.4	0.1	0.54	0.1	0.93
Nitrogen/Nitrite	NA	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Perchlorate	0.0049	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND
Selenium	0.05	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.0048	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.0038	0.0025	ND	0.0025	0.0025
Silver	0.05	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Sulfate	400	20	64	20	90	20	87	20	97	20	48	20	83	20	96	20	140	25	85	15	97
Thallium	0.002	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Total Dissolved Solids	1,200	10	580	10	680	10	670	10	1,300	10	590	10	540	10	710	10	750	30	630	30	680
Vanadium	0.049	0.005	ND	0.005	ND^	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Zinc	5	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Benzene	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
BETX	11.705	0.0025	0.0018	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
pH	6.5 - 9.0	NA	7.47	NA	7.51	NA	7.48	NA	7.36	NA	7.31	NA	7.55	NA	7.27	NA	7.09	NA	7.23	NA	7.06
Temperature	NA	NA	21.38	NA	12.69	NA	12.70	NA	12.10	NA	12.40	NA	13.75	NA	12.80	NA	12.00	NA	13.10	NA	14.50
Conductivity	NA	NA	1.143	NA	0.784	NA	1.129	NA	2.720	NA	1.020	NA	8.950	NA	1.052	NA	1.100	NA	1.327	NA	1.230
Dissolved Oxygen	NA	NA	3.97	NA	9.73	NA	2.96	NA	6.71	NA	27.40	NA	5.54	NA	7.22	NA	6.48	NA	4.62	NA	3.98
ORP	NA	NA	92.9	NA	6.0	NA	113.5	NA	-281.3	NA	189.6	NA	-22.6	NA	158.8	NA	282.5	NA	187.6	NA	150.9

Notes: Standards obtained from IAC, Title 35, Chapter I, Part 620, Subpart D, Section 620.410 - Groundwater Quality Standards for Class I: Potable Resource Groundwater

All values are in mg/L (ppm) unless otherwise noted.

Temperature	°C	degrees Celsius
Conductivity	ms/cm^c	millisiemens/centimeters
Dissolved Oxygen	mg/L	milligrams/liter
Oxygen Reduction Potential (ORP)	mV	millivolts

DL - Detection limit
NA - Not Applicable
ND - Not Detected
NS - Not Sampled

^ - Instrument related QC outside limit.
F1- MS and/or MSD recovery exceeds control limits.
J- Estimated concentration. Less than RL but at or above MDL.

Table 2. Groundwater Analytical Results - Midwest Generation LLC, Joliet Station #29, Joliet, IL

Sample: MW-08	Date	8/1/2018		10/16/2018		2/5/2019		5/6/2019		8/6/2019		11/7/2019		2/12/2020		5/20/2020		7/30/2020		10/22/2020	
Parameter	Standards	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result
Antimony	0.006	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND
Arsenic	0.01	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND
Barium	2	0.0025	0.037	0.0025	0.044	0.0025	0.046	0.0025	0.031	0.0025	0.027	0.0025	0.034	0.0025	0.054	0.0025	0.041	0.0025	0.047	0.0025	0.062
Beryllium	0.004	0.001	ND	0.001	ND^	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND ^	0.001	ND	0.001	ND
Boron	2	0.05	0.15	0.05	0.15	0.05	0.089	0.05	0.09	0.05	0.12	0.05	0.14	0.05	0.11	0.05	0.14	0.05	0.11	0.05	0.18
Cadmium	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Chloride	200	10	120	10	85	10	200	10	310	10	270	10	70	10	230	10	370	10	160	10	180
Chromium	0.1	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Cobalt	1	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND
Copper	0.65	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Cyanide	0.2	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.005	0.0062	0.01	ND
Fluoride	4	0.1	0.31	0.1	0.3	0.1	0.34	0.1	0.4	0.1	0.28	0.1	0.26	0.1	0.33	0.1	0.34	0.1	0.3	0.1	0.27
Iron	5	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND
Lead	0.0075	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Manganese	0.15	0.0025	ND	0.0025	0.0027	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
Mercury	0.002	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND
Nickel	0.1	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	0.0055	0.002	0.0024	0.002	ND	0.002	0.002
Nitrogen/Nitrate	10	0.1	0.49	0.1	0.63	0.1	0.89	0.1	2.3	0.1	0.76	0.1	0.94	0.1	1	0.1	3.6	0.1	1.4	0.1	1.4
Nitrogen/Nitrate, Nitrite	NA	0.1	0.49	0.1	0.63	0.1	0.89	0.1	2.3	0.1	0.76	0.1	0.94	0.1	1	0.1	3.6	0.1	1.4	0.1	1.4
Nitrogen/Nitrite	NA	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Perchlorate	0.0049	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND
Selenium	0.05	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.0043	0.0025	ND	0.0025	ND
Silver	0.05	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Sulfate	400	20	43	20	31	20	26	20	39	20	16	20	29	20	63	20	89	25	83	15	140
Thallium	0.002	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Total Dissolved Solids	1,200	10	520	10	480	10	560	10	930	10	420	10	470	10	750	10	1100	30	650	30	800
Vanadium	0.049	0.005	ND	0.005	ND^	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Zinc	5	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Benzene	0.005	0.0005	0.0022	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
BETX	11.705	0.0025	0.0249	0.0025	0.0016	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
pH	6.5 - 9.0	NA	7.41	NA	7.47	NA	7.45	NA	7.38	NA	7.41	NA	7.01	NA	7.25	NA	7.10	NA	6.97	NA	7.14
Temperature	NA	NA	18.27	NA	14.62	NA	14.20	NA	13.80	NA	12.40	NA	11.31	NA	13.30	NA	12.80	NA	13.20	NA	12.90
Conductivity	NA	NA	0.854	NA	0.691	NA	1.062	NA	2.200	NA	0.850	NA	8.020	NA	1.112	NA	1.860	NA	1.297	NA	1.880
Dissolved Oxygen	NA	NA	5.48	NA	5.97	NA	5.22	NA	6.50	NA	48.30	NA	6.97	NA	7.14	NA	9.68	NA	6.97	NA	3.88
ORP	NA	NA	85.3	NA	83.5	NA	112.6	NA	-291.4	NA	190.0	NA	-24.4	NA	177.6	NA	139.8	NA	185.2	NA	189.0

Notes: Standards obtained from IAC, Title 35, Chapter I, Part 620, Subpart D, Section 620.410 - Groundwater Quality Standards for Class I: Potable Resource Groundwater

All values are in mg/L (ppm) unless otherwise noted.

Temperature	°C	degrees Celsius
Conductivity	ms/cm^c	millisiemens/centimeters
Dissolved Oxygen	mg/L	milligrams/liter
Oxygen Reduction Potential (ORP)	mV	millivolts

DL - Detection limit
NA - Not Applicable
ND - Not Detected
NS - Not Sampled

^ - Instrument related QC outside limit.
F1- MS and/or MSD recovery exceeds control limits.
J- Estimated concentration. Less than RL but at or above MDL.

Table 2. Groundwater Analytical Results - Midwest Generation LLC, Joliet Station #29, Joliet, IL

Sample: MW-09	Date	8/1/2018		10/16/2018		2/5/2019		5/7/2019		8/7/2019		11/7/2019		2/12/2020		5/20/2020		8/5/2020		10/22/2020	
Parameter	Standards	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result
Antimony	0.006	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND
Arsenic	0.01	0.001	0.0013	0.001	0.0013	0.001	0.0023	0.001	0.0042	0.001	0.0016	0.001	0.0047	0.001	0.0038	0.001	0.0062	0.001	0.001	0.001	0.034
Barium	2	0.0025	0.0083	0.0025	0.011	0.0025	0.011	0.0025	0.012	0.0025	0.0084	0.0025	0.012	0.0025	0.01	0.0025	0.013	0.0025	0.01	0.0025	0.086
Beryllium	0.004	0.001	ND	0.001	ND^	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND ^	0.001	ND	0.001	ND ^
Boron	2	0.05	0.29	0.05	0.27	0.05	0.35	0.05	0.45	0.05	0.33	0.05	0.73	0.05	0.33	0.05	0.3	0.05	0.29	0.05	0.37
Cadmium	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	0.0021
Chloride	200	10	210	10	210	10	140	10	57	10	180	10	23	10	75	10	6.1 F1	10	140	10	190
Chromium	0.1	0.005	ND	0.005	ND	0.005	0.005	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	0.028
Cobalt	1	0.001	0.021	0.001	0.022	0.001	0.033	0.001	0.059	0.001	0.031	0.001	0.065	0.001	0.032	0.001	0.04	0.001	0.016	0.001	0.046
Copper	0.65	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	0.041
Cyanide	0.2	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.005	0.0053	0.01	ND
Fluoride	4	0.1	0.38	0.1	0.43	0.1	0.46	0.1	0.57	0.1	0.41	0.1	0.63	0.1	0.52	0.1	0.71	0.1	0.66	0.1	0.66
Iron	5	1	750	1	530	1	1200	1	2,700	1	630	1	1800	1	960	1	1900	10	400	0.5	970
Lead	0.0075	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	0.036
Manganese	0.15	0.0025	1.3	0.0025	0.96	0.0025	2.1	0.0025	4.2	0.0025	1.4	0.0025	4.4	0.0025	2.2	0.0025	3	0.0025	0.96	0.0025	2.3
Mercury	0.002	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND
Nickel	0.1	0.002	0.046	0.002	0.03	0.002	0.077	0.002	0.2	0.002	0.051	0.002	0.22	0.002	0.084	0.002	0.13	0.002	0.036	0.002	0.1
Nitrogen/Nitrate	10	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND
Nitrogen/Nitrate, Nitrite	NA	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND F1	0.1	ND	5	ND	0.1	ND
Nitrogen/Nitrite	NA	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Perchlorate	0.0049	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND
Selenium	0.05	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.0027
Silver	0.05	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Sulfate	400	500	2500	500	1900	500	3400	500	8900	500	2800	500	7100	500	ND	500	6800	250	2000	250	1500
Thallium	0.002	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Total Dissolved Solids	1,200	13	4900	10	3700	10	5900	10	15000	10	5000	10	11000	10	6600	10	11000	150	2900	150	3000
Vanadium	0.049	0.005	ND	0.005	ND^	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	0.026
Zinc	5	0.02	0.56	0.02	0.3	0.02	0.74	0.02	4.1	0.02	0.6	0.02	2.6	0.02	1	0.02	2.4	0.02	0.42	0.02	1.2
Benzene	0.005	0.0005	0.0039	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
BETX	11.705	0.0025	0.0252	0.0025	0.0011	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
pH	6.5 - 9.0	NA	7.30	NA	6.47	NA	6.16	NA	5.70	NA	6.07	NA	5.53	NA	5.74	NA	5.41	NA	6.26	NA	5.73
Temperature	NA	NA	22.20	NA	14.34	NA	12.60	NA	12.40	NA	13.10	NA	12.17	NA	12.60	NA	12.10	NA	13.90	NA	17.70
Conductivity	NA	NA	3.619	NA	2.920	NA	4.982	NA	13.650	NA	4.050	NA	7.426	NA	4.789	NA	7.209	NA	3.080	NA	4.030
Dissolved Oxygen	NA	NA	1.32	NA	2.45	NA	1.58	NA	0.48	NA	0.36	NA	1.18	NA	5.13	NA	1.17	NA	NS	NA	0.47
ORP	NA	NA	35.8	NA	39.2	NA	-41.8	NA	-402.4	NA	-25.1	NA	35.2	NA	24.8	NA	25.9	NA	-44.5	NA	-91.4

Notes: Standards obtained from IAC, Title 35, Chapter I, Part 620, Subpart D, Section 620.410 - Groundwater Quality Standards for Class I: Potable Resource Groundwater

All values are in mg/L (ppm) unless otherwise noted.

Temperature °C degrees Celsius
Conductivity ms/cm^c millisiemens/centimeters
Dissolved Oxygen mg/L milligrams/liter
Oxygen Reduction Potential (ORP) mV millivolts

DL - Detection limit
NA - Not Applicable
ND - Not Detected
NS - Not Sampled

^ - Instrument related QC outside limit.
F1- MS and/or MSD recovery exceeds control limits.
J- Estimated concentration. Less than RL but at or above MDL.

Table 2. Groundwater Analytical Results - Midwest Generation LLC, Joliet Station #29, Joliet, IL

Sample: MW-10	Date	8/1/2018		10/17/2018		2/5/2019		5/7/2019		8/6/2019		11/7/2019		2/12/2020		5/20/2020		7/30/2020		10/22/2020	
Parameter	Standards	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result
Antimony	0.006	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND
Arsenic	0.01	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND
Barium	2	0.0025	0.042	0.0025	0.04	0.0025	0.044	0.0025	0.05	0.0025	0.037	0.0025	0.033	0.0025	0.044	0.0025	0.045	0.0025	0.036	0.0025	0.04
Beryllium	0.004	0.001	ND	0.001	ND^	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND ^	0.001	ND	0.001	ND
Boron	2	0.05	0.27	0.05	0.6	0.05	0.25	0.05	0.49	0.05	0.35	0.05	0.29	0.05	0.29	0.05	0.7	0.05	0.24	0.05	0.29
Cadmium	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Chloride	200	10	240	10	170	10	210	10	410	10	200	10	130	10	180	10	250	2	170	10	230
Chromium	0.1	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Cobalt	1	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND
Copper	0.65	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	0.0029	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Cyanide	0.2	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.005	ND	0.01	ND
Fluoride	4	0.1	0.39	0.1	0.4	0.1	0.41	0.1	0.4	0.1	0.35	0.1	0.37	0.1	0.44	0.1	0.42	0.1	0.42	0.1	0.41
Iron	5	0.1	ND	0.1	ND	0.1	ND	0.1	0.44	0.1	ND	0.1	0.25	0.1	ND	0.1	1.8	0.1	ND	0.1	ND
Lead	0.0075	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Manganese	0.15	0.0025	ND	0.0025	0.0028	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.0029	0.0025	ND	0.0025	0.0034	0.0025	ND	0.0025	ND
Mercury	0.002	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND
Nickel	0.1	0.002	ND	0.002	0.0021	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	0.0023	0.002	ND	0.002	ND	0.002	ND
Nitrogen/Nitrate	10	0.1	1.7	0.1	0.96	0.1	1.3	0.1	2.4	0.1	ND	0.1	1.8	0.1	1.7	0.1	1.4	0.1	2.8	0.1	3.8
Nitrogen/Nitrate, Nitrite	NA	0.1	1.7	0.1	0.96	0.1	1.3	0.1	2.4	0.1	2.3	0.1	1.8	0.1	1.7	0.1	1.4	0.5	2.8	0.5	3.8
Nitrogen/Nitrite	NA	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Perchlorate	0.0049	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND
Selenium	0.05	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.0041	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.0035	0.0025	ND	0.0025	ND
Silver	0.05	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Sulfate	400	25	110	25	120	25	85	25	100	25	95	25	ND	25	110	25	170	25	88	15	94
Thallium	0.002	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Total Dissolved Solids	1,200	10	1000	10	750	10	910	10	1000	10	810	10	660	10	810	10	1000	30	720	30	850
Vanadium	0.049	0.005	ND	0.005	ND^	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Zinc	5	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Benzene	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
BETX	11.705	0.0025	0.0024	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
pH	6.5 - 9.0	NA	7.35	NA	7.30	NA	7.31	NA	7.17	NA	7.4	NA	7.4	NA	7.28	NA	6.9	NA	6.95	NA	7.11
Temperature	NA	NA	17.55	NA	14.62	NA	12.5	NA	11.8	NA	12.3	NA	11.89	NA	12.9	NA	12.5	NA	12.3	NA	12.7
Conductivity	NA	NA	1.147	NA	1.113	NA	1.39	NA	2.74	NA	1.45	NA	1.085	NA	1.133	NA	1.61	NA	1.405	NA	1.51
Dissolved Oxygen	NA	NA	7.00	NA	8.75	NA	5.60	NA	7.18	NA	5.45	NA	9.30	NA	7.73	NA	8.65	NA	7.68	NA	4.79
ORP	NA	NA	89.1	NA	34.6	NA	127.7	NA	-231.3	NA	167.5	NA	-12.2	NA	166.3	NA	133.9	NA	138.6	NA	172.5

Notes: Standards obtained from IAC, Title 35, Chapter I, Part 620, Subpart D, Section 620.410 - Groundwater Quality Standards for Class I: Potable Resource Groundwater

All values are in mg/L (ppm) unless otherwise noted.

Temperature	°C	degrees Celsius
Conductivity	ms/cm^{c}	millisiemens/centimeters
Dissolved Oxygen	mg/L	milligrams/liter
Oxygen Reduction Potential (ORP)	mV	millivolts

DL - Detection limit
NA - Not Applicable
ND - Not Detected
NS - Not Sampled

^ - Instrument related QC outside limit.
F1- MS and/or MSD recovery exceeds control limits.
J- Estimated concentration. Less than RL but at or above MDL.

Table 2. Groundwater Analytical Results - Midwest Generation LLC, Joliet Station #29, Joliet, IL

Sample: MW-11	Date	8/1/2018		10/17/2018		2/5/2019		5/7/2019		8/6/2019		11/7/2019		2/13/2020		5/20/2020		7/30/2020		10/22/2020	
Parameter	Standards	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result	DL	Result
Antimony	0.006	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND	0.003	ND
Arsenic	0.01	0.001	0.0012	0.001	0.0015	0.001	0.0013	0.001	0.0019	0.001	0.0011	0.001	ND	0.001	0.0014	0.001	0.0023	0.001	0.0011	0.001	ND
Barium	2	0.0025	0.046	0.0025	0.064	0.0025	0.063	0.0025	0.058	0.0025	0.051	0.0025	0.033	0.0025	0.065	0.0025	0.085	0.0025	0.051	0.0025	0.055
Beryllium	0.004	0.001	ND	0.001	ND^	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND ^	0.001	ND	0.001	ND
Boron	2	0.05	1.2 V	0.05	1.2	0.05	2.7	0.05	0.98	0.05	1.1	0.05	0.29	0.05	1.4	0.05	0.51	0.05	0.86	0.05	0.44
Cadmium	0.005	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Chloride	200	10	120	10	160	10	170	10	290	10	130	10	130	10	200	10	520	10	170	10	170
Chromium	0.1	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Cobalt	1	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND
Copper	0.65	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	0.0029	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Cyanide	0.2	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.005	ND	0.01	ND
Fluoride	4	0.1	0.29	0.1	0.27	0.1	0.27	0.1	0.34	0.1	0.24	0.1	0.37	0.1	0.3	0.1	0.34	0.1	0.3	0.1	0.28
Iron	5	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	ND	0.1	0.25	0.1	ND	0.1	0.23	0.1	ND	0.1	ND
Lead	0.0075	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Manganese	0.15	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	0.0029	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
Mercury	0.002	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND	0.0002	ND
Nickel	0.1	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Nitrogen/Nitrate	10	0.1	0.41	0.1	0.66	0.1	0.92	0.1	1.4	0.1	0.34	0.1	1.8	0.1	0.79	0.1	2	0.1	0.85	0.1	0.59
Nitrogen/Nitrate, Nitrite	NA	0.1	0.41	0.1	0.66	0.1	0.92	0.1	1.4	0.1	0.34	0.1	1.8	0.1	0.79	0.1	2	0.1	0.85	0.1	0.59
Nitrogen/Nitrite	NA	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND F1	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Perchlorate	0.0049	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND	0.004	ND
Selenium	0.05	0.0025	0.0032 F1	0.0025	0.0029	0.0025	0.0056	0.0025	0.0056	0.0025	0.003	0.0025	ND	0.0025	0.0029	0.0025	0.0039	0.0025	ND	0.0025	ND
Silver	0.05	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
Sulfate	400	25	84	50	93	50	91	50	81	50	78	50	ND	50	110	50	82	25	100	15	89
Thallium	0.002	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND	0.002	ND
Total Dissolved Solids	1,200	10	720	10	740	10	780	10	810	10	590	10	660	10	710	10	1400	30	670	30	710
Vanadium	0.049	0.005	ND	0.005	ND^	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND
Zinc	5	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND
Benzene	0.005	0.0005	0.0029	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND	0.0005	ND
BETX	11.705	0.0025	0.0106	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND	0.0025	ND
pH	6.5 - 9.0	NA	7.39	NA	7.37	NA	7.33	NA	7.45	NA	7.42	NA	7.4	NA	7.3	NA	7.12	NA	7.13	NA	7.11
Temperature	NA	NA	18.04	NA	14.41	NA	13.1	NA	10.9	NA	12.3	NA	11.89	NA	13.7	NA	12.2	NA	12.1	NA	12.7
Conductivity	NA	NA	0.965	NA	0.866	NA	1.212	NA	2.24	NA	1.05	NA	1.085	NA	1.138	NA	2.323	NA	1.332	NA	1.51
Dissolved Oxygen	NA	NA	5.84	NA	8.17	NA	7.00	NA	10.94	NA	7.00	NA	9.30	NA	8.76	NA	11.05	NA	9.19	NA	4.79
ORP	NA	NA	88.9	NA	30.5	NA	122.0	NA	-234.2	NA	163.4	NA	-12.2	NA	156.1	NA	139.8	NA	140.8	NA	172.5

Notes: Standards obtained from IAC, Title 35, Chapter I, Part 620, Subpart D, Section 620.410 - Groundwater Quality Standards for Class I: Potable Resource Groundwater

All values are in mg/L (ppm) unless otherwise noted.

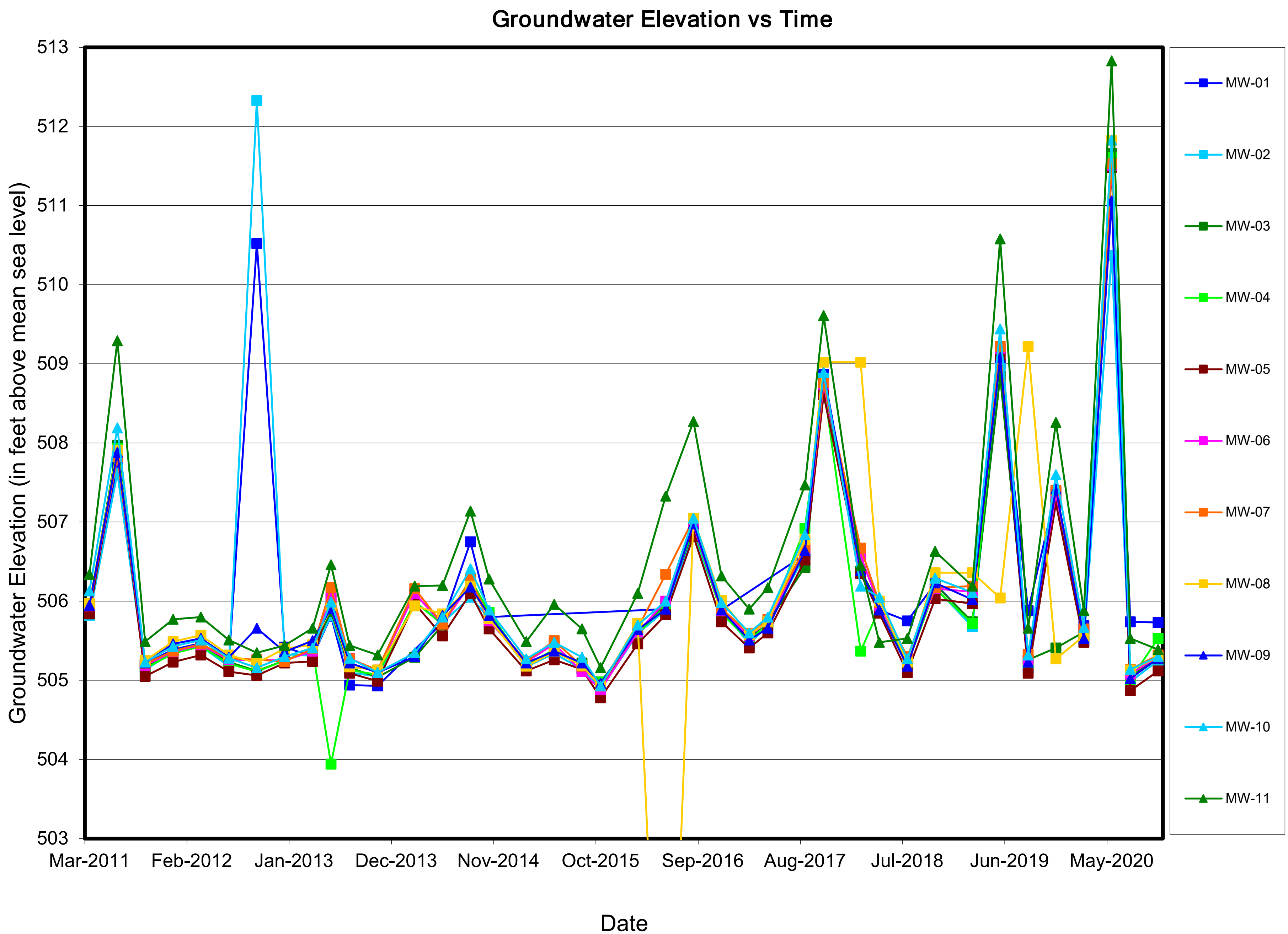
Temperature	°C	degrees Celsius
Conductivity	ms/cm^2	millisiemens/centimeters
Dissolved Oxygen	mg/L	milligrams/liter
Oxygen Reduction Potential (ORP)	mV	millivolts

DL - Detection limit
NA - Not Applicable
ND - Not Detected
NS - Not Sampled

^ - Instrument related QC outside limit.
F1- MS and/or MSD recovery exceeds control limits.
J- Estimated concentration. Less than RL but at or above MDL.

ATTACHMENT 1
Hydrograph

Midwest Generation Joliet Station #29, Joliet, IL



ATTACHMENT 2
Analytical Data Package

eurofins | Environment Testing America

ANALYTICAL REPORT

Eurofins TestAmerica, Chicago
2417 Bond Street
University Park, IL 60484
Tel: (708)534-5200

Laboratory Job ID: 500-189929-1
Client Project/Site: Joliet #29 Station Ash Ponds (CCA)

For:
KPRG and Associates, Inc.
14665 West Lisbon Road,
Suite 1A
Brookfield, Wisconsin 53005

Attn: Richard Gnat

Authorized for release by:
11/13/2020 3:31:31 PM

Diana Mockler, Project Manager I
(219)252-7570
Diana.Mockler@Eurofinset.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

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Certification Summary 52
Field Data Sheets 53

Job ID: 500-189929-1

Laboratory: Eurofins TestAmerica, Chicago

Narrative

Job Narrative
500-189929-1

Comments
No additional comments.

Receipt
The samples were received on 10/22/2020 6:20 PM; the samples arrived in good condition, and where required, properly preserved and on ice. The temperatures of the 3 coolers at receipt time were 5.4º C, 5.7º C and 5.8º C.

Receipt Exceptions

The following sample was submitted for analysis; however, it was not listed on the Chain-of-Custody (COC): Duplicate (500-189929-9) Added to COC and logged in.

GC/MS VOA
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Metals
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Field Service / Mobile Lab
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

General Chemistry
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Method Summary

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Method	Method Description	Protocol	Laboratory
8260B	Volatile Organic Compounds (GC/MS)	SW846	TAL CHI
314.0	Perchlorate (IC)	EPA	TAL SAC
6020A	Metals (ICP/MS)	SW846	TAL CHI
7470A	Mercury (CVAA)	SW846	TAL CHI
9014	Cyanide	SW846	TAL CHI
9038	Sulfate, Turbidimetric	SW846	TAL CHI
9251	Chloride	SW846	TAL CHI
Nitrate by calc	Nitrogen, Nitrate-Nitrite	SM	TAL CHI
SM 2540C	Solids, Total Dissolved (TDS)	SM	TAL CF
SM 4500 F C	Fluoride	SM	TAL CHI
SM 4500 NO2 B	Nitrogen, Nitrite	SM	TAL CHI
SM 4500 NO3 F	Nitrogen, Nitrate	SM	TAL CHI
5030B	Purge and Trap	SW846	TAL CHI
7470A	Preparation, Mercury	SW846	TAL CHI
9010B	Cyanide, Distillation	SW846	TAL CHI
Soluble Metals	Preparation, Soluble	None	TAL CHI

Protocol References:

EPA = US Environmental Protection Agency

None = None

SM = "Standard Methods For The Examination Of Water And Wastewater"

SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.

Laboratory References:

TAL CF = Eurofins TestAmerica, Cedar Falls, 3019 Venture Way, Cedar Falls, IA 50613, TEL (319)277-2401

TAL CHI = Eurofins TestAmerica, Chicago, 2417 Bond Street, University Park, IL 60484, TEL (708)534-5200

TAL SAC = Eurofins TestAmerica, Sacramento, 880 Riverside Parkway, West Sacramento, CA 95605, TEL (916)373-5600

Sample Summary

Client: KPRG and Associates, Inc.
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Job ID: 500-189929-1

Lab Sample ID	Client Sample ID	Matrix	Collected	Received	Asset ID
500-189929-1	MW-03	Water	10/22/20 10:18	10/22/20 18:20	
500-189929-2	MW-04	Water	10/22/20 11:11	10/22/20 18:20	
500-189929-3	MW-05	Water	10/22/20 12:46	10/22/20 18:20	
500-189929-4	MW-06	Water	10/22/20 15:12	10/22/20 18:20	
500-189929-5	MW-07	Water	10/22/20 14:14	10/22/20 18:20	
500-189929-6	MW-08	Water	10/22/20 09:23	10/22/20 18:20	
500-189929-7	MW-10	Water	10/22/20 12:05	10/22/20 18:20	
500-189929-8	MW-11	Water	10/22/20 13:31	10/22/20 18:20	
500-189929-9	Duplicate	Water	10/22/20 00:00	10/22/20 18:20	
500-189929-10	Trip Blank	Water	10/22/20 00:00	10/22/20 18:20	

Client Sample Results

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Client Sample ID: MW-03
Lab Sample ID: 500-189929-1
Date Collected: 10/22/20 10:18
Matrix: Water
Date Received: 10/22/20 18:20

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			10/31/20 02:41	1
Toluene	<0.00050		0.00050		mg/L			10/31/20 02:41	1
Ethylbenzene	<0.00050		0.00050		mg/L			10/31/20 02:41	1
Xylenes, Total	<0.0010		0.0010		mg/L			10/31/20 02:41	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*114*		*75 - 126*		*10/31/20 02:41*	*1*
Toluene-d8 (Surr)	*100*		*75 - 120*		*10/31/20 02:41*	*1*
4-Bromofluorobenzene (Surr)	*98*		*72 - 124*		*10/31/20 02:41*	*1*
Dibromofluoromethane	*115*		*75 - 120*		*10/31/20 02:41*	*1*

Method: 314.0 - Perchlorate (IC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			10/27/20 15:16	1

Method: 6020A - Metals (ICP/MS) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.0030		0.0030		mg/L		11/02/20 12:38	11/02/20 14:08	1
Arsenic	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:08	1
Barium	**0.10**		0.0025		mg/L		11/02/20 12:38	11/02/20 14:08	1
Beryllium	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:08	1
Boron	**0.29**		0.050		mg/L		11/02/20 12:38	11/02/20 14:08	1
Cadmium	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:08	1
Chromium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:08	1
Cobalt	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:08	1
Copper	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:08	1
Iron	<0.10		0.10		mg/L		11/02/20 12:38	11/02/20 14:08	1
Lead	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:08	1
Manganese	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:08	1
Nickel	**0.0031**		0.0020		mg/L		11/02/20 12:38	11/02/20 14:08	1
Selenium	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:08	1
Silver	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:08	1
Thallium	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:08	1
Vanadium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:08	1
Zinc	<0.020		0.020		mg/L		11/02/20 12:38	11/02/20 14:08	1

Method: 7470A - Mercury (CVAA) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		10/29/20 10:20	10/30/20 08:26	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**760**		30		mg/L			10/27/20 16:49	1

General Chemistry - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Cyanide, Total	<0.010		0.010		mg/L		11/05/20 10:35	11/05/20 13:25	1
Sulfate	**91**		15		mg/L			10/30/20 12:00	3
Chloride	**180**		10		mg/L			11/03/20 09:43	5
Nitrogen, Nitrate	**2.8**		0.10		mg/L			11/08/20 12:23	1
Fluoride	**0.44**		0.10		mg/L			11/04/20 14:02	1

Client Sample Results

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Client Sample ID: MW-03
Lab Sample ID: 500-189929-1
Date Collected: 10/22/20 10:18
Matrix: Water
Date Received: 10/22/20 18:20

General Chemistry - Dissolved (Continued)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrite	<0.020		0.020		mg/L			10/23/20 08:18	1
Nitrogen, Nitrate Nitrite	**2.8**		0.50		mg/L			11/05/20 13:22	5

Client Sample Results

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Client Sample ID: MW-04
Lab Sample ID: 500-189929-2
Date Collected: 10/22/20 11:11
Matrix: Water
Date Received: 10/22/20 18:20

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			10/31/20 03:09	1
Toluene	<0.00050		0.00050		mg/L			10/31/20 03:09	1
Ethylbenzene	<0.00050		0.00050		mg/L			10/31/20 03:09	1
Xylenes, Total	<0.0010		0.0010		mg/L			10/31/20 03:09	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*113*		*75 - 126*		*10/31/20 03:09*	*1*
Toluene-d8 (Surr)	*100*		*75 - 120*		*10/31/20 03:09*	*1*
4-Bromofluorobenzene (Surr)	*96*		*72 - 124*		*10/31/20 03:09*	*1*
Dibromofluoromethane	*112*		*75 - 120*		*10/31/20 03:09*	*1*

Method: 314.0 - Perchlorate (IC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			10/27/20 16:11	1

Method: 6020A - Metals (ICP/MS) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.0030		0.0030		mg/L		11/02/20 12:38	11/02/20 14:11	1
Arsenic	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:11	1
Barium	**0.090**		0.0025		mg/L		11/02/20 12:38	11/02/20 14:11	1
Beryllium	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:11	1
Boron	**0.29**		0.050		mg/L		11/02/20 12:38	11/02/20 14:11	1
Cadmium	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:11	1
Chromium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:11	1
Cobalt	**0.0041**		0.0010		mg/L		11/02/20 12:38	11/02/20 14:11	1
Copper	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:11	1
Iron	<0.10		0.10		mg/L		11/02/20 12:38	11/02/20 14:11	1
Lead	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:11	1
Manganese	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:11	1
Nickel	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:11	1
Selenium	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:11	1
Silver	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:11	1
Thallium	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:11	1
Vanadium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:11	1
Zinc	<0.020		0.020		mg/L		11/02/20 12:38	11/02/20 14:11	1

Method: 7470A - Mercury (CVAA) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		10/29/20 10:20	10/30/20 08:28	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**760**		30		mg/L			10/27/20 16:49	1

General Chemistry - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Cyanide, Total	<0.010		0.010		mg/L		11/05/20 10:35	11/05/20 13:27	1
Sulfate	**82**		15		mg/L			10/30/20 12:01	3
Chloride	**190**		10		mg/L			11/03/20 09:44	5
Nitrogen, Nitrate	**3.4**		0.10		mg/L			11/08/20 12:23	1
Fluoride	**0.49**		0.10		mg/L			11/04/20 14:13	1

Client Sample Results

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Client Sample ID: MW-04
Lab Sample ID: 500-189929-2
Date Collected: 10/22/20 11:11
Matrix: Water
Date Received: 10/22/20 18:20

General Chemistry - Dissolved (Continued)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrite	<0.020		0.020		mg/L			10/23/20 08:23	1
Nitrogen, Nitrate Nitrite	**3.4**		0.50		mg/L			11/05/20 13:14	5

Client Sample Results

Client: KPRG and Associates, Inc.
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Job ID: 500-189929-1

Client Sample ID: MW-05
Date Collected: 10/22/20 12:46
Date Received: 10/22/20 18:20

Lab Sample ID: 500-189929-3
Matrix: Water

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			10/31/20 03:38	1
Toluene	<0.00050		0.00050		mg/L			10/31/20 03:38	1
Ethylbenzene	<0.00050		0.00050		mg/L			10/31/20 03:38	1
Xylenes, Total	<0.0010		0.0010		mg/L			10/31/20 03:38	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*116*		*75 - 126*		*10/31/20 03:38*	*1*
Toluene-d8 (Surr)	*100*		*75 - 120*		*10/31/20 03:38*	*1*
4-Bromofluorobenzene (Surr)	*99*		*72 - 124*		*10/31/20 03:38*	*1*
Dibromofluoromethane	*115*		*75 - 120*		*10/31/20 03:38*	*1*

Method: 314.0 - Perchlorate (IC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			10/27/20 16:29	1

Method: 6020A - Metals (ICP/MS) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.0030		0.0030		mg/L		11/02/20 12:38	11/02/20 14:14	1
Arsenic	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:14	1
Barium	**0.070**		0.0025		mg/L		11/02/20 12:38	11/02/20 14:14	1
Beryllium	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:14	1
Boron	**0.47**		0.050		mg/L		11/02/20 12:38	11/02/20 14:14	1
Cadmium	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:14	1
Chromium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:14	1
Cobalt	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:14	1
Copper	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:14	1
Iron	<0.10		0.10		mg/L		11/02/20 12:38	11/02/20 14:14	1
Lead	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:14	1
Manganese	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:14	1
Nickel	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:14	1
Selenium	**0.0032**		0.0025		mg/L		11/02/20 12:38	11/02/20 14:14	1
Silver	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:14	1
Thallium	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:14	1
Vanadium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:14	1
Zinc	<0.020		0.020		mg/L		11/02/20 12:38	11/02/20 14:14	1

Method: 7470A - Mercury (CVAA) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		10/29/20 10:20	10/30/20 08:31	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**690**		30		mg/L			10/27/20 16:49	1

General Chemistry - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Cyanide, Total	<0.010		0.010		mg/L		11/05/20 10:35	11/05/20 13:28	1
Sulfate	**84**		15		mg/L			10/30/20 12:01	3
Chloride	**180**		10		mg/L			11/03/20 09:45	5
Nitrogen, Nitrate	**0.99**		0.10		mg/L			11/08/20 12:23	1
Fluoride	**0.38**		0.10		mg/L			11/04/20 14:16	1

Client Sample Results

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Client Sample ID: MW-05
Lab Sample ID: 500-189929-3
Date Collected: 10/22/20 12:46
Matrix: Water
Date Received: 10/22/20 18:20

General Chemistry - Dissolved (Continued)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrite	<0.020		0.020		mg/L			10/23/20 08:23	1
Nitrogen, Nitrate Nitrite	**0.99**		0.10		mg/L			11/04/20 11:07	1

Client Sample ID: MW-06 **Lab Sample ID: 500-189929-4**
Date Collected: 10/22/20 15:12 **Matrix: Water**
Date Received: 10/22/20 18:20

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			10/31/20 04:06	1
Toluene	<0.00050		0.00050		mg/L			10/31/20 04:06	1
Ethylbenzene	<0.00050		0.00050		mg/L			10/31/20 04:06	1
Xylenes, Total	<0.0010		0.0010		mg/L			10/31/20 04:06	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*114*		*75 - 126*		*10/31/20 04:06*	*1*
Toluene-d8 (Surr)	*100*		*75 - 120*		*10/31/20 04:06*	*1*
4-Bromofluorobenzene (Surr)	*95*		*72 - 124*		*10/31/20 04:06*	*1*
Dibromofluoromethane	*115*		*75 - 120*		*10/31/20 04:06*	*1*

Method: 314.0 - Perchlorate (IC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			10/27/20 16:48	1

Method: 6020A - Metals (ICP/MS) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.0030		0.0030		mg/L		11/02/20 12:38	11/02/20 14:18	1
Arsenic	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:18	1
Barium	**0.13**		0.0025		mg/L		11/02/20 12:38	11/02/20 14:18	1
Beryllium	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:18	1
Boron	**0.23**		0.050		mg/L		11/02/20 12:38	11/02/20 14:18	1
Cadmium	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:18	1
Chromium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:18	1
Cobalt	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:18	1
Copper	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:18	1
Iron	<0.10		0.10		mg/L		11/02/20 12:38	11/02/20 14:18	1
Lead	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:18	1
Manganese	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:18	1
Nickel	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:18	1
Selenium	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:18	1
Silver	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:18	1
Thallium	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:18	1
Vanadium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:18	1
Zinc	<0.020		0.020		mg/L		11/02/20 12:38	11/02/20 14:18	1

Method: 7470A - Mercury (CVAA) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		10/29/20 10:20	10/30/20 08:33	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**640**		30		mg/L			10/27/20 16:49	1

General Chemistry - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Cyanide, Total	<0.010		0.010		mg/L		11/05/20 10:35	11/05/20 13:30	1
Sulfate	**83**		15		mg/L			10/30/20 12:01	3
Chloride	**160**		10		mg/L			11/03/20 09:45	5
Nitrogen, Nitrate	**0.56**		0.10		mg/L			11/08/20 12:23	1
Fluoride	**0.31**		0.10		mg/L			11/04/20 14:18	1

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Client Sample Results

Client: KPRG and Associates, Inc.
Project/Site: Joliet #29 Station Ash Ponds (CCA)
Job ID: 500-189929-1

Client Sample ID: MW-06
Date Collected: 10/22/20 15:12
Date Received: 10/22/20 18:20

Lab Sample ID: 500-189929-4
Matrix: Water

General Chemistry - Dissolved (Continued)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrite	<0.020		0.020		mg/L			10/23/20 08:24	1
Nitrogen, Nitrate Nitrite	**0.56**		0.10		mg/L			11/04/20 11:09	1

Client Sample Results

Client: KPRG and Associates, Inc. Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Client Sample ID: MW-07 Lab Sample ID: 500-189929-5
Date Collected: 10/22/20 14:14 **Matrix: Water**
Date Received: 10/22/20 18:20

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			10/31/20 04:34	1
Toluene	<0.00050		0.00050		mg/L			10/31/20 04:34	1
Ethylbenzene	<0.00050		0.00050		mg/L			10/31/20 04:34	1
Xylenes, Total	<0.0010		0.0010		mg/L			10/31/20 04:34	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*115*		*75 - 126*		*10/31/20 04:34*	*1*
Toluene-d8 (Surr)	*100*		*75 - 120*		*10/31/20 04:34*	*1*
4-Bromofluorobenzene (Surr)	*98*		*72 - 124*		*10/31/20 04:34*	*1*
Dibromofluoromethane	*114*		*75 - 120*		*10/31/20 04:34*	*1*

Method: 314.0 - Perchlorate (IC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			10/27/20 17:06	1

Method: 6020A - Metals (ICP/MS) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.0030		0.0030		mg/L		11/02/20 12:38	11/02/20 14:42	1
Arsenic	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:42	1
Barium	**0.13**		0.0025		mg/L		11/02/20 12:38	11/02/20 14:42	1
Beryllium	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:42	1
Boron	**0.34**		0.050		mg/L		11/02/20 12:38	11/02/20 14:42	1
Cadmium	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:42	1
Chromium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:42	1
Cobalt	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:42	1
Copper	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:42	1
Iron	<0.10		0.10		mg/L		11/02/20 12:38	11/02/20 14:42	1
Lead	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:42	1
Manganese	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:42	1
Nickel	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:42	1
Selenium	**0.0025**		0.0025		mg/L		11/02/20 12:38	11/02/20 14:42	1
Silver	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:42	1
Thallium	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:42	1
Vanadium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:42	1
Zinc	<0.020		0.020		mg/L		11/02/20 12:38	11/02/20 14:42	1

Method: 7470A - Mercury (CVAA) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		10/29/20 10:20	10/30/20 08:35	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**680**		30		mg/L			10/27/20 16:49	1

General Chemistry - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Cyanide, Total	<0.010		0.010		mg/L		11/05/20 10:35	11/05/20 13:32	1
Sulfate	**97**		15		mg/L			10/30/20 12:03	3
Chloride	**150**		10		mg/L			11/03/20 09:47	5
Nitrogen, Nitrate	**0.93**		0.10		mg/L			11/08/20 12:23	1
Fluoride	**0.28**		0.10		mg/L			11/04/20 14:22	1

Eurofins TestAmerica, Chicago

Client Sample Results

Client: KPRG and Associates, Inc.
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Job ID: 500-189929-1

Client Sample ID: MW-07

Date Collected: 10/22/20 14:14
Date Received: 10/22/20 18:20

Lab Sample ID: 500-189929-5
Matrix: Water

General Chemistry - Dissolved (Continued)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrite	<0.020		0.020		mg/L			10/23/20 08:24	1
Nitrogen, Nitrate Nitrite	**0.93**		0.10		mg/L			11/04/20 11:11	1

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Client Sample Results

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Client Sample ID: MW-08
Lab Sample ID: 500-189929-6
Date Collected: 10/22/20 09:23
Matrix: Water
Date Received: 10/22/20 18:20

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			10/31/20 05:03	1
Toluene	<0.00050		0.00050		mg/L			10/31/20 05:03	1
Ethylbenzene	<0.00050		0.00050		mg/L			10/31/20 05:03	1
Xylenes, Total	<0.0010		0.0010		mg/L			10/31/20 05:03	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*115*		*75 - 126*		*10/31/20 05:03*	*1*
Toluene-d8 (Surr)	*99*		*75 - 120*		*10/31/20 05:03*	*1*
4-Bromofluorobenzene (Surr)	*97*		*72 - 124*		*10/31/20 05:03*	*1*
Dibromofluoromethane	*115*		*75 - 120*		*10/31/20 05:03*	*1*

Method: 314.0 - Perchlorate (IC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			10/28/20 16:16	1

Method: 6020A - Metals (ICP/MS) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.0030		0.0030		mg/L		11/02/20 12:38	11/02/20 14:45	1
Arsenic	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:45	1
Barium	**0.062**		0.0025		mg/L		11/02/20 12:38	11/02/20 14:45	1
Beryllium	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:45	1
Boron	**0.18**		0.050		mg/L		11/02/20 12:38	11/02/20 14:45	1
Cadmium	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:45	1
Chromium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:45	1
Cobalt	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:45	1
Copper	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:45	1
Iron	<0.10		0.10		mg/L		11/02/20 12:38	11/02/20 14:45	1
Lead	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:45	1
Manganese	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:45	1
Nickel	**0.0020**		0.0020		mg/L		11/02/20 12:38	11/02/20 14:45	1
Selenium	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:45	1
Silver	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:45	1
Thallium	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:45	1
Vanadium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:45	1
Zinc	<0.020		0.020		mg/L		11/02/20 12:38	11/02/20 14:45	1

Method: 7470A - Mercury (CVAA) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		10/29/20 10:20	10/30/20 08:37	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**800**		30		mg/L			10/27/20 16:49	1

General Chemistry - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Cyanide, Total	<0.010		0.010		mg/L		11/05/20 10:35	11/05/20 16:15	1
Sulfate	**140**		15		mg/L			10/30/20 12:03	3
Chloride	**180**		10		mg/L			11/03/20 09:48	5
Nitrogen, Nitrate	**1.4**		0.10		mg/L			11/08/20 12:23	1
Fluoride	**0.27**		0.10		mg/L			11/04/20 14:26	1

Client Sample Results

Client: KPRG and Associates, Inc.
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Job ID: 500-189929-1

Client Sample ID: MW-08
Date Collected: 10/22/20 09:23
Date Received: 10/22/20 18:20

Lab Sample ID: 500-189929-6
Matrix: Water

General Chemistry - Dissolved (Continued)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrite	<0.020		0.020		mg/L			10/23/20 08:25	1
Nitrogen, Nitrate Nitrite	**1.4**		0.10		mg/L			11/04/20 11:13	1

Client Sample Results

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Client Sample ID: MW-10
Lab Sample ID: 500-189929-7
Date Collected: 10/22/20 12:05
Matrix: Water
Date Received: 10/22/20 18:20

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			10/31/20 05:31	1
Toluene	<0.00050		0.00050		mg/L			10/31/20 05:31	1
Ethylbenzene	<0.00050		0.00050		mg/L			10/31/20 05:31	1
Xylenes, Total	<0.0010		0.0010		mg/L			10/31/20 05:31	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*116*		*75 - 126*		*10/31/20 05:31*	*1*
Toluene-d8 (Surr)	*100*		*75 - 120*		*10/31/20 05:31*	*1*
4-Bromofluorobenzene (Surr)	*100*		*72 - 124*		*10/31/20 05:31*	*1*
Dibromofluoromethane	*114*		*75 - 120*		*10/31/20 05:31*	*1*

Method: 314.0 - Perchlorate (IC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			10/28/20 17:11	1

Method: 6020A - Metals (ICP/MS) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.0030		0.0030		mg/L		11/02/20 12:38	11/02/20 14:49	1
Arsenic	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:49	1
Barium	**0.040**		0.0025		mg/L		11/02/20 12:38	11/02/20 14:49	1
Beryllium	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:49	1
Boron	**0.29**		0.050		mg/L		11/02/20 12:38	11/02/20 14:49	1
Cadmium	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:49	1
Chromium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:49	1
Cobalt	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:49	1
Copper	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:49	1
Iron	<0.10		0.10		mg/L		11/02/20 12:38	11/02/20 14:49	1
Lead	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:49	1
Manganese	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:49	1
Nickel	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:49	1
Selenium	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:49	1
Silver	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:49	1
Thallium	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:49	1
Vanadium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:49	1
Zinc	<0.020		0.020		mg/L		11/02/20 12:38	11/02/20 14:49	1

Method: 7470A - Mercury (CVAA) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		10/29/20 10:20	10/30/20 08:39	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**850**		30		mg/L			10/28/20 13:56	1

General Chemistry - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Cyanide, Total	<0.010		0.010		mg/L		11/05/20 10:35	11/05/20 16:17	1
Sulfate	**94**		15		mg/L			10/30/20 12:03	3
Chloride	**230**		10		mg/L			11/03/20 09:48	5
Nitrogen, Nitrate	**3.8**		0.10		mg/L			11/08/20 12:23	1
Fluoride	**0.41**		0.10		mg/L			11/04/20 14:38	1

Client Sample ID: MW-10 **Lab Sample ID: 500-189929-7**
Date Collected: 10/22/20 12:05 **Matrix: Water**
Date Received: 10/22/20 18:20

General Chemistry - Dissolved (Continued)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrite	<0.020		0.020		mg/L			10/23/20 08:25	1
Nitrogen, Nitrate Nitrite	**3.8**		0.50		mg/L			11/05/20 13:16	5

Client Sample Results

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Client Sample ID: MW-11
Lab Sample ID: 500-189929-8
Date Collected: 10/22/20 13:31
Matrix: Water
Date Received: 10/22/20 18:20

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			10/31/20 05:59	1
Toluene	<0.00050		0.00050		mg/L			10/31/20 05:59	1
Ethylbenzene	<0.00050		0.00050		mg/L			10/31/20 05:59	1
Xylenes, Total	<0.0010		0.0010		mg/L			10/31/20 05:59	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*115*		*75 - 126*		*10/31/20 05:59*	*1*
Toluene-d8 (Surr)	*100*		*75 - 120*		*10/31/20 05:59*	*1*
4-Bromofluorobenzene (Surr)	*97*		*72 - 124*		*10/31/20 05:59*	*1*
Dibromofluoromethane	*115*		*75 - 120*		*10/31/20 05:59*	*1*

Method: 314.0 - Perchlorate (IC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			10/28/20 17:29	1

Method: 6020A - Metals (ICP/MS) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.0030		0.0030		mg/L		11/02/20 12:38	11/02/20 14:52	1
Arsenic	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:52	1
Barium	**0.055**		0.0025		mg/L		11/02/20 12:38	11/02/20 14:52	1
Beryllium	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:52	1
Boron	**0.44**		0.050		mg/L		11/02/20 12:38	11/02/20 14:52	1
Cadmium	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:52	1
Chromium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:52	1
Cobalt	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:52	1
Copper	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:52	1
Iron	<0.10		0.10		mg/L		11/02/20 12:38	11/02/20 14:52	1
Lead	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:52	1
Manganese	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:52	1
Nickel	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:52	1
Selenium	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:52	1
Silver	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:52	1
Thallium	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:52	1
Vanadium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:52	1
Zinc	<0.020		0.020		mg/L		11/02/20 12:38	11/02/20 14:52	1

Method: 7470A - Mercury (CVAA) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		10/29/20 10:20	10/30/20 08:41	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**710**		30		mg/L			10/28/20 13:56	1

General Chemistry - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Cyanide, Total	<0.010		0.010		mg/L		11/05/20 10:35	11/05/20 16:19	1
Sulfate	**89**		15		mg/L			10/30/20 12:03	3
Chloride	**170**		10		mg/L			11/03/20 09:50	5
Nitrogen, Nitrate	**0.59**		0.10		mg/L			11/08/20 12:24	1
Fluoride	**0.28**		0.10		mg/L			11/04/20 14:41	1

Client Sample Results

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Client Sample ID: MW-11
Lab Sample ID: 500-189929-8
Date Collected: 10/22/20 13:31
Matrix: Water
Date Received: 10/22/20 18:20

General Chemistry - Dissolved (Continued)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrite	<0.020		0.020		mg/L			10/23/20 08:25	1
Nitrogen, Nitrate Nitrite	**0.59**		0.10		mg/L			11/13/20 09:36	1

Client Sample ID: Duplicate — Lab Sample ID: 500-189929-9

Date Collected: 10/22/20 00:00 — **Matrix: Water**
Date Received: 10/22/20 18:20

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			10/31/20 06:28	1
Toluene	<0.00050		0.00050		mg/L			10/31/20 06:28	1
Ethylbenzene	<0.00050		0.00050		mg/L			10/31/20 06:28	1
Xylenes, Total	<0.0010		0.0010		mg/L			10/31/20 06:28	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*117*		*75 - 126*		*10/31/20 06:28*	*1*
Toluene-d8 (Surr)	*100*		*75 - 120*		*10/31/20 06:28*	*1*
4-Bromofluorobenzene (Surr)	*99*		*72 - 124*		*10/31/20 06:28*	*1*
Dibromofluoromethane	*113*		*75 - 120*		*10/31/20 06:28*	*1*

Method: 314.0 - Perchlorate (IC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			10/28/20 17:48	1

Method: 6020A - Metals (ICP/MS) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.0030		0.0030		mg/L		11/02/20 12:38	11/02/20 14:56	1
Arsenic	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:56	1
Barium	**0.091**		0.0025		mg/L		11/02/20 12:38	11/02/20 14:56	1
Beryllium	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:56	1
Boron	**0.28**		0.050		mg/L		11/02/20 12:38	11/02/20 14:56	1
Cadmium	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:56	1
Chromium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:56	1
Cobalt	**0.0052**		0.0010		mg/L		11/02/20 12:38	11/02/20 14:56	1
Copper	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:56	1
Iron	<0.10		0.10		mg/L		11/02/20 12:38	11/02/20 14:56	1
Lead	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:56	1
Manganese	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:56	1
Nickel	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:56	1
Selenium	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:56	1
Silver	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:56	1
Thallium	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:56	1
Vanadium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:56	1
Zinc	<0.020		0.020		mg/L		11/02/20 12:38	11/02/20 14:56	1

Method: 7470A - Mercury (CVAA) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		10/29/20 10:20	10/30/20 08:54	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	**740**		30		mg/L			10/28/20 13:56	1

General Chemistry - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Cyanide, Total	<0.010		0.010		mg/L		11/05/20 10:35	11/05/20 16:20	1
Sulfate	**82**		15		mg/L			10/30/20 12:04	3
Chloride	**190**		10		mg/L			11/03/20 09:50	5
Nitrogen, Nitrate	**3.4**		0.10		mg/L			11/08/20 12:23	1
Fluoride	**0.48**		0.10		mg/L			11/04/20 14:45	1

Client Sample ID: Duplicate **Lab Sample ID: 500-189929-9**
Date Collected: 10/22/20 00:00 **Matrix: Water**
Date Received: 10/22/20 18:20

General Chemistry - Dissolved (Continued)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrite	<0.020		0.020		mg/L			10/23/20 08:27	1
Nitrogen, Nitrate Nitrite	**3.4**		0.50		mg/L			11/05/20 13:24	5

Client Sample Results

Client: KPRG and Associates, Inc. Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Client Sample ID: Trip Blank Lab Sample ID: 500-189929-10

Date Collected: 10/22/20 00:00 **Matrix: Water**
Date Received: 10/22/20 18:20

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			10/30/20 23:23	1
Toluene	<0.00050		0.00050		mg/L			10/30/20 23:23	1
Ethylbenzene	<0.00050		0.00050		mg/L			10/30/20 23:23	1
Xylenes, Total	<0.0010		0.0010		mg/L			10/30/20 23:23	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*115*		*75 - 126*		*10/30/20 23:23*	*1*
Toluene-d8 (Surr)	*101*		*75 - 120*		*10/30/20 23:23*	*1*
4-Bromofluorobenzene (Surr)	*98*		*72 - 124*		*10/30/20 23:23*	*1*
Dibromofluoromethane	*113*		*75 - 120*		*10/30/20 23:23*	*1*

Definitions/Glossary

Client: KPRG and Associates, Inc. Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Qualifiers

General Chemistry

Qualifier	Qualifier Description
4	MS, MSD: The analyte present in the original sample is greater than 4 times the matrix spike concentration; therefore, control limits are not applicable.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CFU	Colony Forming Unit
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MCL	EPA recommended "Maximum Contaminant Level"
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
MPN	Most Probable Number
MQL	Method Quantitation Limit
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
NEG	Negative / Absent
POS	Positive / Present
PQL	Practical Quantitation Limit
PRES	Presumptive
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)
TNTC	Too Numerous To Count

1 2 3 4 5 6 7 8 9 10 11 12 13 14

GC/MS VOA

Analysis Batch: 569473

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Total/NA	Water	8260B	
500-189929-2	MW-04	Total/NA	Water	8260B	
500-189929-3	MW-05	Total/NA	Water	8260B	
500-189929-4	MW-06	Total/NA	Water	8260B	
500-189929-5	MW-07	Total/NA	Water	8260B	
500-189929-6	MW-08	Total/NA	Water	8260B	
500-189929-7	MW-10	Total/NA	Water	8260B	
500-189929-8	MW-11	Total/NA	Water	8260B	
500-189929-9	Duplicate	Total/NA	Water	8260B	
500-189929-10	Trip Blank	Total/NA	Water	8260B	
MB 500-569473/6	Method Blank	Total/NA	Water	8260B	
LCS 500-569473/4	Lab Control Sample	Total/NA	Water	8260B	
500-189929-9 MS	Duplicate	Total/NA	Water	8260B	
500-189929-9 MSD	Duplicate	Total/NA	Water	8260B	

HPLC/IC

Analysis Batch: 425701

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Total/NA	Water	314.0	
500-189929-2	MW-04	Total/NA	Water	314.0	
500-189929-3	MW-05	Total/NA	Water	314.0	
500-189929-4	MW-06	Total/NA	Water	314.0	
500-189929-5	MW-07	Total/NA	Water	314.0	
MB 320-425701/5	Method Blank	Total/NA	Water	314.0	
LCS 320-425701/6	Lab Control Sample	Total/NA	Water	314.0	
MRL 320-425701/4	Lab Control Sample	Total/NA	Water	314.0	
500-189929-1 MS	MW-03	Total/NA	Water	314.0	
500-189929-1 MSD	MW-03	Total/NA	Water	314.0	

Analysis Batch: 426124

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-6	MW-08	Total/NA	Water	314.0	
500-189929-7	MW-10	Total/NA	Water	314.0	
500-189929-8	MW-11	Total/NA	Water	314.0	
500-189929-9	Duplicate	Total/NA	Water	314.0	
MB 320-426124/5	Method Blank	Total/NA	Water	314.0	
LCS 320-426124/6	Lab Control Sample	Total/NA	Water	314.0	
MRL 320-426124/4	Lab Control Sample	Total/NA	Water	314.0	
500-189929-6 MS	MW-08	Total/NA	Water	314.0	
500-189929-6 MSD	MW-08	Total/NA	Water	314.0	

Metals

Prep Batch: 569235

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Dissolved	Water	7470A	
500-189929-2	MW-04	Dissolved	Water	7470A	
500-189929-3	MW-05	Dissolved	Water	7470A	
500-189929-4	MW-06	Dissolved	Water	7470A	
500-189929-5	MW-07	Dissolved	Water	7470A	
500-189929-6	MW-08	Dissolved	Water	7470A	

Metals (Continued)

Prep Batch: 569235 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-7	MW-10	Dissolved	Water	7470A	
500-189929-8	MW-11	Dissolved	Water	7470A	
500-189929-9	Duplicate	Dissolved	Water	7470A	
MB 500-569235/12-A	Method Blank	Total/NA	Water	7470A	
LCS 500-569235/13-A	Lab Control Sample	Total/NA	Water	7470A	
500-189929-8 MS	MW-11	Dissolved	Water	7470A	
500-189929-8 MSD	MW-11	Dissolved	Water	7470A	
500-189929-8 DU	MW-11	Dissolved	Water	7470A	

Analysis Batch: 569446

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Dissolved	Water	7470A	569235
500-189929-2	MW-04	Dissolved	Water	7470A	569235
500-189929-3	MW-05	Dissolved	Water	7470A	569235
500-189929-4	MW-06	Dissolved	Water	7470A	569235
500-189929-5	MW-07	Dissolved	Water	7470A	569235
500-189929-6	MW-08	Dissolved	Water	7470A	569235
500-189929-7	MW-10	Dissolved	Water	7470A	569235
500-189929-8	MW-11	Dissolved	Water	7470A	569235
500-189929-9	Duplicate	Dissolved	Water	7470A	569235
MB 500-569235/12-A	Method Blank	Total/NA	Water	7470A	569235
LCS 500-569235/13-A	Lab Control Sample	Total/NA	Water	7470A	569235
500-189929-8 MS	MW-11	Dissolved	Water	7470A	569235
500-189929-8 MSD	MW-11	Dissolved	Water	7470A	569235
500-189929-8 DU	MW-11	Dissolved	Water	7470A	569235

Prep Batch: 569853

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Dissolved	Water	Soluble Metals	
500-189929-2	MW-04	Dissolved	Water	Soluble Metals	
500-189929-3	MW-05	Dissolved	Water	Soluble Metals	
500-189929-4	MW-06	Dissolved	Water	Soluble Metals	
500-189929-5	MW-07	Dissolved	Water	Soluble Metals	
500-189929-6	MW-08	Dissolved	Water	Soluble Metals	
500-189929-7	MW-10	Dissolved	Water	Soluble Metals	
500-189929-8	MW-11	Dissolved	Water	Soluble Metals	
500-189929-9	Duplicate	Dissolved	Water	Soluble Metals	
MB 500-569853/1-A	Method Blank	Soluble	Water	Soluble Metals	
LCS 500-569853/2-A	Lab Control Sample	Soluble	Water	Soluble Metals	
500-189929-4 MS	MW-06	Dissolved	Water	Soluble Metals	
500-189929-4 MSD	MW-06	Dissolved	Water	Soluble Metals	
500-189929-4 DU	MW-06	Dissolved	Water	Soluble Metals	

Analysis Batch: 570004

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Dissolved	Water	6020A	569853
500-189929-2	MW-04	Dissolved	Water	6020A	569853
500-189929-3	MW-05	Dissolved	Water	6020A	569853
500-189929-4	MW-06	Dissolved	Water	6020A	569853
500-189929-5	MW-07	Dissolved	Water	6020A	569853
500-189929-6	MW-08	Dissolved	Water	6020A	569853

Metals (Continued)

Analysis Batch: 570004 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-7	MW-10	Dissolved	Water	6020A	569853
500-189929-8	MW-11	Dissolved	Water	6020A	569853
500-189929-9	Duplicate	Dissolved	Water	6020A	569853
MB 500-569853/1-A	Method Blank	Soluble	Water	6020A	569853
LCS 500-569853/2-A	Lab Control Sample	Soluble	Water	6020A	569853
500-189929-4 MS	MW-06	Dissolved	Water	6020A	569853
500-189929-4 MSD	MW-06	Dissolved	Water	6020A	569853
500-189929-4 DU	MW-06	Dissolved	Water	6020A	569853

General Chemistry

Analysis Batch: 297244

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Total/NA	Water	SM 2540C	
500-189929-2	MW-04	Total/NA	Water	SM 2540C	
500-189929-3	MW-05	Total/NA	Water	SM 2540C	
500-189929-4	MW-06	Total/NA	Water	SM 2540C	
500-189929-5	MW-07	Total/NA	Water	SM 2540C	
500-189929-6	MW-08	Total/NA	Water	SM 2540C	
MB 310-297244/1	Method Blank	Total/NA	Water	SM 2540C	
LCS 310-297244/2	Lab Control Sample	Total/NA	Water	SM 2540C	

Analysis Batch: 297381

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-7	MW-10	Total/NA	Water	SM 2540C	
500-189929-8	MW-11	Total/NA	Water	SM 2540C	
500-189929-9	Duplicate	Total/NA	Water	SM 2540C	
MB 310-297381/1	Method Blank	Total/NA	Water	SM 2540C	
LCS 310-297381/2	Lab Control Sample	Total/NA	Water	SM 2540C	
500-189929-8 DU	MW-11	Total/NA	Water	SM 2540C	

Analysis Batch: 568249

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Dissolved	Water	SM 4500 NO2 B	
500-189929-2	MW-04	Dissolved	Water	SM 4500 NO2 B	
500-189929-3	MW-05	Dissolved	Water	SM 4500 NO2 B	
500-189929-4	MW-06	Dissolved	Water	SM 4500 NO2 B	
500-189929-5	MW-07	Dissolved	Water	SM 4500 NO2 B	
500-189929-6	MW-08	Dissolved	Water	SM 4500 NO2 B	
500-189929-7	MW-10	Dissolved	Water	SM 4500 NO2 B	
500-189929-8	MW-11	Dissolved	Water	SM 4500 NO2 B	
500-189929-9	Duplicate	Dissolved	Water	SM 4500 NO2 B	
MB 500-568249/9	Method Blank	Total/NA	Water	SM 4500 NO2 B	
LCS 500-568249/10	Lab Control Sample	Total/NA	Water	SM 4500 NO2 B	
500-189929-1 MS	MW-03	Dissolved	Water	SM 4500 NO2 B	
500-189929-1 MSD	MW-03	Dissolved	Water	SM 4500 NO2 B	

Analysis Batch: 569487

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Dissolved	Water	9038	
500-189929-2	MW-04	Dissolved	Water	9038	

General Chemistry (Continued)

Analysis Batch: 569487 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-3	MW-05	Dissolved	Water	9038	
500-189929-4	MW-06	Dissolved	Water	9038	
500-189929-5	MW-07	Dissolved	Water	9038	
500-189929-6	MW-08	Dissolved	Water	9038	
500-189929-7	MW-10	Dissolved	Water	9038	
500-189929-8	MW-11	Dissolved	Water	9038	
500-189929-9	Duplicate	Dissolved	Water	9038	
MB 500-569487/15	Method Blank	Total/NA	Water	9038	
LCS 500-569487/16	Lab Control Sample	Total/NA	Water	9038	

Analysis Batch: 570023

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Dissolved	Water	9251	
500-189929-2	MW-04	Dissolved	Water	9251	
500-189929-3	MW-05	Dissolved	Water	9251	
500-189929-4	MW-06	Dissolved	Water	9251	
500-189929-5	MW-07	Dissolved	Water	9251	
500-189929-6	MW-08	Dissolved	Water	9251	
500-189929-7	MW-10	Dissolved	Water	9251	
500-189929-8	MW-11	Dissolved	Water	9251	
500-189929-9	Duplicate	Dissolved	Water	9251	
MB 500-570023/12	Method Blank	Total/NA	Water	9251	
LCS 500-570023/13	Lab Control Sample	Total/NA	Water	9251	
500-189929-7 MS	MW-10	Dissolved	Water	9251	
500-189929-7 MSD	MW-10	Dissolved	Water	9251	

Analysis Batch: 570289

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-3	MW-05	Dissolved	Water	SM 4500 NO3 F	
500-189929-4	MW-06	Dissolved	Water	SM 4500 NO3 F	
500-189929-5	MW-07	Dissolved	Water	SM 4500 NO3 F	
500-189929-6	MW-08	Dissolved	Water	SM 4500 NO3 F	
MB 500-570289/203	Method Blank	Total/NA	Water	SM 4500 NO3 F	
LCS 500-570289/204	Lab Control Sample	Total/NA	Water	SM 4500 NO3 F	
LCSD 500-570289/205	Lab Control Sample Dup	Total/NA	Water	SM 4500 NO3 F	

Analysis Batch: 570407

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Dissolved	Water	SM 4500 F C	
500-189929-2	MW-04	Dissolved	Water	SM 4500 F C	
500-189929-3	MW-05	Dissolved	Water	SM 4500 F C	
500-189929-4	MW-06	Dissolved	Water	SM 4500 F C	
500-189929-5	MW-07	Dissolved	Water	SM 4500 F C	
500-189929-6	MW-08	Dissolved	Water	SM 4500 F C	
500-189929-7	MW-10	Dissolved	Water	SM 4500 F C	
500-189929-8	MW-11	Dissolved	Water	SM 4500 F C	
500-189929-9	Duplicate	Dissolved	Water	SM 4500 F C	
MB 500-570407/3	Method Blank	Total/NA	Water	SM 4500 F C	
LCS 500-570407/4	Lab Control Sample	Total/NA	Water	SM 4500 F C	
500-189929-1 MS	MW-03	Dissolved	Water	SM 4500 F C	
500-189929-1 MSD	MW-03	Dissolved	Water	SM 4500 F C	

QC Association Summary

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

General Chemistry

Prep Batch: 570453

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Dissolved	Water	9010B	
500-189929-2	MW-04	Dissolved	Water	9010B	
500-189929-3	MW-05	Dissolved	Water	9010B	
500-189929-4	MW-06	Dissolved	Water	9010B	
500-189929-5	MW-07	Dissolved	Water	9010B	
MB 500-570453/1-A	Method Blank	Total/NA	Water	9010B	
HLCS 500-570453/2-A	Lab Control Sample	Total/NA	Water	9010B	
LCS 500-570453/3-A	Lab Control Sample	Total/NA	Water	9010B	
LLCS 500-570453/4-A	Lab Control Sample	Total/NA	Water	9010B	

Prep Batch: 570455

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-6	MW-08	Dissolved	Water	9010B	
500-189929-7	MW-10	Dissolved	Water	9010B	
500-189929-8	MW-11	Dissolved	Water	9010B	
500-189929-9	Duplicate	Dissolved	Water	9010B	
MB 500-570455/1-A	Method Blank	Total/NA	Water	9010B	
HLCS 500-570455/2-A	Lab Control Sample	Total/NA	Water	9010B	
LCS 500-570455/3-A	Lab Control Sample	Total/NA	Water	9010B	
LLCS 500-570455/4-A	Lab Control Sample	Total/NA	Water	9010B	

Analysis Batch: 570507

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Dissolved	Water	SM 4500 NO3 F	
500-189929-2	MW-04	Dissolved	Water	SM 4500 NO3 F	
500-189929-7	MW-10	Dissolved	Water	SM 4500 NO3 F	
500-189929-9	Duplicate	Dissolved	Water	SM 4500 NO3 F	
MB 500-570507/46	Method Blank	Total/NA	Water	SM 4500 NO3 F	
LCS 500-570507/47	Lab Control Sample	Total/NA	Water	SM 4500 NO3 F	
LCSD 500-570507/76	Lab Control Sample Dup	Total/NA	Water	SM 4500 NO3 F	

Analysis Batch: 570534

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Dissolved	Water	9014	570453
500-189929-2	MW-04	Dissolved	Water	9014	570453
500-189929-3	MW-05	Dissolved	Water	9014	570453
500-189929-4	MW-06	Dissolved	Water	9014	570453
500-189929-5	MW-07	Dissolved	Water	9014	570453
MB 500-570453/1-A	Method Blank	Total/NA	Water	9014	570453
HLCS 500-570453/2-A	Lab Control Sample	Total/NA	Water	9014	570453
LCS 500-570453/3-A	Lab Control Sample	Total/NA	Water	9014	570453
LLCS 500-570453/4-A	Lab Control Sample	Total/NA	Water	9014	570453

Analysis Batch: 570535

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-6	MW-08	Dissolved	Water	9014	570455
500-189929-7	MW-10	Dissolved	Water	9014	570455
500-189929-8	MW-11	Dissolved	Water	9014	570455
500-189929-9	Duplicate	Dissolved	Water	9014	570455
MB 500-570455/1-A	Method Blank	Total/NA	Water	9014	570455
HLCS 500-570455/2-A	Lab Control Sample	Total/NA	Water	9014	570455

QC Association Summary

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

General Chemistry (Continued)

Analysis Batch: 570535 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
LCS 500-570455/3-A	Lab Control Sample	Total/NA	Water	9014	570455
LLCS 500-570455/4-A	Lab Control Sample	Total/NA	Water	9014	570455

Analysis Batch: 570885

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-1	MW-03	Dissolved	Water	Nitrate by calc	
500-189929-2	MW-04	Dissolved	Water	Nitrate by calc	
500-189929-3	MW-05	Dissolved	Water	Nitrate by calc	
500-189929-4	MW-06	Dissolved	Water	Nitrate by calc	
500-189929-5	MW-07	Dissolved	Water	Nitrate by calc	
500-189929-6	MW-08	Dissolved	Water	Nitrate by calc	
500-189929-7	MW-10	Dissolved	Water	Nitrate by calc	
500-189929-8	MW-11	Dissolved	Water	Nitrate by calc	
500-189929-9	Duplicate	Dissolved	Water	Nitrate by calc	

Analysis Batch: 572019

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-189929-8	MW-11	Dissolved	Water	SM 4500 NO3 F	
MB 500-572019/25	Method Blank	Total/NA	Water	SM 4500 NO3 F	
LCS 500-572019/26	Lab Control Sample	Total/NA	Water	SM 4500 NO3 F	

Surrogate Summary

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Method: 8260B - Volatile Organic Compounds (GC/MS)

Matrix: Water **Prep Type: Total/NA**

		Percent Surrogate Recovery (Acceptance Limits)			
		DCA	TOL	BFB	DBFM
Lab Sample ID	Client Sample ID	(75-126)	(75-120)	(72-124)	(75-120)
500-189929-1	MW-03	114	100	98	115
500-189929-2	MW-04	113	100	96	112
500-189929-3	MW-05	116	100	99	115
500-189929-4	MW-06	114	100	95	115
500-189929-5	MW-07	115	100	98	114
500-189929-6	MW-08	115	99	97	115
500-189929-7	MW-10	116	100	100	114
500-189929-8	MW-11	115	100	97	115
500-189929-9	Duplicate	117	100	99	113
500-189929-9 MS	Duplicate	113	100	98	112
500-189929-9 MSD	Duplicate	112	100	96	110
500-189929-10	Trip Blank	115	101	98	113
LCS 500-569473/4	Lab Control Sample	111	100	98	110
MB 500-569473/6	Method Blank	113	101	96	111

Surrogate Legend

DCA = 1,2-Dichloroethane-d4 (Surr)
TOL = Toluene-d8 (Surr)
BFB = 4-Bromofluorobenzene (Surr)
DBFM = Dibromofluoromethane

QC Sample Results

Client: KPRG and Associates, Inc. Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Method: 8260B - Volatile Organic Compounds (GC/MS)

Lab Sample ID: MB 500-569473/6 **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 569473

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			10/30/20 22:27	1
Toluene	<0.00050		0.00050		mg/L			10/30/20 22:27	1
Ethylbenzene	<0.00050		0.00050		mg/L			10/30/20 22:27	1
Xylenes, Total	<0.0010		0.0010		mg/L			10/30/20 22:27	1

Surrogate	*MB %Recovery*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*113*		*75 - 126*		*10/30/20 22:27*	*1*
Toluene-d8 (Surr)	*101*		*75 - 120*		*10/30/20 22:27*	*1*
4-Bromofluorobenzene (Surr)	*96*		*72 - 124*		*10/30/20 22:27*	*1*
Dibromofluoromethane	*111*		*75 - 120*		*10/30/20 22:27*	*1*

Lab Sample ID: LCS 500-569473/4 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 569473

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Benzene	0.0500	0.0583		mg/L		117	70 - 120
Toluene	0.0500	0.0549		mg/L		110	70 - 125
Ethylbenzene	0.0500	0.0535		mg/L		107	70 - 123
Xylenes, Total	0.100	0.109		mg/L		109	70 - 125

Surrogate	*LCS %Recovery*	*LCS Qualifier*	*Limits*
1,2-Dichloroethane-d4 (Surr)	*111*		*75 - 126*
Toluene-d8 (Surr)	*100*		*75 - 120*
4-Bromofluorobenzene (Surr)	*98*		*72 - 124*
Dibromofluoromethane	*110*		*75 - 120*

Lab Sample ID: 500-189929-9 MS **Client Sample ID: Duplicate**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 569473

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Benzene	<0.00050		0.0500	0.0575		mg/L		115	70 - 120
Toluene	<0.00050		0.0500	0.0534		mg/L		107	70 - 125
Ethylbenzene	<0.00050		0.0500	0.0529		mg/L		106	70 - 123
Xylenes, Total	<0.0010		0.100	0.106		mg/L		106	70 - 125

Surrogate	*MS %Recovery*	*MS Qualifier*	*Limits*
1,2-Dichloroethane-d4 (Surr)	*113*		*75 - 126*
Toluene-d8 (Surr)	*100*		*75 - 120*
4-Bromofluorobenzene (Surr)	*98*		*72 - 124*
Dibromofluoromethane	*112*		*75 - 120*

Method: 8260B - Volatile Organic Compounds (GC/MS) (Continued)

Lab Sample ID: 500-189929-9 MSD | **Client Sample ID: Duplicate**
Matrix: Water | **Prep Type: Total/NA**
Analysis Batch: 569473

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Benzene	<0.00050		0.0500	0.0582		mg/L		116	70 - 120	1	20
Toluene	<0.00050		0.0500	0.0551		mg/L		110	70 - 125	3	20
Ethylbenzene	<0.00050		0.0500	0.0537		mg/L		107	70 - 123	2	20
Xylenes, Total	<0.0010		0.100	0.109		mg/L		109	70 - 125	3	20

Surrogate	*MSD %Recovery*	*MSD Qualifier*	*Limits*
1,2-Dichloroethane-d4 (Surr)	*112*		*75 - 126*
Toluene-d8 (Surr)	*100*		*75 - 120*
4-Bromofluorobenzene (Surr)	*96*		*72 - 124*
Dibromofluoromethane	*110*		*75 - 120*

Method: 314.0 - Perchlorate (IC)

Lab Sample ID: MB 320-425701/5 | **Client Sample ID: Method Blank**
Matrix: Water | **Prep Type: Total/NA**
Analysis Batch: 425701

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			10/27/20 11:38	1

Lab Sample ID: LCS 320-425701/6 | **Client Sample ID: Lab Control Sample**
Matrix: Water | **Prep Type: Total/NA**
Analysis Batch: 425701

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Perchlorate	0.0500	0.0507		mg/L		101	85 - 115

Lab Sample ID: MRL 320-425701/4 | **Client Sample ID: Lab Control Sample**
Matrix: Water | **Prep Type: Total/NA**
Analysis Batch: 425701

Analyte	Spike Added	MRL Result	MRL Qualifier	Unit	D	%Rec	%Rec. Limits
Perchlorate	4.00	<4.0		ug/L		95	75 - 125

Lab Sample ID: 500-189929-1 MS | **Client Sample ID: MW-03**
Matrix: Water | **Prep Type: Total/NA**
Analysis Batch: 425701

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Perchlorate	<0.0040		0.0500	0.0472		mg/L		94	80 - 120

Lab Sample ID: 500-189929-1 MSD | **Client Sample ID: MW-03**
Matrix: Water | **Prep Type: Total/NA**
Analysis Batch: 425701

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Perchlorate	<0.0040		0.0500	0.0469		mg/L		94	80 - 120	0	20

Client: KPRG and Associates, Inc. Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Method: 314.0 - Perchlorate (IC) (Continued)

Lab Sample ID: MB 320-426124/5 **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 426124

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			10/28/20 11:32	1

Lab Sample ID: LCS 320-426124/6 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 426124

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Perchlorate	0.0500	0.0504		mg/L		101	85 - 115

Lab Sample ID: MRL 320-426124/4 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 426124

Analyte	Spike Added	MRL Result	MRL Qualifier	Unit	D	%Rec	%Rec. Limits
Perchlorate	4.00	4.09		ug/L		102	75 - 125

Lab Sample ID: 500-189929-6 MS **Client Sample ID: MW-08**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 426124

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Perchlorate	<0.0040		0.0500	0.0462		mg/L		92	80 - 120

Lab Sample ID: 500-189929-6 MSD **Client Sample ID: MW-08**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 426124

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Perchlorate	<0.0040		0.0500	0.0460		mg/L		92	80 - 120	1	20

Method: 6020A - Metals (ICP/MS)

Lab Sample ID: 500-189929-4 MS **Client Sample ID: MW-06**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 570004 **Prep Batch: 569853**

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Antimony	<0.0030		0.500	0.498		mg/L		100	75 - 125
Arsenic	<0.0010		0.100	0.106		mg/L		106	75 - 125
Barium	0.13		0.500	0.655		mg/L		105	75 - 125
Beryllium	<0.0010		0.0500	0.0480		mg/L		96	75 - 125
Boron	0.23		1.00	1.22		mg/L		99	75 - 125
Cadmium	<0.00050		0.0500	0.0516		mg/L		103	75 - 125
Chromium	<0.0050		0.200	0.199		mg/L		100	75 - 125
Cobalt	<0.0010		0.500	0.487		mg/L		97	75 - 125
Copper	<0.0020		0.250	0.257		mg/L		103	75 - 125
Iron	<0.10		1.00	1.01		mg/L		101	75 - 125
Lead	<0.00050		0.100	0.103		mg/L		103	75 - 125
Manganese	<0.0025		0.500	0.497		mg/L		99	75 - 125
Nickel	<0.0020		0.500	0.485		mg/L		97	75 - 125

Client: KPRG and Associates, Inc. Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Method: 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: 500-189929-4 MS **Client Sample ID: MW-06**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 570004 **Prep Batch: 569853**

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Selenium	<0.0025		0.100	0.113		mg/L		111	75 - 125
Silver	<0.00050		0.0500	0.0459		mg/L		92	75 - 125
Thallium	<0.0020		0.100	0.107		mg/L		107	75 - 125
Vanadium	<0.0050		0.500	0.499		mg/L		99	75 - 125
Zinc	<0.020		0.500	0.521		mg/L		104	75 - 125

Lab Sample ID: 500-189929-4 MSD **Client Sample ID: MW-06**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 570004 **Prep Batch: 569853**

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Antimony	<0.0030		0.500	0.508		mg/L		102	75 - 125	2	20
Arsenic	<0.0010		0.100	0.107		mg/L		107	75 - 125	1	20
Barium	0.13		0.500	0.655		mg/L		106	75 - 125	0	20
Beryllium	<0.0010		0.0500	0.0477		mg/L		95	75 - 125	1	20
Boron	0.23		1.00	1.24		mg/L		101	75 - 125	2	20
Cadmium	<0.00050		0.0500	0.0518		mg/L		104	75 - 125	0	20
Chromium	<0.0050		0.200	0.202		mg/L		101	75 - 125	2	20
Cobalt	<0.0010		0.500	0.491		mg/L		98	75 - 125	1	20
Copper	<0.0020		0.250	0.259		mg/L		104	75 - 125	1	20
Iron	<0.10		1.00	1.02		mg/L		102	75 - 125	1	20
Lead	<0.00050		0.100	0.105		mg/L		105	75 - 125	2	20
Manganese	<0.0025		0.500	0.498		mg/L		100	75 - 125	0	20
Nickel	<0.0020		0.500	0.495		mg/L		99	75 - 125	2	20
Selenium	<0.0025		0.100	0.113		mg/L		111	75 - 125	0	20
Silver	<0.00050		0.0500	0.0459		mg/L		92	75 - 125	0	20
Thallium	<0.0020		0.100	0.108		mg/L		108	75 - 125	1	20
Vanadium	<0.0050		0.500	0.494		mg/L		98	75 - 125	1	20
Zinc	<0.020		0.500	0.516		mg/L		103	75 - 125	1	20

Lab Sample ID: 500-189929-4 DU **Client Sample ID: MW-06**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 570004 **Prep Batch: 569853**

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Antimony	<0.0030		<0.0030		mg/L		NC	20
Arsenic	<0.0010		<0.0010		mg/L		NC	20
Barium	0.13		0.131		mg/L		3	20
Beryllium	<0.0010		<0.0010		mg/L		NC	20
Boron	0.23		0.233		mg/L		2	20
Cadmium	<0.00050		<0.00050		mg/L		NC	20
Chromium	<0.0050		<0.0050		mg/L		NC	20
Cobalt	<0.0010		<0.0010		mg/L		NC	20
Copper	<0.0020		<0.0020		mg/L		NC	20
Iron	<0.10		<0.10		mg/L		NC	20
Lead	<0.00050		<0.00050		mg/L		NC	20
Manganese	<0.0025		<0.0025		mg/L		NC	20
Nickel	<0.0020		<0.0020		mg/L		NC	20
Selenium	<0.0025		0.00292		mg/L		NC	20

Client: KPRG and Associates, Inc. Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Method: 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: 500-189929-4 DU **Client Sample ID: MW-06**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 570004 **Prep Batch: 569853**

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Silver	<0.00050		<0.00050		mg/L		NC	20
Thallium	<0.0020		<0.0020		mg/L		NC	20
Vanadium	<0.0050		<0.0050		mg/L		NC	20
Zinc	<0.020		<0.020		mg/L		NC	20

Lab Sample ID: MB 500-569853/1-A **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Soluble**
Analysis Batch: 570004 **Prep Batch: 569853**

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Antimony	<0.0030		0.0030		mg/L		11/02/20 12:38	11/02/20 14:01	1
Arsenic	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:01	1
Barium	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:01	1
Beryllium	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:01	1
Boron	<0.050		0.050		mg/L		11/02/20 12:38	11/02/20 14:01	1
Cadmium	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:01	1
Chromium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:01	1
Cobalt	<0.0010		0.0010		mg/L		11/02/20 12:38	11/02/20 14:01	1
Copper	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:01	1
Iron	<0.10		0.10		mg/L		11/02/20 12:38	11/02/20 14:01	1
Lead	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:01	1
Manganese	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:01	1
Nickel	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:01	1
Selenium	<0.0025		0.0025		mg/L		11/02/20 12:38	11/02/20 14:01	1
Silver	<0.00050		0.00050		mg/L		11/02/20 12:38	11/02/20 14:01	1
Thallium	<0.0020		0.0020		mg/L		11/02/20 12:38	11/02/20 14:01	1
Vanadium	<0.0050		0.0050		mg/L		11/02/20 12:38	11/02/20 14:01	1
Zinc	<0.020		0.020		mg/L		11/02/20 12:38	11/02/20 14:01	1

Lab Sample ID: LCS 500-569853/2-A **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Soluble**
Analysis Batch: 570004 **Prep Batch: 569853**

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Antimony	0.500	0.464		mg/L		93	80 - 120
Arsenic	0.100	0.0971		mg/L		97	80 - 120
Barium	0.500	0.485		mg/L		97	80 - 120
Beryllium	0.0500	0.0463		mg/L		93	80 - 120
Boron	1.00	1.01		mg/L		101	80 - 120
Cadmium	0.0500	0.0502		mg/L		100	80 - 120
Chromium	0.200	0.201		mg/L		101	80 - 120
Cobalt	0.500	0.491		mg/L		98	80 - 120
Copper	0.250	0.247		mg/L		99	80 - 120
Iron	1.00	0.986		mg/L		99	80 - 120
Lead	0.100	0.0987		mg/L		99	80 - 120
Manganese	0.500	0.498		mg/L		100	80 - 120
Nickel	0.500	0.486		mg/L		97	80 - 120
Selenium	0.100	0.0969		mg/L		97	80 - 120
Silver	0.0500	0.0494		mg/L		99	80 - 120

QC Sample Results

Method: 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: LCS 500-569853/2-A **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Soluble**
Analysis Batch: 570004 **Prep Batch: 569853**

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Thallium	0.100	0.100		mg/L		100	80 - 120
Vanadium	0.500	0.482		mg/L		96	80 - 120
Zinc	0.500	0.498		mg/L		100	80 - 120

Method: 7470A - Mercury (CVAA)

Lab Sample ID: MB 500-569235/12-A **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 569446 **Prep Batch: 569235**

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		10/29/20 10:20	10/30/20 08:22	1

Lab Sample ID: LCS 500-569235/13-A **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 569446 **Prep Batch: 569235**

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Mercury	0.00200	0.00210		mg/L		105	80 - 120

Lab Sample ID: 500-189929-8 MS **Client Sample ID: MW-11**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 569446 **Prep Batch: 569235**

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Mercury	<0.00020		0.00100	0.000958		mg/L		96	75 - 125

Lab Sample ID: 500-189929-8 MSD **Client Sample ID: MW-11**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 569446 **Prep Batch: 569235**

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Mercury	<0.00020		0.00100	0.000940		mg/L		94	75 - 125	2	20

Lab Sample ID: 500-189929-8 DU **Client Sample ID: MW-11**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 569446 **Prep Batch: 569235**

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Mercury	<0.00020		<0.00020		mg/L		NC	20

Method: 9014 - Cyanide

Lab Sample ID: MB 500-570453/1-A **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570534 **Prep Batch: 570453**

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Cyanide, Total	<0.010		0.010		mg/L		11/05/20 10:35	11/05/20 12:42	1

Method: 9014 - Cyanide (Continued)

Lab Sample ID: HLCS 500-570453/2-A **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570534 **Prep Batch: 570453**

Analyte	Spike Added	HLCS Result	HLCS Qualifier	Unit	D	%Rec	%Rec. Limits
Cyanide, Total	0.500	0.473		mg/L		95	90 - 110

Lab Sample ID: LCS 500-570453/3-A **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570534 **Prep Batch: 570453**

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Cyanide, Total	0.100	0.111		mg/L		111	85 - 115

Lab Sample ID: LLCS 500-570453/4-A **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570534 **Prep Batch: 570453**

Analyte	Spike Added	LLCS Result	LLCS Qualifier	Unit	D	%Rec	%Rec. Limits
Cyanide, Total	0.0500	0.0445		mg/L		89	75 - 125

Lab Sample ID: MB 500-570455/1-A **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570535 **Prep Batch: 570455**

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Cyanide, Total	<0.010		0.010		mg/L		11/05/20 10:35	11/05/20 15:32	1

Lab Sample ID: HLCS 500-570455/2-A **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570535 **Prep Batch: 570455**

Analyte	Spike Added	HLCS Result	HLCS Qualifier	Unit	D	%Rec	%Rec. Limits
Cyanide, Total	0.500	0.458		mg/L		92	90 - 110

Lab Sample ID: LCS 500-570455/3-A **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570535 **Prep Batch: 570455**

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Cyanide, Total	0.100	0.105		mg/L		105	85 - 115

Lab Sample ID: LLCS 500-570455/4-A **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570535 **Prep Batch: 570455**

Analyte	Spike Added	LLCS Result	LLCS Qualifier	Unit	D	%Rec	%Rec. Limits
Cyanide, Total	0.0500	0.0521		mg/L		104	75 - 125

QC Sample Results

Client: KPRG and Associates, Inc. Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Method: 9038 - Sulfate, Turbidimetric

Lab Sample ID: MB 500-569487/15 **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 569487

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Sulfate	<5.0		5.0		mg/L			10/30/20 11:59	1

Lab Sample ID: LCS 500-569487/16 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 569487

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Sulfate	20.0	19.3		mg/L		96	80 - 120

Method: 9251 - Chloride

Lab Sample ID: MB 500-570023/12 **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570023

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chloride	<2.0		2.0		mg/L			11/03/20 08:56	1

Lab Sample ID: LCS 500-570023/13 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570023

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Chloride	50.0	49.5		mg/L		99	80 - 120

Lab Sample ID: 500-189929-7 MS **Client Sample ID: MW-10**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 570023

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Chloride	230		50.0	268	4	mg/L		81	75 - 125

Lab Sample ID: 500-189929-7 MSD **Client Sample ID: MW-10**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 570023

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Chloride	230		50.0	264	4	mg/L		73	75 - 125	2	20

Method: SM 2540C - Solids, Total Dissolved (TDS)

Lab Sample ID: MB 310-297244/1 **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 297244

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	<30		30		mg/L			10/27/20 16:49	1

Client: KPRG and Associates, Inc. Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Method: SM 2540C - Solids, Total Dissolved (TDS) (Continued)

Lab Sample ID: LCS 310-297244/2 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 297244

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Total Dissolved Solids	1000	946		mg/L		95	90 - 110

Lab Sample ID: MB 310-297381/1 **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 297381

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	<30		30		mg/L			10/28/20 13:56	1

Lab Sample ID: LCS 310-297381/2 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 297381

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Total Dissolved Solids	1000	982		mg/L		98	90 - 110

Lab Sample ID: 500-189929-8 DU **Client Sample ID: MW-11**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 297381

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Total Dissolved Solids	710		712		mg/L		0.8	24

Method: SM 4500 F C - Fluoride

Lab Sample ID: MB 500-570407/3 **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570407

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	<0.10		0.10		mg/L			11/04/20 13:53	1

Lab Sample ID: LCS 500-570407/4 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570407

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Fluoride	10.0	10.9		mg/L		109	80 - 120

Lab Sample ID: 500-189929-1 MS **Client Sample ID: MW-03**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 570407

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Fluoride	0.44		5.00	6.02		mg/L		112	75 - 125

Method: SM 4500 F C - Fluoride (Continued)

Lab Sample ID: 500-189929-1 MSD — **Client Sample ID: MW-03**
Matrix: Water — **Prep Type: Dissolved**
Analysis Batch: 570407

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Fluoride	0.44		5.00	6.05		mg/L		112	75 - 125	0	20

Method: SM 4500 NO2 B - Nitrogen, Nitrite

Lab Sample ID: MB 500-568249/9 — **Client Sample ID: Method Blank**
Matrix: Water — **Prep Type: Total/NA**
Analysis Batch: 568249

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrite	<0.020		0.020		mg/L			10/23/20 08:17	1

Lab Sample ID: LCS 500-568249/10 — **Client Sample ID: Lab Control Sample**
Matrix: Water — **Prep Type: Total/NA**
Analysis Batch: 568249

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Nitrogen, Nitrite	0.100	0.0989		mg/L		99	80 - 120

Lab Sample ID: 500-189929-1 MS — **Client Sample ID: MW-03**
Matrix: Water — **Prep Type: Dissolved**
Analysis Batch: 568249

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Nitrogen, Nitrite	<0.020		0.100	0.0910		mg/L		91	75 - 125

Lab Sample ID: 500-189929-1 MSD — **Client Sample ID: MW-03**
Matrix: Water — **Prep Type: Dissolved**
Analysis Batch: 568249

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Nitrogen, Nitrite	<0.020		0.100	0.0915		mg/L		92	75 - 125	1	20

Method: SM 4500 NO3 F - Nitrogen, Nitrate

Lab Sample ID: MB 500-570289/203 — **Client Sample ID: Method Blank**
Matrix: Water — **Prep Type: Total/NA**
Analysis Batch: 570289

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrate Nitrite	<0.10		0.10		mg/L			11/04/20 10:31	1

Lab Sample ID: LCS 500-570289/204 — **Client Sample ID: Lab Control Sample**
Matrix: Water — **Prep Type: Total/NA**
Analysis Batch: 570289

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Nitrogen, Nitrate Nitrite	1.00	1.03		mg/L		103	80 - 120

Method: SM 4500 NO3 F - Nitrogen, Nitrate (Continued)

Lab Sample ID: LCSD 500-570289/205 **Client Sample ID: Lab Control Sample Dup**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570289

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Nitrogen, Nitrate Nitrite	1.00	1.10		mg/L		110	80 - 120	2	20

Lab Sample ID: MB 500-570507/46 **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570507

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrate Nitrite	<0.10		0.10		mg/L			11/05/20 13:05	1

Lab Sample ID: LCS 500-570507/47 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570507

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Nitrogen, Nitrate Nitrite	1.00	1.12		mg/L		112	80 - 120

Lab Sample ID: LCSD 500-570507/76 **Client Sample ID: Lab Control Sample Dup**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 570507

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Nitrogen, Nitrate Nitrite	1.00	1.16		mg/L		116	80 - 120	5	20

Lab Sample ID: MB 500-572019/25 **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 572019

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrate Nitrite	<0.10		0.10		mg/L			11/13/20 09:12	1

Lab Sample ID: LCS 500-572019/26 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 572019

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Nitrogen, Nitrate Nitrite	1.00	0.978		mg/L		98	80 - 120

Eurofins TestAmerica, Chicago
2417 Bond Street
University Park, IL 60484
Phone: 708-534-5200 Fax: 708-534-5211

Chain of Custody Record

eurofins | Environment Testing America

Client Information	Sampler:	Lab PM: Mockler, Diana J	Carrier Tracking No(s):	COC No: 500-85987-38853.1
Client Contact: Erin Bulson	Phone:	E-Mail: Diana.Mockler@Eurofinset.com		Page: Page 1 of 2
Company: KPRG and Associates, Inc.		Analysis Requested		Job #: 500-189929
Address: 14665 West Lisbon Road, Suite 1A	Due Date Requested:			Preservation Codes:
City: Brookfield	TAT Requested (days):			
State, Zip: WI, 53005				
Phone: 815-671-2258(Tel)	PO #: 4500051862			
Email: erinb@kprginc.com	WO #:			
Project Name: Midwest Generation Joliet Groundwater	Project #: 50005078			Other:
Site:	SSOW#:			

500-189929 COC

Preservation Codes:
A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA
M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)

Sample Identification	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	6020, 7470A	2540C, 4500_F_C, 9251	SM4500_NO2_B - Nitrogen, Nitrite	9014 - Total Cyanide	SM4500_NO3_F - Nitrogen, Nitrate Nitrite	8260B - BTEX	314.0 - Perchlorate	9056A - Sulfate	Total Number of containers	Special Instructions/Note:
				Preservation Code:			D	N	N	B	S	A	N	N		
MW-01	[crossed out]	[crossed out]		Water												
MW-02	[crossed out]	[crossed out]		Water												
1 MW-03	10-22	1018		Water												
2 MW-04		1111		Water												
3 MW-05		1246		Water												
4 MW-06		1512		Water												
5 MW-07		1414		Water												
6 MW-08	10-22	0933		Water												
MW-09	[crossed out]	[crossed out]		Water												
7 MW-10	10-22	1205		Water												
8 MW-11	10-22	1331		Water												

Possible Hazard Identification
☐ *Non-Hazard* ☐ *Flammable* ☐ *Skin Irritant* ☐ *Poison B* ☐ *Unknown* ☐ *Radiological*

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For* ______ *Months*

Deliverable Requested: I, II, III, IV, Other (specify)

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:	Time:	Method of Shipment:

Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
[signature]	10-22 1820		Aaron Kimbrough	10/22/20 18:20	TAI

Custody Seals Intact: Δ Yes Δ No | Custody Seal No.: | Cooler Temperature(s) °C and Other Remarks: 5.8, 5.4, 5.7

* All samples taken 10-22-20

Ver: 01/16/2019 11/13/2020

Eurofins TestAmerica, Chicago
2417 Bond Street
University Park, IL 60484
Phone: 708-534-5200 Fax: 708-534-5211

eurofins Environment Testing America

Chain of Custody Record

Client Information	Sampler:	Lab PM: Mockler, Diana J	Carrier Tracking No(s):	COC No: 500-85987-38853.2
Client Contact: Erin Bulson	Phone:	E-Mail: Diana.Mockler@Eurofinset.com		Page: Page 2 of 2
Company: KPRG and Associates, Inc.		**Analysis Requested**		Job #: 500-189929
Address: 14665 West Lisbon Road, Suite 1A	**Due Date Requested:**			**Preservation Codes:**
City: Brookfield	**TAT Requested (days):**			
State, Zip: WI, 53005				
Phone: 815-671-2258(Tel)	PO #: 4500051862			
Email: erinb@kprginc.com	WO #:			
Project Name: Midwest Generation Joliet Groundwater	Project #: 50005078			
Site	SSOW#:			**Other:**

Preservation Codes:
A - HCL; B - NaOH; C - Zn Acetate; D - Nitric Acid; E - NaHSO4; F - MeOH; G - Amchlor; H - Ascorbic Acid; I - Ice; J - DI Water; K - EDTA; L - EDA
M - Hexane; N - None; O - AsNaO2; P - Na2O4S; Q - Na2SO3; R - Na2S2O3; S - H2SO4; T - TSP Dodecahydrate; U - Acetone; V - MCAA; W - pH 4-5; Z - other (specify)

Sample Identification	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	6020, 7470A	2540C, 4500_F_C, 9251	SM4500_NO2_B - Nitrogen, Nitrite	9014 - Total Cyanide	SM4500_NO3_F - Nitrogen, Nitrate Nitrite	8260B - BTEX	314.0 - Perchlorate	9056A - Sulfate	Total Number of containers	Special Instructions/Note:
				Preservation Code:	X	X	D	N	N	B	S	A	N	N	X	
9 Duplicate				Water												Added by TA
10 Trip Blank				Water												
				Water												
				Water												

Possible Hazard Identification
☐ *Non-Hazard* ☐ *Flammable* ☐ *Skin Irritant* ☐ *Poison B* ☐ *Unknown* ☐ *Radiological*

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For ________ Months*

Deliverable Requested: I, II, III, IV, Other (specify)

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:	Time:	Method of Shipment:

Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
[signature]	10-22 1820		Aaron Kimbrough	10/22/20 18:20	TAI

Custody Seals Intact: Δ Yes Δ No	Custody Seal No.:	Cooler Temperature(s) °C and Other Remarks:

Eurofins TestAmerica, Chicago
2417 Bond Street
University Park, IL 60484
Phone: 708-534-5200 Fax: 708-534-5211

Chain of Custody Record

eurofins | Environment Testing America

Client Information (Sub Contract Lab)	Sampler:	Lab PM: Mockler, Diana J	Carrier Tracking No(s):	COC No: 500-141335.1
Client Contact: Shipping/Receiving	Phone:	E-Mail: Diana.Mockler@Eurofinset.com	State of Origin: Illinois	Page: Page 1 of 1
Company: TestAmerica Laboratories, Inc		Accreditations Required (See note): NELAP - Illinois		Job #: 500-189929-1
Address: 3019 Venture Way,	Due Date Requested: 11/4/2020			
City: Cedar Falls	TAT Requested (days):			
State, Zip: IA, 50613				
Phone: 319-277-2401(Tel) 319-277-2425(Fax)	PO #:			
Email:	WO #:			
Project Name: Joliet #29 Station Ash Ponds (CCA)	Project #: 50005078			
Site:	SSOW#:			

Analysis Requested

Preservation Codes:
A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA
M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
Other:

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	2540C_Calcd/ Total Dissolved Solids	Total Number of containers	Special Instructions/Note:
				Preservation Code:					
MW-03 (500-189929-1)	10/22/20	10:18 Central		Water			X	1	
MW-04 (500-189929-2)	10/22/20	11:11 Central		Water			X	1	
MW-05 (500-189929-3)	10/22/20	12:46 Central		Water			X	1	
MW-06 (500-189929-4)	10/22/20	15:12 Central		Water			X	1	
MW-07 (500-189929-5)	10/22/20	14:14 Central		Water			X	1	
MW-08 (500-189929-6)	10/22/20	09:23 Central		Water			X	1	
MW-10 (500-189929-7)	10/22/20	12:05 Central		Water			X	1	
MW-11 (500-189929-8)	10/22/20	13:31 Central		Water			X	1	
Duplicate (500-189929-9)	10/22/20	Central		Water			X	1	

Note: Since laboratory accreditations are subject to change, Eurofins TestAmerica places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody. If the laboratory does not currently maintain accreditation in the State of Origin listed above for analysis/tests/matrix being analyzed, the samples must be shipped back to the Eurofins TestAmerica laboratory or other instructions will be provided. Any changes to accreditation status should be brought to Eurofins TestAmerica attention immediately. If all requested accreditations are current to date, return the signed Chain of Custody attesting to said complicance to Eurofins TestAmerica.

Possible Hazard Identification *Unconfirmed*	*Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)* ☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For ____ Months*
Deliverable Requested: I, II, III, IV, Other (specify) Primary Deliverable Rank: 2	Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:		Time:	Method of Shipment:	
Relinquished by: [signature]	Date/Time: 10/23/20 1700	Company: TA	Received by: [signature]	Date/Time: 10-24-20 0950	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Custody Seals Intact: Δ Yes Δ No	Custody Seal No.:		Cooler Temperature(s) °C and Other Remarks:		

Ver: 01/16/2019

eurofins | Environment Testing
TestAmerica

Place COC scanning label here

Cooler/Sample Receipt and Temperature Log Form

Client Information

Client: ETA Chicago

City/State: CITY University Park STATE IL | Project: Joilet #29 Station Ash Pond (CCR)

Receipt Information

Date/Time Received: DATE 10-24-20 TIME 0950 | Received By: ER

Delivery Type: ☐ UPS ☒ FedEx SAT ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee
☐ Lab Courier ☐ Lab Field Services ☐ Client Drop-off ☐ Other:______

Condition of Cooler/Containers

Sample(s) received in Cooler?	☒ Yes	☐ No	*If yes:* Cooler ID:		
Multiple Coolers?	☐ Yes	☒ No	*If yes:* Cooler # ____ of ____		
Cooler Custody Seals Present?	~~☒ Yes~~	☐ No	*If yes:* Cooler custody seals intact?	~~☐ Yes~~	☐ No
Sample Custody Seals Present?	☐ Yes	☒ No	*If yes:* Sample custody seals intact?	☐ Yes	☐ No
Trip Blank Present?	☐ Yes	☒ No	*If yes:* Which VOA samples are in cooler? ↓		

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:______ ☐ NONE

Thermometer ID: O | Correction Factor (°C): 0.0

• Temp Blank Temperature – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): — 10-24-20 ER | Corrected Temp (°C):

• Sample Container Temperature

	CONTAINER 1	CONTAINER 2
Container(s) used:	plastic 250mL	
Uncorrected Temp (°C):	1.8	
Corrected Temp (°C):	1.8	

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
 a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

Document: CF-LG-WI-002
Revision: 25
Date: 06/17/2019

Eurofins TestAmerica, Cedar Falls

General temperature criteria is 0 to 6°C
Bacteria temperature criteria is 0 to 10°C

Eurofins TestAmerica, Chicago
2417 Bond Street
University Park, IL 60484
Phone: 708-534-5200 Fax: 708-534-5211

Chain of Custody Record

eurofins Environment Testing America

Client Information (Sub Contract Lab)	Sampler:	Lab PM: Mockler, Diana J	Carrier Tracking No(s):	COC No: 500-141340.1
Client Contact: Shipping/Receiving	Phone:	E-Mail: Diana.Mockler@Eurofinset.com	State of Origin: Illinois	Page: Page 1 of 1
Company: TestAmerica Laboratories, Inc.		Accreditations Required (See note): NELAP - Illinois		Job #: 500-189929-1
Address: 880 Riverside Parkway, ,	Due Date Requested: 11/4/2020			
City: West Sacramento	TAT Requested (days):			
State, Zip: CA, 95605				
Phone: 916-373-5600(Tel) 916-372-1059(Fax)	PO #:			
Email:	WO #:			
Project Name: Joliet #29 Station Ash Ponds (CCA)	Project #: 50005078			
Site:	SSOW#:			

Analysis Requested

Preservation Codes:
A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA
M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
Other:

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	314.0/ Perchlorate	Total Number of containers	Special Instructions/Note:
			Preservation Code:						
MW-03 (500-189929-1)	10/22/20	10:18 Central		Water			X	1	
MW-04 (500-189929-2)	10/22/20	11:11 Central		Water			X	1	
MW-05 (500-189929-3)	10/22/20	12:46 Central		Water			X	1	
MW-06 (500-189929-4)	10/22/20	15:12 Central		Water			X	1	
MW-07 (500-189929-5)	10/22/20	14:14 Central		Water			X	1	
MW-08 (500-189929-6)	10/22/20	09:23 Central		Water			X	1	
MW-10 (500-189929-7)	10/22/20	12:05 Central		Water			X	1	
MW-11 (500-189929-8)	10/22/20	13:31 Central		Water			X	1	
Duplicate (500-189929-9)	10/22/20	Central		Water			X	1	

Note: Since laboratory accreditations are subject to change, Eurofins TestAmerica places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody. If the laboratory does not currently maintain accreditation in the State of Origin listed above for analysis/tests/matrix being analyzed, the samples must be shipped back to the Eurofins TestAmerica laboratory or other instructions will be provided. Any changes to accreditation status should be brought to Eurofins TestAmerica attention immediately. If all requested accreditations are current to date, return the signed Chain of Custody attesting to said complicance to Eurofins TestAmerica.

Possible Hazard Identification *Unconfirmed*	***Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)*** ☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For* ____ *Months*
Deliverable Requested: I, II, III, IV, Other (specify) Primary Deliverable Rank: 2	Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:		Time:	Method of Shipment:	
Relinquished by: [signature]	Date/Time: 10/23/20 1700	Company: TA	Received by: [signature]	Date/Time: 10/24/20 09:15	Company: ETA-SAC
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Custody Seals Intact: ✓ Yes Δ No	Custody Seal No.: 1346997		Cooler Temperature(s) °C and Other Remarks: OB: 0.5 CORR: 0.0		

Ver: 01/16/2019

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc.

Job Number: 500-189929-1

Login Number: 189929
List Number: 1
Creator: Scott, Sherri L

List Source: Eurofins TestAmerica, Chicago

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	5.8,5.4,5.7
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	False	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc.

Job Number: 500-189929-1

Login Number: 189929
List Number: 3
Creator: Bovy, Lorrainna L

List Source: Eurofins TestAmerica, Cedar Falls
List Creation: 10/26/20 09:56 AM

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	False	Received project as a subcontract.
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc.

Job Number: 500-189929-1

Login Number: 189929
List Number: 2
Creator: Saephan, Kae C

List Source: Eurofins TestAmerica, Sacramento
List Creation: 10/24/20 11:38 AM

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	1346997
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	ob: 0.5c corr: 0.0c
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	False	Received project as a subcontract.
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	N/A	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Accreditation/Certification Summary

Client: KPRG and Associates, Inc.
Job ID: 500-189929-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Laboratory: Eurofins TestAmerica, Chicago

The accreditations/certifications listed below are applicable to this report.

Authority	Program	Identification Number	Expiration Date
Illinois	NELAP	IL00035	04-29-21

Laboratory: Eurofins TestAmerica, Cedar Falls

All accreditations/certifications held by this laboratory are listed. Not all accreditations/certifications are applicable to this report.

Authority	Program	Identification Number	Expiration Date
AIHA-LAP, LLC	Industrial Hygiene Laboratory Accreditation Program (IHLAP)	101044	10-28-20
Colorado	Petroleum Storage Tank Program	IA100001 (OR)	09-29-21
Georgia	State	IA100001 (OR)	09-29-21
Illinois	NELAP	200024	11-29-20
Iowa	State	007	12-01-21
Kansas	NELAP	E-10341	01-31-21
Minnesota	NELAP	019-999-319	11-02-20
Minnesota (Petrofund)	State	3349	08-22-21
North Dakota	State	R-186	09-29-21
Oregon	NELAP	IA100001	09-29-21
USDA	US Federal Programs	P330-19-00003	01-02-22

Laboratory: Eurofins TestAmerica, Sacramento

Unless otherwise noted, all analytes for this laboratory were covered under each accreditation/certification below.

Authority	Program	Identification Number	Expiration Date
Illinois	NELAP	200060	03-17-21

The following analytes are included in this report, but the laboratory is not certified by the governing authority. This list may include analytes for which the agency does not offer certification.

Analysis Method	Prep Method	Matrix	Analyte
314.0		Water	Perchlorate

eurofins | Environment Testing TestAmerica

Sacramento
Sample Receiving Notes

500-189929 Field Sheet

Job: ____

Tracking #: 189344499056

SO / PO / FO / SAT / 2-Day / Ground / UPS / CDO / Courier
GSO / OnTrac / Goldstreak / USPS / Other____

Use this form to record Sample Custody Seal, Cooler Custody Seal, Temperature & corrected Temperature & other observations.
File in the job folder with the COC.

Therm. ID: AK-5 Corr. Factor: (+/-) 0.5 °C

Ice X Wet X Gel ____ Other ____

Cooler Custody Seal: 1346997

Cooler ID: —

Temp Observed: 0.5 °C Corrected: 0.0 °C

From: Temp Blank ☐ Sample ☑

Opening/Processing The Shipment	Yes	No	NA
Cooler compromised/tampered with?	☐	☑	☐
Cooler Temperature is acceptable?	☑	☐	☐

Initials: [initials] Date: 10/24/20

Unpacking/Labeling The Samples	Yes	No	NA
CoC is complete w/o discrepancies?	☑	☐	☐
Samples compromised/tampered with?	☐	☑	☐
Sample containers have legible labels?	☑	☐	☐
Sample custody seal?	☐	☐	☑
Containers are not broken or leaking?	☑	☐	☐
Sample date/times are provided?	☑	☐	☐
Appropriate containers are used?	☑	☐	☐
Sample bottles are completely filled?	☐	☑	☐
Sample preservatives verified?	☐	☐	☑
Samples w/o discrepancies?	☑	☐	☐
Zero headspace?*	☐	☐	☑
Alkalinity has no headspace?	☐	☐	☑
Perchlorate has headspace? (Methods 314, 331, 6850)	☑	☐	☐
Multiphasic samples are not present?	☑	☐	☐

*Containers requiring zero headspace have no headspace, or bubble < 6 mm (1/4")

Initials: [initials] Date: 10/24/20

Notes: ____

Trizma Lot #(s): ____

Login Completion	Yes	No	NA
Receipt Temperature on COC?	☑	☐	☐
Samples received within hold time?	☑	☐	☐
NCM Filed?	☐	☐	☑
Log Release checked in TALS?	☐	☐	☑

Initials: [initials] Date: 10/24/20

\\TACORP\CORP\QA\QA_FACILITIES\SACRAMENTO-QA\DOCUMENT-MANAGEMENT\FORMS\QA-812 SAMPLE RECEIVING NOTES.DOC QA-812 TGT 6/11/2020

W25E

eurofins | Environment Testing America

1 2 3 4 5 6 7 8 9 10 11 12 13 14

ANALYTICAL REPORT

Eurofins TestAmerica, Chicago
2417 Bond Street
University Park, IL 60484
Tel: (708)534-5200

Laboratory Job ID: 500-190570-1
Client Project/Site: Joliet #29 Station Ash Ponds (CCA)

For:
KPRG and Associates, Inc.
14665 West Lisbon Road,
Suite 1A
Brookfield, Wisconsin 53005

Attn: Richard Gnat

Authorized for release by:
11/23/2020 2:38:39 PM

Diana Mockler, Project Manager I
(219)252-7570
Diana.Mockler@Eurofinset.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

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Job ID: 500-190570-1

Laboratory: Eurofins TestAmerica, Chicago

Narrative

Job Narrative
500-190570-1

Comments
No additional comments.

Receipt
The sample was received on 11/4/2020 3:30 PM; the sample arrived in good condition, and where required, properly preserved and on ice. The temperature of the cooler at receipt was 5.1º C.

GC/MS VOA
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Metals
Method 6020A: The low level continuing calibration verification (CCVL) at line 59, associated with batch 500-571798 recovered above the upper control limit for Beryllium. The samples associated with this CCVL were non-detects for the affected analyte; therefore, the data have been reported.

Method 6020A: The continuing calibration blank and verification (CCV/CCB) at lines 39 and 40 were outside the control limits for Boron bracketing the laboratory control sample (LCS). The LCS was within the method control limits. The associated samples were bracketed by CCV/CCB that were within control limits. Therefore, the data have been reported.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

Field Service / Mobile Lab
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

General Chemistry
Method 9038: Due to an instrument error, the low level CCV (CCVL) was not analyzed for the samples analyzed at the end of Sulfate batch 500-571365. All sample results were in the upper portion of the curve (greater than the LCS). The high level CCV (CCVH) was analyzed as expected and met criteria; therefore, data has been reported. The following samples were affected: MW-09 (500-190570-1), (LCS 500-571365/121) and (MB 500-571365/120).

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

Method Summary

Client: KPRG and Associates, Inc. Job ID: 500-190570-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Method	Method Description	Protocol	Laboratory
8260B	Volatile Organic Compounds (GC/MS)	SW846	TAL CHI
314.0	Perchlorate (IC)	EPA	TAL SAC
6020A	Metals (ICP/MS)	SW846	TAL CHI
7470A	Mercury (CVAA)	SW846	TAL CHI
9014	Cyanide	SW846	TAL CHI
9038	Sulfate, Turbidimetric	SW846	TAL CHI
9251	Chloride	SW846	TAL CHI
Nitrate by calc	Nitrogen, Nitrate-Nitrite	SM	TAL CHI
SM 2540C	Solids, Total Dissolved (TDS)	SM	TAL CF
SM 4500 F C	Fluoride	SM	TAL CHI
SM 4500 NO2 B	Nitrogen, Nitrite	SM	TAL CHI
SM 4500 NO3 F	Nitrogen, Nitrate	SM	TAL CHI
3005A	Preparation, Total Recoverable or Dissolved Metals	SW846	TAL CHI
5030B	Purge and Trap	SW846	TAL CHI
7470A	Preparation, Mercury	SW846	TAL CHI
9010C	Cyanide, Distillation	SW846	TAL CHI
Filtration	Sample Filtration	None	TAL CF
FILTRATION	Sample Filtration	None	TAL CHI

Protocol References:

EPA = US Environmental Protection Agency

None = None

SM = "Standard Methods For The Examination Of Water And Wastewater"

SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.

Laboratory References:

TAL CF = Eurofins TestAmerica, Cedar Falls, 3019 Venture Way, Cedar Falls, IA 50613, TEL (319)277-2401

TAL CHI = Eurofins TestAmerica, Chicago, 2417 Bond Street, University Park, IL 60484, TEL (708)534-5200

TAL SAC = Eurofins TestAmerica, Sacramento, 880 Riverside Parkway, West Sacramento, CA 95605, TEL (916)373-5600

Sample Summary

Lab Sample ID	Client Sample ID	Matrix	Collected	Received	Asset ID
500-190570-1	MW-09	Water	11/04/20 14:00	11/04/20 15:30	

Client Sample Results

Client: KPRG and Associates, Inc. Job ID: 500-190570-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Client Sample ID: MW-09 **Lab Sample ID: 500-190570-1**
Date Collected: 11/04/20 14:00 **Matrix: Water**
Date Received: 11/04/20 15:30

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			11/09/20 19:09	1
Toluene	<0.00050		0.00050		mg/L			11/09/20 19:09	1
Ethylbenzene	<0.00050		0.00050		mg/L			11/09/20 19:09	1
Xylenes, Total	<0.0010		0.0010		mg/L			11/09/20 19:09	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*111*		*75 - 126*		*11/09/20 19:09*	*1*
Toluene-d8 (Surr)	*96*		*75 - 120*		*11/09/20 19:09*	*1*
4-Bromofluorobenzene (Surr)	*96*		*72 - 124*		*11/09/20 19:09*	*1*
Dibromofluoromethane	*94*		*75 - 120*		*11/09/20 19:09*	*1*

Method: 314.0 - Perchlorate (IC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			11/16/20 18:51	1

Method: 6020A - Metals (ICP/MS) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Silver	<0.00050		0.00050		mg/L		11/11/20 08:01	11/12/20 13:17	1
Arsenic	**0.034**		0.0010		mg/L		11/11/20 08:01	11/12/20 13:17	1
Boron	**0.37**		0.050		mg/L		11/11/20 08:01	11/12/20 13:17	1
Barium	**0.086**		0.0025		mg/L		11/11/20 08:01	11/12/20 13:17	1
Beryllium	<0.0010	^	0.0010		mg/L		11/11/20 08:01	11/12/20 13:17	1
Cadmium	**0.0021**		0.00050		mg/L		11/11/20 08:01	11/12/20 13:17	1
Cobalt	**0.046**		0.0010		mg/L		11/11/20 08:01	11/12/20 13:17	1
Chromium	**0.028**		0.0050		mg/L		11/11/20 08:01	11/12/20 13:17	1
Copper	**0.041**		0.0020		mg/L		11/11/20 08:01	11/12/20 13:17	1
Iron	**970**		0.50		mg/L		11/11/20 08:01	11/12/20 13:21	5
Manganese	**2.3**		0.0025		mg/L		11/11/20 08:01	11/12/20 13:17	1
Nickel	**0.10**		0.0020		mg/L		11/11/20 08:01	11/12/20 13:17	1
Lead	**0.036**		0.00050		mg/L		11/11/20 08:01	11/12/20 13:17	1
Antimony	<0.0030		0.0030		mg/L		11/11/20 08:01	11/12/20 13:17	1
Selenium	**0.0027**		0.0025		mg/L		11/11/20 08:01	11/12/20 13:17	1
Thallium	<0.0020		0.0020		mg/L		11/11/20 08:01	11/12/20 13:17	1
Vanadium	**0.026**		0.0050		mg/L		11/11/20 08:01	11/12/20 13:17	1
Zinc	**1.2**		0.020		mg/L		11/11/20 08:01	11/12/20 13:17	1

Method: 7470A - Mercury (CVAA) - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		11/13/20 09:15	11/16/20 07:50	1

General Chemistry - Dissolved

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Cyanide, Total	<0.010		0.010		mg/L		11/18/20 17:30	11/18/20 19:06	1
Sulfate	**1500**		250		mg/L			11/10/20 16:33	50
Chloride	**190**		10		mg/L			11/12/20 09:01	5
Nitrogen, Nitrate	<0.10		0.10		mg/L			11/23/20 13:32	1
Total Dissolved Solids	**3000**		150		mg/L			11/11/20 15:48	1
Fluoride	**0.66**		0.10		mg/L			11/18/20 14:46	1
Nitrogen, Nitrite	<0.020		0.020		mg/L			11/05/20 09:15	1
Nitrogen, Nitrate Nitrite	<0.10		0.10		mg/L			11/22/20 11:20	1

Definitions/Glossary

Qualifiers

Metals

Qualifier	Qualifier Description
^	ICV,CCV,ICB,CCB, ISA, ISB, CRI, CRA, DLCK or MRL standard: Instrument related QC is outside acceptance limits.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CFU	Colony Forming Unit
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MCL	EPA recommended "Maximum Contaminant Level"
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
MPN	Most Probable Number
MQL	Method Quantitation Limit
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
NEG	Negative / Absent
POS	Positive / Present
PQL	Practical Quantitation Limit
PRES	Presumptive
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)
TNTC	Too Numerous To Count

1 2 3 4 5 6 7 8 9 10 11 12 13 14

QC Association Summary

Client: KPRG and Associates, Inc.
Job ID: 500-190570-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

GC/MS VOA

Analysis Batch: 571009

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Total/NA	Water	8260B	
MB 500-571009/9	Method Blank	Total/NA	Water	8260B	
LCS 500-571009/5	Lab Control Sample	Total/NA	Water	8260B	

HPLC/IC

Analysis Batch: 432093

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Total/NA	Water	314.0	
MB 320-432093/5	Method Blank	Total/NA	Water	314.0	
LCS 320-432093/6	Lab Control Sample	Total/NA	Water	314.0	
MRL 320-432093/4	Lab Control Sample	Total/NA	Water	314.0	

Metals

Filtration Batch: 571221

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	FILTRATION	
MB 500-571221/1-C	Method Blank	Dissolved	Water	FILTRATION	
MB 500-571221/1-G	Method Blank	Dissolved	Water	FILTRATION	

Prep Batch: 571464

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	3005A	571221
MB 500-571221/1-C	Method Blank	Dissolved	Water	3005A	571221
LCS 500-571464/2-A	Lab Control Sample	Total Recoverable	Water	3005A	

Analysis Batch: 571798

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	6020A	571464
500-190570-1	MW-09	Dissolved	Water	6020A	571464
MB 500-571221/1-C	Method Blank	Dissolved	Water	6020A	571464
LCS 500-571464/2-A	Lab Control Sample	Total Recoverable	Water	6020A	571464

Prep Batch: 571982

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	7470A	571221
MB 500-571221/1-G	Method Blank	Dissolved	Water	7470A	571221
MB 500-571982/12-A	Method Blank	Total/NA	Water	7470A	
LCS 500-571982/15-A	Lab Control Sample	Total/NA	Water	7470A	

Analysis Batch: 572324

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	7470A	571982
MB 500-571221/1-G	Method Blank	Dissolved	Water	7470A	571982
MB 500-571982/12-A	Method Blank	Total/NA	Water	7470A	571982
LCS 500-571982/15-A	Lab Control Sample	Total/NA	Water	7470A	571982

QC Association Summary

Client: KPRG and Associates, Inc.
Job ID: 500-190570-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

General Chemistry

Filtration Batch: 298972

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	Filtration	
MB 310-298972/1-A	Method Blank	Dissolved	Water	Filtration	
500-190570-1 DU	MW-09	Dissolved	Water	Filtration	

Analysis Batch: 299001

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	SM 2540C	298972
MB 310-298972/1-A	Method Blank	Dissolved	Water	SM 2540C	298972
LCS 310-299001/2	Lab Control Sample	Total/NA	Water	SM 2540C	
500-190570-1 DU	MW-09	Dissolved	Water	SM 2540C	298972

Analysis Batch: 571059

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	SM 4500 NO2 B	571221
MB 500-571059/9	Method Blank	Total/NA	Water	SM 4500 NO2 B	
LCS 500-571059/10	Lab Control Sample	Total/NA	Water	SM 4500 NO2 B	

Filtration Batch: 571221

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	FILTRATION	

Analysis Batch: 571365

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	9038	
MB 500-571365/120	Method Blank	Total/NA	Water	9038	
LCS 500-571365/121	Lab Control Sample	Total/NA	Water	9038	

Analysis Batch: 571749

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	9251	571781

Filtration Batch: 571781

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	FILTRATION	

Analysis Batch: 572899

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	SM 4500 F C	573346

Prep Batch: 572904

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	9010C	573346

Analysis Batch: 573064

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	9014	572904

Filtration Batch: 573346

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	FILTRATION	
500-190570-1	MW-09	Dissolved	Water	FILTRATION	

QC Association Summary

Client: KPRG and Associates, Inc.
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Job ID: 500-190570-1

General Chemistry

Analysis Batch: 573490

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	SM 4500 NO3 F	573580
LCS 500-573490/83	Lab Control Sample	Total/NA	Water	SM 4500 NO3 F	

Filtration Batch: 573580

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	FILTRATION	

Analysis Batch: 573642

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
500-190570-1	MW-09	Dissolved	Water	Nitrate by calc	571221

Surrogate Summary

Client: KPRG and Associates, Inc.
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Job ID: 500-190570-1

Method: 8260B - Volatile Organic Compounds (GC/MS)

Matrix: Water **Prep Type: Total/NA**

		Percent Surrogate Recovery (Acceptance Limits)			
		DCA	TOL	BFB	DBFM
Lab Sample ID	Client Sample ID	(75-126)	(75-120)	(72-124)	(75-120)
500-190570-1	MW-09	111	96	96	94
LCS 500-571009/5	Lab Control Sample	107	97	93	96
MB 500-571009/9	Method Blank	105	96	94	92

Surrogate Legend

DCA = 1,2-Dichloroethane-d4 (Surr)
TOL = Toluene-d8 (Surr)
BFB = 4-Bromofluorobenzene (Surr)
DBFM = Dibromofluoromethane

QC Sample Results

Client: KPRG and Associates, Inc.
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Job ID: 500-190570-1

Method: 8260B - Volatile Organic Compounds (GC/MS)

Lab Sample ID: MB 500-571009/9
Matrix: Water
Analysis Batch: 571009

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzene	<0.00050		0.00050		mg/L			11/09/20 12:47	1
Toluene	<0.00050		0.00050		mg/L			11/09/20 12:47	1
Ethylbenzene	<0.00050		0.00050		mg/L			11/09/20 12:47	1
Xylenes, Total	<0.0010		0.0010		mg/L			11/09/20 12:47	1

Surrogate	*MB %Recovery*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
1,2-Dichloroethane-d4 (Surr)	*105*		*75 - 126*		*11/09/20 12:47*	*1*
Toluene-d8 (Surr)	*96*		*75 - 120*		*11/09/20 12:47*	*1*
4-Bromofluorobenzene (Surr)	*94*		*72 - 124*		*11/09/20 12:47*	*1*
Dibromofluoromethane	*92*		*75 - 120*		*11/09/20 12:47*	*1*

Lab Sample ID: LCS 500-571009/5
Matrix: Water
Analysis Batch: 571009

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Benzene	0.0500	0.0476		mg/L		95	70 - 120
Toluene	0.0500	0.0469		mg/L		94	70 - 125
Ethylbenzene	0.0500	0.0473		mg/L		95	70 - 123
Xylenes, Total	0.100	0.0922		mg/L		92	70 - 125

Surrogate	*LCS %Recovery*	*LCS Qualifier*	*Limits*
1,2-Dichloroethane-d4 (Surr)	*107*		*75 - 126*
Toluene-d8 (Surr)	*97*		*75 - 120*
4-Bromofluorobenzene (Surr)	*93*		*72 - 124*
Dibromofluoromethane	*96*		*75 - 120*

Method: 314.0 - Perchlorate (IC)

Lab Sample ID: MB 320-432093/5
Matrix: Water
Analysis Batch: 432093

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Perchlorate	<0.0040		0.0040		mg/L			11/16/20 14:24	1

Lab Sample ID: LCS 320-432093/6
Matrix: Water
Analysis Batch: 432093

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Perchlorate	0.0500	0.0526		mg/L		105	85 - 115

Lab Sample ID: MRL 320-432093/4
Matrix: Water
Analysis Batch: 432093

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	MRL Result	MRL Qualifier	Unit	D	%Rec	%Rec. Limits
Perchlorate	4.00	<4.0		ug/L		99	75 - 125

Client: KPRG and Associates, Inc. Job ID: 500-190570-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Method: 6020A - Metals (ICP/MS)

Lab Sample ID: LCS 500-571464/2-A **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total Recoverable**
Analysis Batch: 571798 **Prep Batch: 571464**

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Silver	0.0500	0.0463		mg/L		93	80 - 120
Arsenic	0.100	0.0949		mg/L		95	80 - 120
Boron	1.00	0.976	^	mg/L		98	80 - 120
Barium	2.00	1.95		mg/L		97	80 - 120
Beryllium	0.0500	0.0495	^	mg/L		99	80 - 120
Cadmium	0.0500	0.0476		mg/L		95	80 - 120
Cobalt	0.500	0.502		mg/L		100	80 - 120
Chromium	0.200	0.203		mg/L		102	80 - 120
Copper	0.250	0.259		mg/L		104	80 - 120
Iron	1.00	1.03		mg/L		103	80 - 120
Manganese	0.500	0.496		mg/L		99	80 - 120
Nickel	0.500	0.506		mg/L		101	80 - 120
Lead	0.100	0.104		mg/L		104	80 - 120
Antimony	0.500	0.459		mg/L		92	80 - 120
Selenium	0.100	0.0996		mg/L		100	80 - 120
Thallium	0.100	0.106		mg/L		106	80 - 120
Vanadium	0.500	0.496		mg/L		99	80 - 120
Zinc	0.500	0.505		mg/L		101	80 - 120

Lab Sample ID: MB 500-571221/1-C **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 571798 **Prep Batch: 571464**

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Silver	<0.00050		0.00050		mg/L		11/11/20 08:01	11/12/20 13:14	1
Arsenic	<0.0010		0.0010		mg/L		11/11/20 08:01	11/12/20 13:14	1
Boron	<0.050		0.050		mg/L		11/11/20 08:01	11/12/20 13:14	1
Barium	<0.0025		0.0025		mg/L		11/11/20 08:01	11/12/20 13:14	1
Beryllium	<0.0010	^	0.0010		mg/L		11/11/20 08:01	11/12/20 13:14	1
Cadmium	<0.00050		0.00050		mg/L		11/11/20 08:01	11/12/20 13:14	1
Cobalt	<0.0010		0.0010		mg/L		11/11/20 08:01	11/12/20 13:14	1
Chromium	<0.0050		0.0050		mg/L		11/11/20 08:01	11/12/20 13:14	1
Copper	<0.0020		0.0020		mg/L		11/11/20 08:01	11/12/20 13:14	1
Iron	<0.10		0.10		mg/L		11/11/20 08:01	11/12/20 13:14	1
Manganese	<0.0025		0.0025		mg/L		11/11/20 08:01	11/12/20 13:14	1
Nickel	<0.0020		0.0020		mg/L		11/11/20 08:01	11/12/20 13:14	1
Lead	<0.00050		0.00050		mg/L		11/11/20 08:01	11/12/20 13:14	1
Antimony	<0.0030		0.0030		mg/L		11/11/20 08:01	11/12/20 13:14	1
Selenium	<0.0025		0.0025		mg/L		11/11/20 08:01	11/12/20 13:14	1
Thallium	<0.0020		0.0020		mg/L		11/11/20 08:01	11/12/20 13:14	1
Vanadium	<0.0050		0.0050		mg/L		11/11/20 08:01	11/12/20 13:14	1
Zinc	<0.020		0.020		mg/L		11/11/20 08:01	11/12/20 13:14	1

Method: 7470A - Mercury (CVAA)

Lab Sample ID: MB 500-571982/12-A — **Client Sample ID: Method Blank**
Matrix: Water — **Prep Type: Total/NA**
Analysis Batch: 572324 — **Prep Batch: 571982**

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		11/13/20 09:15	11/16/20 07:10	1

Lab Sample ID: LCS 500-571982/15-A — **Client Sample ID: Lab Control Sample**
Matrix: Water — **Prep Type: Total/NA**
Analysis Batch: 572324 — **Prep Batch: 571982**

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Mercury	0.00200	0.00193		mg/L		96	80 - 120

Lab Sample ID: MB 500-571221/1-G — **Client Sample ID: Method Blank**
Matrix: Water — **Prep Type: Dissolved**
Analysis Batch: 572324 — **Prep Batch: 571982**

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	<0.00020		0.00020		mg/L		11/13/20 09:15	11/16/20 07:27	1

Method: 9038 - Sulfate, Turbidimetric

Lab Sample ID: MB 500-571365/120 — **Client Sample ID: Method Blank**
Matrix: Water — **Prep Type: Total/NA**
Analysis Batch: 571365

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Sulfate	<5.0		5.0		mg/L			11/10/20 16:28	1

Lab Sample ID: LCS 500-571365/121 — **Client Sample ID: Lab Control Sample**
Matrix: Water — **Prep Type: Total/NA**
Analysis Batch: 571365

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Sulfate	20.0	21.0		mg/L		105	80 - 120

Method: SM 2540C - Solids, Total Dissolved (TDS)

Lab Sample ID: LCS 310-299001/2 — **Client Sample ID: Lab Control Sample**
Matrix: Water — **Prep Type: Total/NA**
Analysis Batch: 299001

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Total Dissolved Solids	1000	1020		mg/L		102	90 - 110

Lab Sample ID: MB 310-298972/1-A — **Client Sample ID: Method Blank**
Matrix: Water — **Prep Type: Dissolved**
Analysis Batch: 299001

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Dissolved Solids	<30		30		mg/L			11/11/20 15:48	1

Method: SM 2540C - Solids, Total Dissolved (TDS) (Continued)

Lab Sample ID: 500-190570-1 DU **Client Sample ID: MW-09**
Matrix: Water **Prep Type: Dissolved**
Analysis Batch: 299001

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Total Dissolved Solids	3000		3040		mg/L		0	24

Method: SM 4500 NO2 B - Nitrogen, Nitrite

Lab Sample ID: MB 500-571059/9 **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 571059

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrogen, Nitrite	<0.020		0.020		mg/L			11/05/20 09:02	1

Lab Sample ID: LCS 500-571059/10 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 571059

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Nitrogen, Nitrite	0.100	0.103		mg/L		103	80 - 120

Method: SM 4500 NO3 F - Nitrogen, Nitrate

Lab Sample ID: LCS 500-573490/83 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 573490

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Nitrogen, Nitrate Nitrite	1.00	1.03		mg/L		103	80 - 120

Chain of Custody Record

375541 eurofins | Environment Testing TestAmerica

Address: ______________________

Regulatory Program: ☐ DW ☐ NPDES ☐ RCRA ☐ Other:

TAL-8210

Client Contact
Company Name: KRRG and Assoc. Inc
Address: 141665 W Lisbon Rd 1A
City/State/Zip: Brookfield, WI 53005
Phone: (262) 781-0475
Fax:
Project Name: Midwest Generation
Site: Joliet 29 Groundwater
PO#: CCA

Project Manager: Diana Mockler
Tel/Email:

Analysis Turnaround Time
☐ CALENDAR DAYS ☐ WORKING DAYS
TAT if different from Below ________
☐ 2 weeks
☐ 1 week
☐ 2 days
☐ 1 day

Site Contact:
Lab Contact:

Date: 11/4/2020
Carrier:

500-190570 COC

COC No:
1 of 1 COCs
Sampler: Erin Bulson
For Lab Use Only:
Walk-in Client: X
Lab Sampling:
Job / SDG No.: 500-190570

Sample Identification	Sample Date	Sample Time	Sample Type (C=Comp, G=Grab)	Matrix	# of Cont.	Filtered Sample (Y / N)	Perform MS / MSD (Y / N)	6020, 7470A	2540C, 4500_F-C, 9038, 9251	SM4500_NO2_B: Nitrogen, Nitrite	SM4500_NO3_F - Nitrogen, Nitrate Nitrite	9014	9260B- BTEX	Sample Specific Notes:
MW-09	11/4	1400		Water		N		X	X	X	X	X	X	Needs to be filtered preservatives were removed from sample bottles

Preservation Used: 1= Ice, 2= HCl; 3= H2SO4; 4=HNO3; 5=NaOH; 6= Other ________

Possible Hazard Identification:
Are any samples from a listed EPA Hazardous Waste? Please List any EPA Waste Codes for the sample in the Comments Section if the lab is to dispose of the sample.
☐ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ Return to Client ☐ Disposal by Lab ☐ Archive for________ Months

Special Instructions/QC Requirements & Comments:

Custody Seals Intact: ☐ Yes ☐ No
Custody Seal No.:
Cooler Temp. (°C): Obs'd: 4.7 Corr'd: 5.1 Therm ID No.: ________

Relinquished by: Erin Bulson	Company: KRRG	Date/Time: 11/4/20 1:30 PM	Received by:	Company:	Date/Time:
Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Relinquished by:	Company:	Date/Time:	Received in Laboratory by: [signature]	Company: ETA	Date/Time: 11/4/20 1530

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TestAmerica

500-190570 Chain of Custody

Cooler/Sample Receipt and Temperature

Client Information

Client: ETA - Chicago

City/State: CITY University Park STATE IL | Project: Joliet

Receipt Information

Date/Time Received: DATE 11/5/20 TIME 1010 | Received By: MRH

Delivery Type: ☐ UPS ☒ FedEx ☐ FedEx Ground ☐ US Mail ☐ Spee-Dee
☐ Lab Courier ☐ Lab Field Services ☐ Client Drop-off ☐ Other:______

Condition of Cooler/Containers

Sample(s) received in Cooler?	☒ Yes ☐ No	*If yes:* Cooler ID:	
Multiple Coolers?	☐ Yes ☒ No	*If yes:* Cooler # ____ of ____	
Cooler Custody Seals Present?	☒ Yes ☐ No	*If yes:* Cooler custody seals intact?	☒ Yes ☐ No
Sample Custody Seals Present?	☐ Yes ☒ No	*If yes:* Sample custody seals intact?	☐ Yes ☐ No
Trip Blank Present?	☐ Yes ☒ No	*If yes:* Which VOA samples are in cooler? ↓	

Temperature Record

Coolant: ☒ Wet ice ☐ Blue ice ☐ Dry ice ☐ Other:______ ☐ NONE

Thermometer ID: 0 | Correction Factor (°C): 0

• Temp Blank Temperature – If no temp blank, or temp blank temperature above criteria, proceed to Sample Container Temperature

Uncorrected Temp (°C): ~~TB~~ MRH 11/5/20 | Corrected Temp (°C):

• Sample Container Temperature

	CONTAINER 1	CONTAINER 2
Container(s) used:	1L Plas NT	
Uncorrected Temp (°C):	1.1	
Corrected Temp (°C):	1.1	

Exceptions Noted

1) If temperature exceeds criteria, was sample(s) received same day of sampling? ☐ Yes ☐ No
   a) *If yes:* Is there evidence that the chilling process began? ☐ Yes ☐ No

2) If temperature is <0°C, are there obvious signs that the integrity of sample containers is compromised? (e.g., bulging septa, broken/cracked bottles, frozen solid?) ☐ Yes ☐ No

NOTE: If yes, contact PM before proceeding. If no, proceed with login

Additional Comments

Document: CF-LG-WI-002
Revision: 25
Date: 06/17/2019

Eurofins TestAmerica, Cedar Falls

General temperature criteria is 0 to 6°C
Bacteria temperature criteria is 0 to 10°C

Eurofins TestAmerica, Chicago
2417 Bond Street
University Park, IL 60484
Phone: 708-534-5200 Fax: 708-534-5211

Chain of Custody Record

eurofins Environment Testing America

Client Information (Sub Contract Lab)	Sampler:	Lab PM: Mockler, Diana J	Carrier Tracking No(s):	COC No: 500-141787.1
Client Contact: Shipping/Receiving	Phone:	E-Mail: Diana.Mockler@Eurofinset.com	State of Origin: Illinois	Page: Page 1 of 1
Company: TestAmerica Laboratories, Inc		Accreditations Required (See note): NELAP - Illinois		Job #: 500-190570-1
Address: 3019 Venture Way, ,	Due Date Requested: 11/16/2020			
City: Cedar Falls	TAT Requested (days):			
State, Zip: IA, 50613				
Phone: 319-277-2401(Tel) 319-277-2425(Fax)	PO #:			
Email:	WO #:			
Project Name: Joliet #29 Station Ash Ponds (CCA)	Project #: 50005078			
Site:	SSOW#:			

Preservation Codes:
A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA, M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)

Other:

Analysis Requested

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	2540C_Calcd/Filtration_WC Total Dissolved Solids	Total Number of containers	Special Instructions/Note:
			Preservation Code:						
MW-09 (500-190570-1)	11/4/20	14:00 Central		Water			X	1	

Note: Since laboratory accreditations are subject to change, Eurofins TestAmerica places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody. If the laboratory does not currently maintain accreditation in the State of Origin listed above for analysis/tests/matrix being analyzed, the samples must be shipped back to the Eurofins TestAmerica laboratory or other instructions will be provided. Any changes to accreditation status should be brought to Eurofins TestAmerica attention immediately. If all requested accreditations are current to date, return the signed Chain of Custody attesting to said complicance to Eurofins TestAmerica.

Possible Hazard Identification	Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
Unconfirmed	☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For ____ Months*
Deliverable Requested: I, II, III, IV, Other (specify) — Primary Deliverable Rank: 2	Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:	Time:	Method of Shipment:		
Relinquished by: [signature]	Date/Time: 11/4/20 1700	Company: ETA	Received by: [signature]	Date/Time: 11/5/20 1010	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Custody Seals Intact: △ Yes △ No	Custody Seal No.:		Cooler Temperature(s) °C and Other Remarks:		

Ver: 01/16/2019

Eurofins TestAmerica, Chicago
2417 Bond Street
University Park, IL 60484
Phone: 708-534-5200 Fax: 708-534-5211

Chain of Custody Record

eurofins | Environment Testing America

Client Information (Sub Contract Lab)	Sampler:	Lab PM: Mockler, Diana J	Carrier Tracking No(s):	COC No: 500-141791.1
Client Contact: Shipping/Receiving	Phone:	E-Mail: Diana.Mockler@Eurofinset.com	State of Origin: Illinois	Page: Page 1 of 1
Company: TestAmerica Laboratories, Inc.		Accreditations Required (See note): NELAP - Illinois		Job #: 500-190570-1
Address: 880 Riverside Parkway, ,	Due Date Requested: 11/16/2020	**Analysis Requested**		**Preservation Codes:**
City: West Sacramento	TAT Requested (days):			
State, Zip: CA, 95605				
Phone: 916-373-5600(Tel) 916-372-1059(Fax)	PO #:			
Email:	WO #:			
Project Name: Joliet #29 Station Ash Ponds (CCA)	Project #: 50005078			
Site:	SSOW#:			Other:

Preservation Codes:
A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA
M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	314.0/ Perchlorate	Total Number of containers	Special Instructions/Note:
			Preservation Code:						
MW-09 (500-190570-1)	11/4/20	14:00 Central		Water			X	1	

Note: Since laboratory accreditations are subject to change, Eurofins TestAmerica places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody. If the laboratory does not currently maintain accreditation in the State of Origin listed above for analysis/tests/matrix being analyzed, the samples must be shipped back to the Eurofins TestAmerica laboratory or other instructions will be provided. Any changes to accreditation status should be brought to Eurofins TestAmerica attention immediately. If all requested accreditations are current to date, return the signed Chain of Custody attesting to said complicance to Eurofins TestAmerica.

Possible Hazard Identification *Unconfirmed*		*Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)* ☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For* ____ *Months*
Deliverable Requested: I, II, III, IV, Other (specify)	Primary Deliverable Rank: 2	Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:		Time:		Method of Shipment:	
Relinquished by: [signature]	Date/Time: 11/4/20 1700	Company: ETA	Received by: [signature]	Date/Time: 11/05/20 900	Company: eta Sac	
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company	
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company	
Custody Seals Intact: Δ Yes Δ No	Custody Seal No.: 1363666		Cooler Temperature(s) °C and Other Remarks: 0.9			

Ver: 01/16/2019

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc.

Job Number: 500-190570-1

Login Number: 190570
List Number: 1
Creator: Scott, Sherri L

List Source: Eurofins TestAmerica, Chicago

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	5.1
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc. | Job Number: 500-190570-1

Login Number: 190570
List Number: 2
Creator: Homolar, Dana J

List Source: Eurofins TestAmerica, Cedar Falls
List Creation: 11/05/20 12:18 PM

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	False	Received project as a subcontract.
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc.

Job Number: 500-190570-1

Login Number: 190570
List Number: 3
Creator: Saephan, Kae C

List Source: Eurofins TestAmerica, Sacramento
List Creation: 11/05/20 11:32 AM

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	1363666
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	ob: 0.9c corr: 0.9c
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	False	Received project as a subcontract.
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	False	Method requires headspace.
Sample Preservation Verified.	N/A	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Accreditation/Certification Summary

Client: KPRG and Associates, Inc. Job ID: 500-190570-1
Project/Site: Joliet #29 Station Ash Ponds (CCA)

Laboratory: Eurofins TestAmerica, Chicago

The accreditations/certifications listed below are applicable to this report.

Authority	Program	Identification Number	Expiration Date
Illinois	NELAP	IL00035	04-29-21

Laboratory: Eurofins TestAmerica, Cedar Falls

All accreditations/certifications held by this laboratory are listed. Not all accreditations/certifications are applicable to this report.

Authority	Program	Identification Number	Expiration Date
Colorado	Petroleum Storage Tank Program	IA100001 (OR)	09-29-21
Georgia	State	IA100001 (OR)	09-29-21
Illinois	NELAP	200024	11-29-20
Iowa	State	007	12-01-21
Kansas	NELAP	E-10341	01-31-21
Minnesota	NELAP	019-999-319	12-31-21
Minnesota (Petrofund)	State	3349	08-22-21
North Dakota	State	R-186	09-29-21
Oregon	NELAP	IA100001	09-29-21
USDA	US Federal Programs	P330-19-00003	01-02-22

Laboratory: Eurofins TestAmerica, Sacramento

Unless otherwise noted, all analytes for this laboratory were covered under each accreditation/certification below.

Authority	Program	Identification Number	Expiration Date
Illinois	NELAP	200060	03-17-21

The following analytes are included in this report, but the laboratory is not certified by the governing authority. This list may include analytes for which the agency does not offer certification.

Analysis Method	Prep Method	Matrix	Analyte
314.0		Water	Perchlorate

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Sacramento
Sample Receiving Notes

500-190570 Field Sheet

Job: ____

Tracking # : 1893 4450 0384

SO / (PO) / FO / SAT / 2-Day / Ground / UPS / CDO / Courier
GSO / OnTrac / Goldstreak / USPS / Other____

Use this form to record Sample Custody Seal, Cooler Custody Seal, Temperature & corrected Temperature & other observations.
File in the job folder with the COC.

Therm. ID: L-01 Corr. Factor: (+ / -) 0 °C

Ice ✓ Wet ____ Gel ____ Other ____

Cooler Custody Seal: 1363666

Cooler ID: —

Temp Observed: 0.9 °C Corrected: 0.9 °C

From: Temp Blank ☐ Sample ☑

Opening/Processing The Shipment	**Yes**	**No**	**NA**
Cooler compromised/tampered with?	☐	☑	☐
Cooler Temperature is acceptable?	☑	☐	☐

Initials: MAN Date: 11/05/20

Unpacking/Labeling The Samples	**Yes**	**No**	**NA**
CoC is complete w/o discrepancies?	☑	☐	☐
Samples compromised/tampered with?	☐	☑	☐
Sample containers have legible labels?	☑	☐	☐
Sample custody seal?	☐	☐	☑
Containers are not broken or leaking?	☑	☐	☐
Sample date/times are provided?	☑	☐	☐
Appropriate containers are used?	☑	☐	☐
Sample bottles are completely filled?	☐	☑	☐
Sample preservatives verified?	☐	☐	☑
Samples w/o discrepancies?	☑	☐	☐
Zero headspace?*	☐	☐	☑
Alkalinity has no headspace?	☐	☐	☑
Perchlorate has headspace? (Methods 314, 331, 6850)	☑	☐	☐
Multiphasic samples are not present?	☑	☐	☐

*Containers requiring zero headspace have no headspace, or bubble < 6 mm (1/4")

Initials: [signature] Date: 11/05/20

Notes: ____

Trizma Lot #(s): ____

Login Completion	**Yes**	**No**	**NA**
Receipt Temperature on COC?	☑	☐	☐
Samples received within hold time?	☑	☐	☐
NCM Filed?	☐	☐	☑
Log Release checked in TALS?	☐	☐	☑

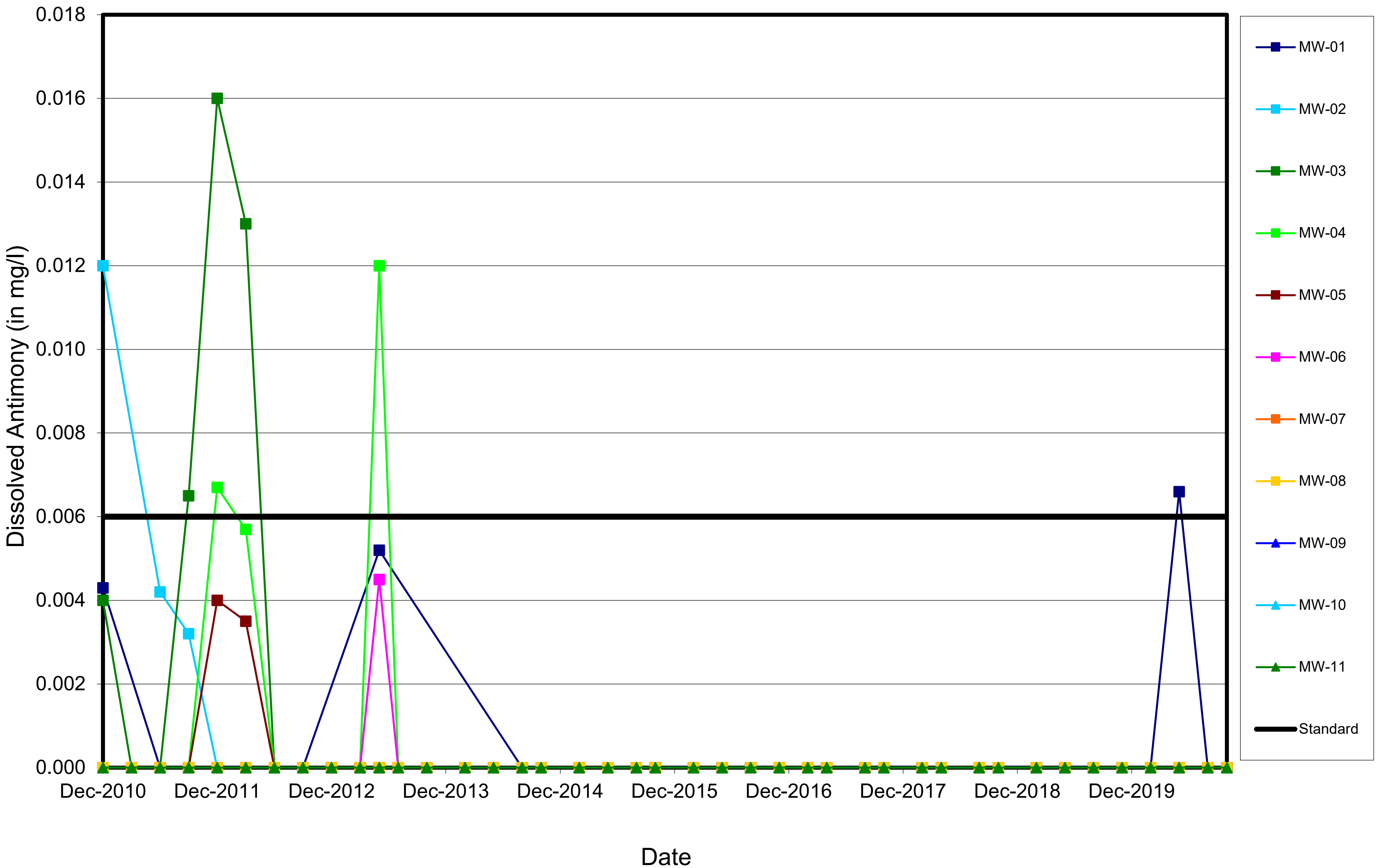
Initials: [signature] Date: 11/05/20

\\TACORP\CORP\QA\QA_FACILITIES\SACRAMENTO-QA\DOCUMENT-MANAGEMENT\FORMS\QA-812 SAMPLE RECEIVING NOTES.DOC QA-812 TGT 6/11/2020

ATTACHMENT 3
Time Vs. Concentration Curves

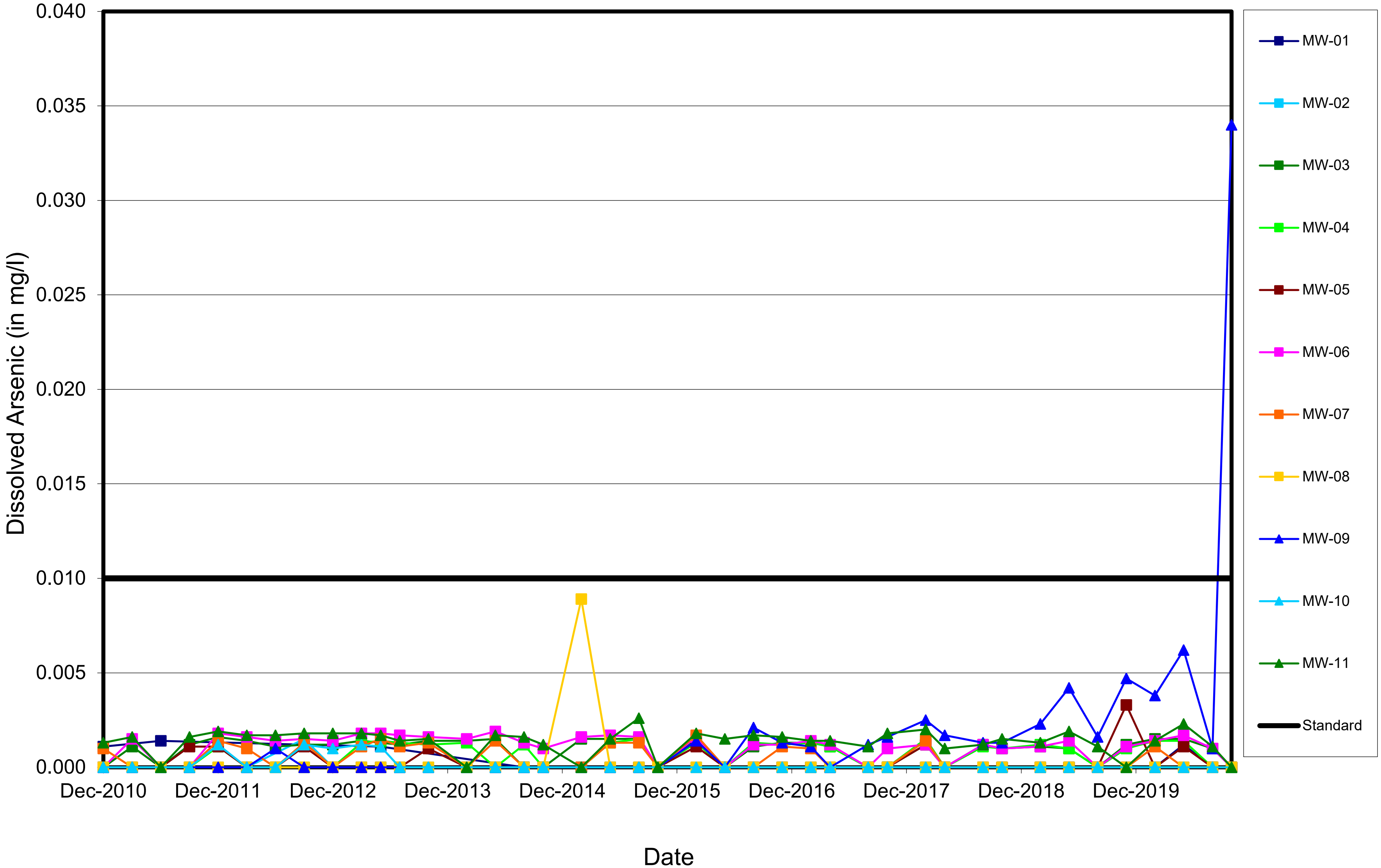
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Antimony vs. Time



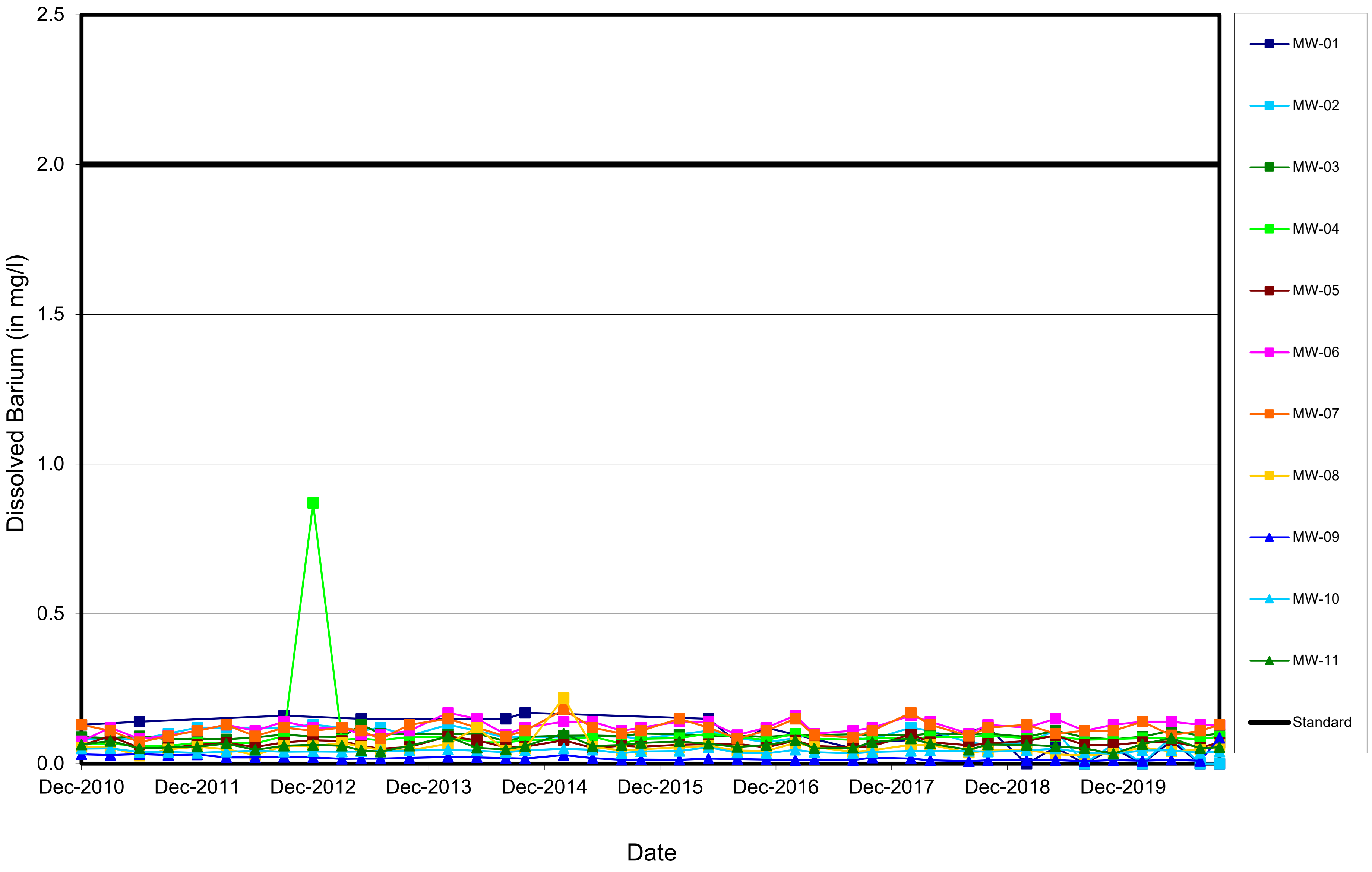
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Arsenic vs. Time



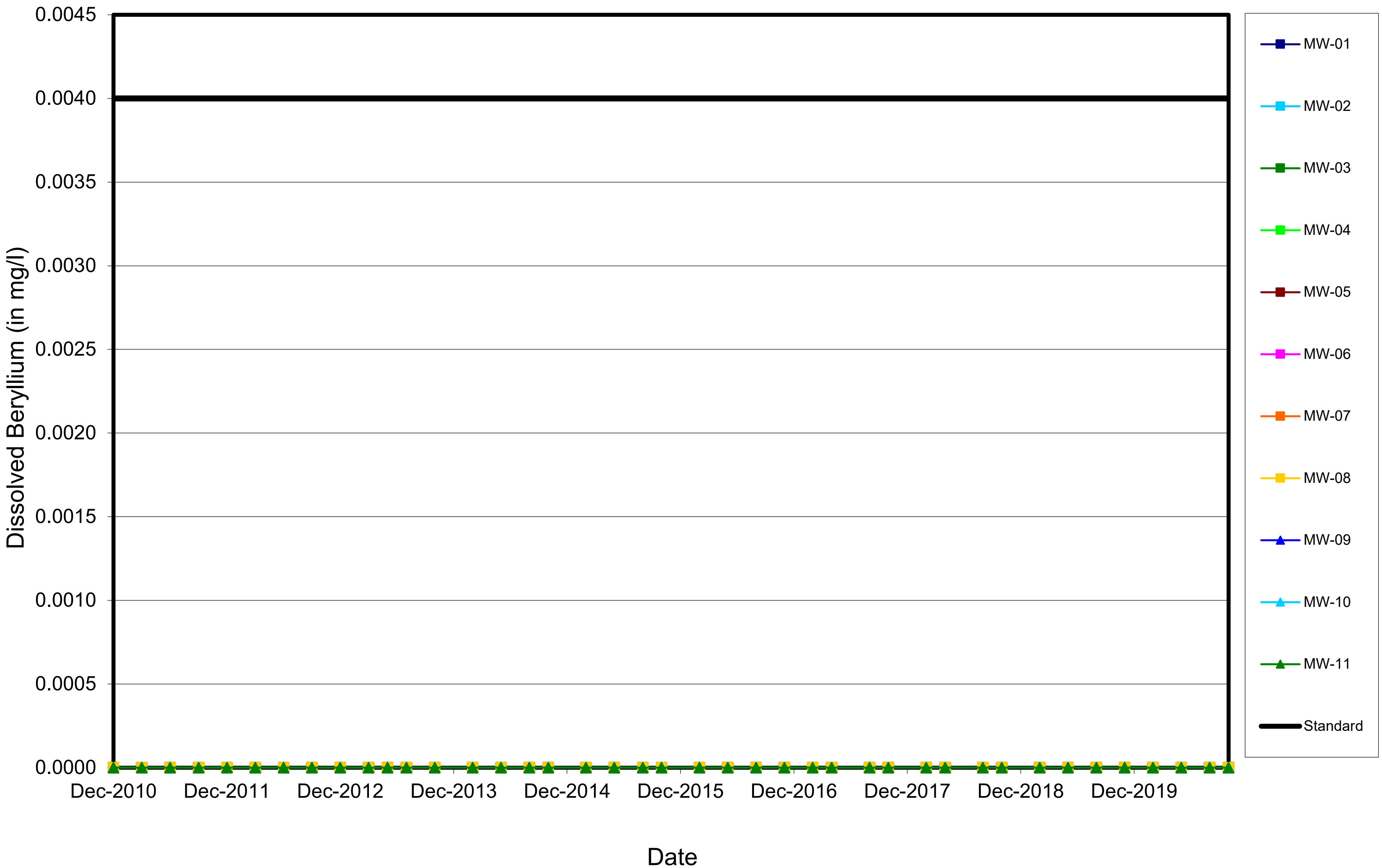
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Barium vs. Time



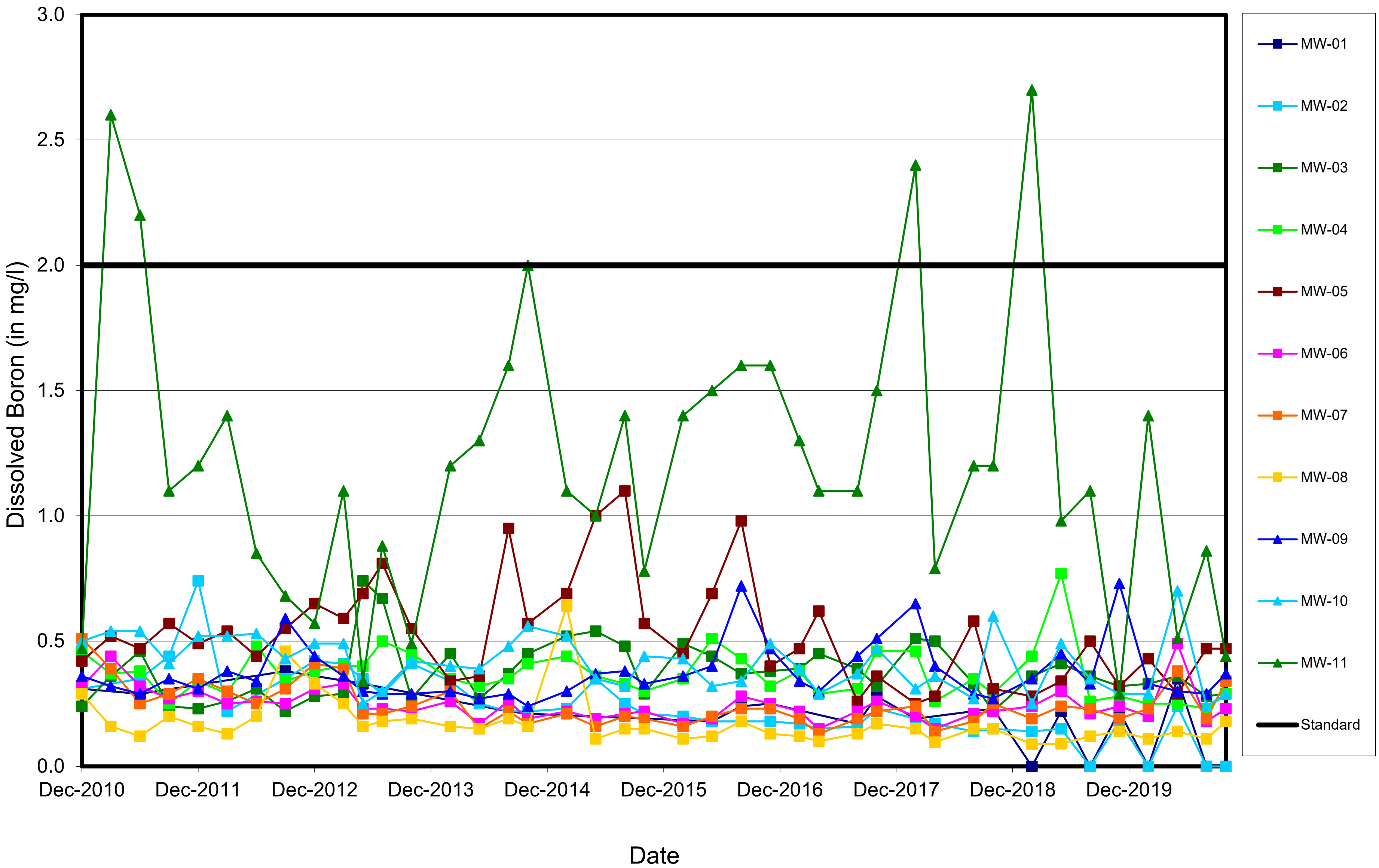
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Beryllium vs. Time



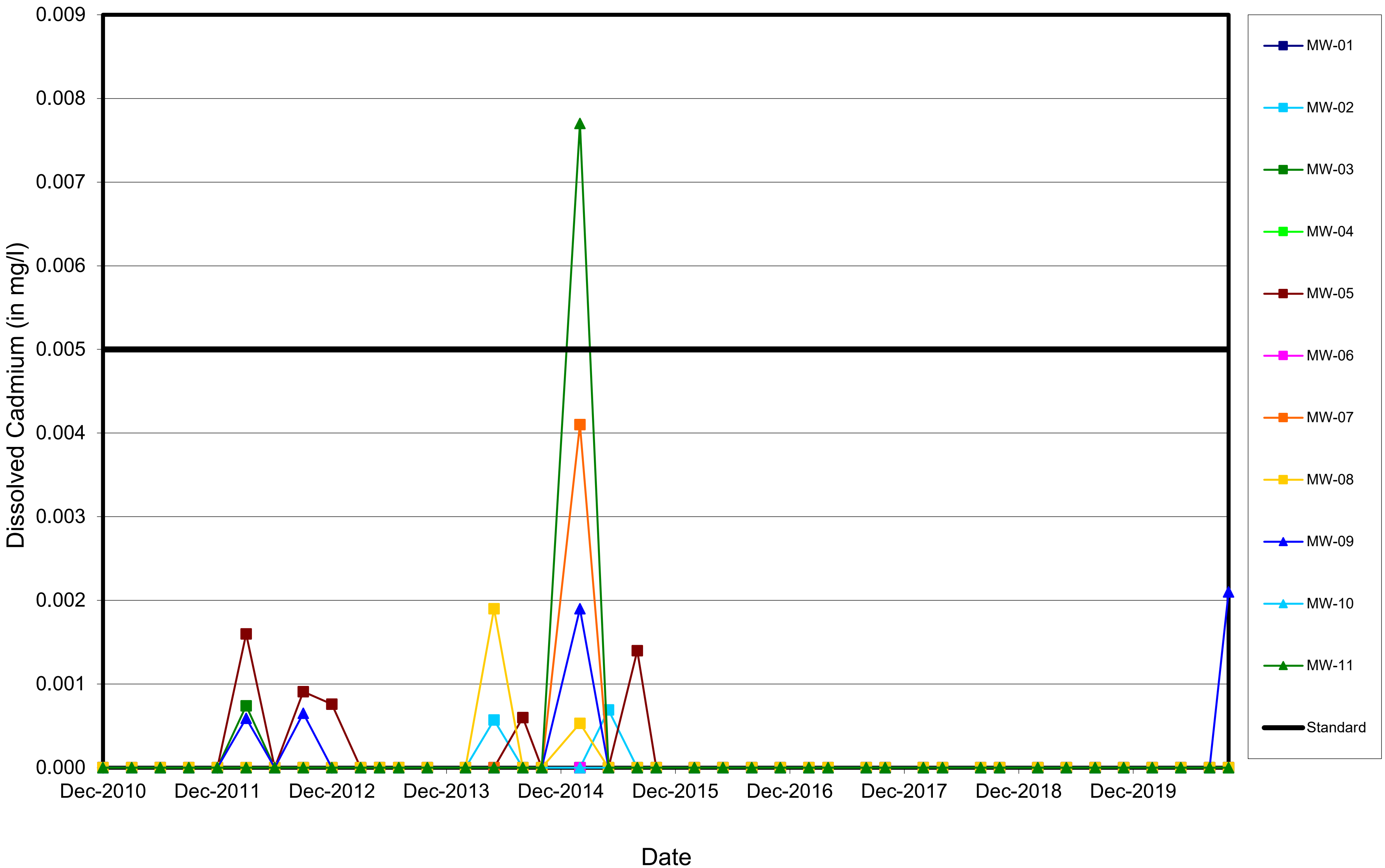
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Boron vs. Time



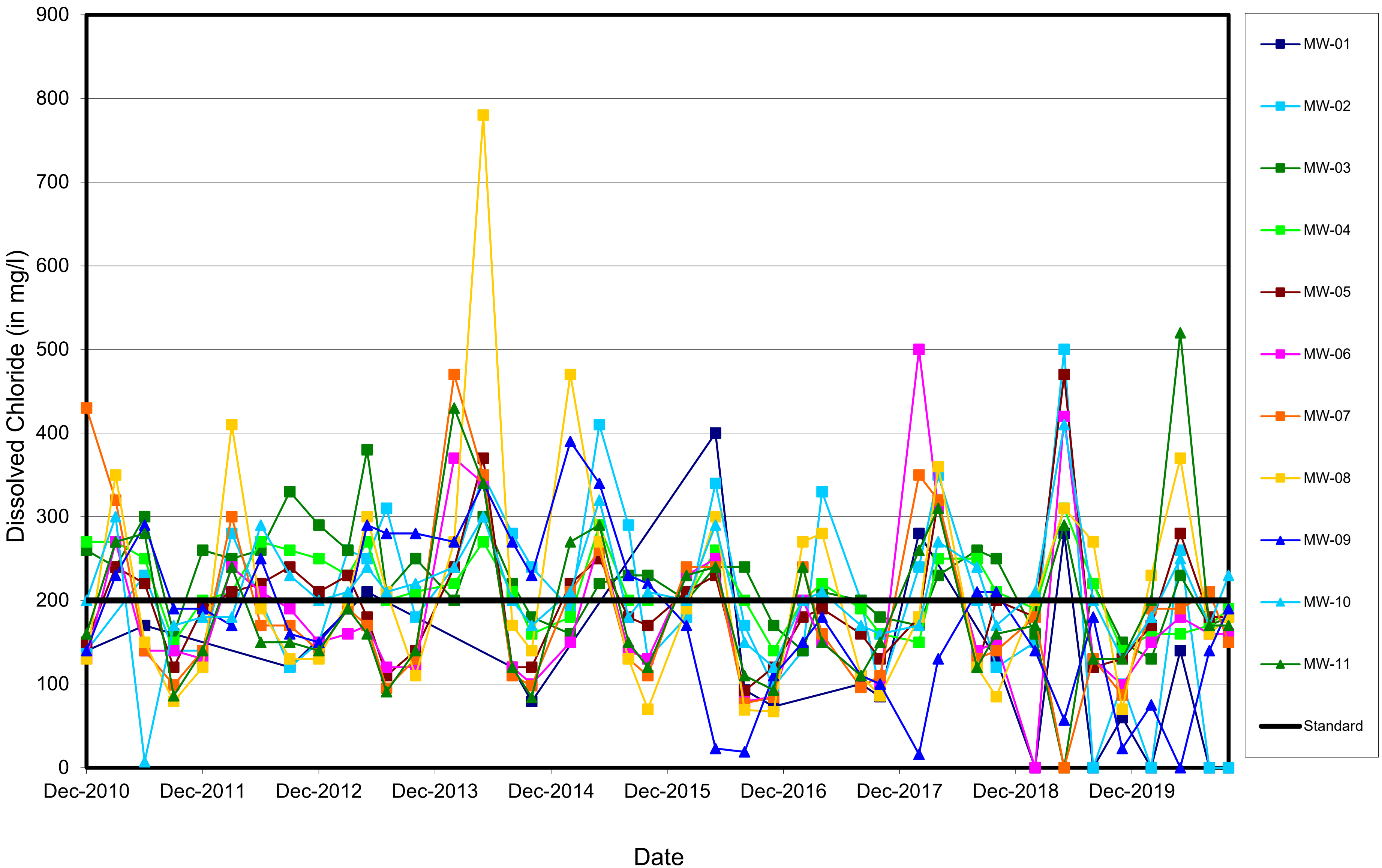
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Cadmium vs. Time



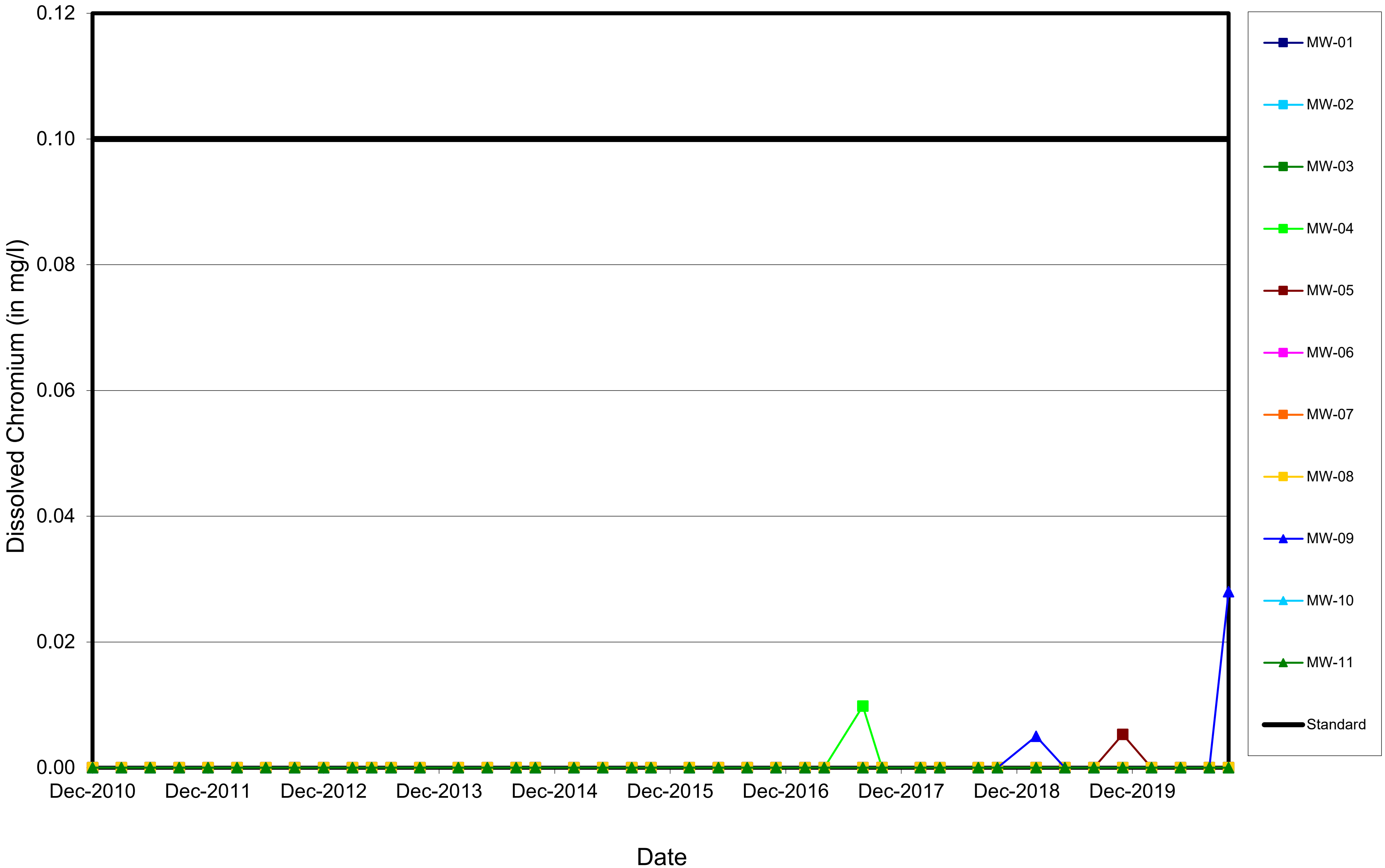
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Chloride vs. Time



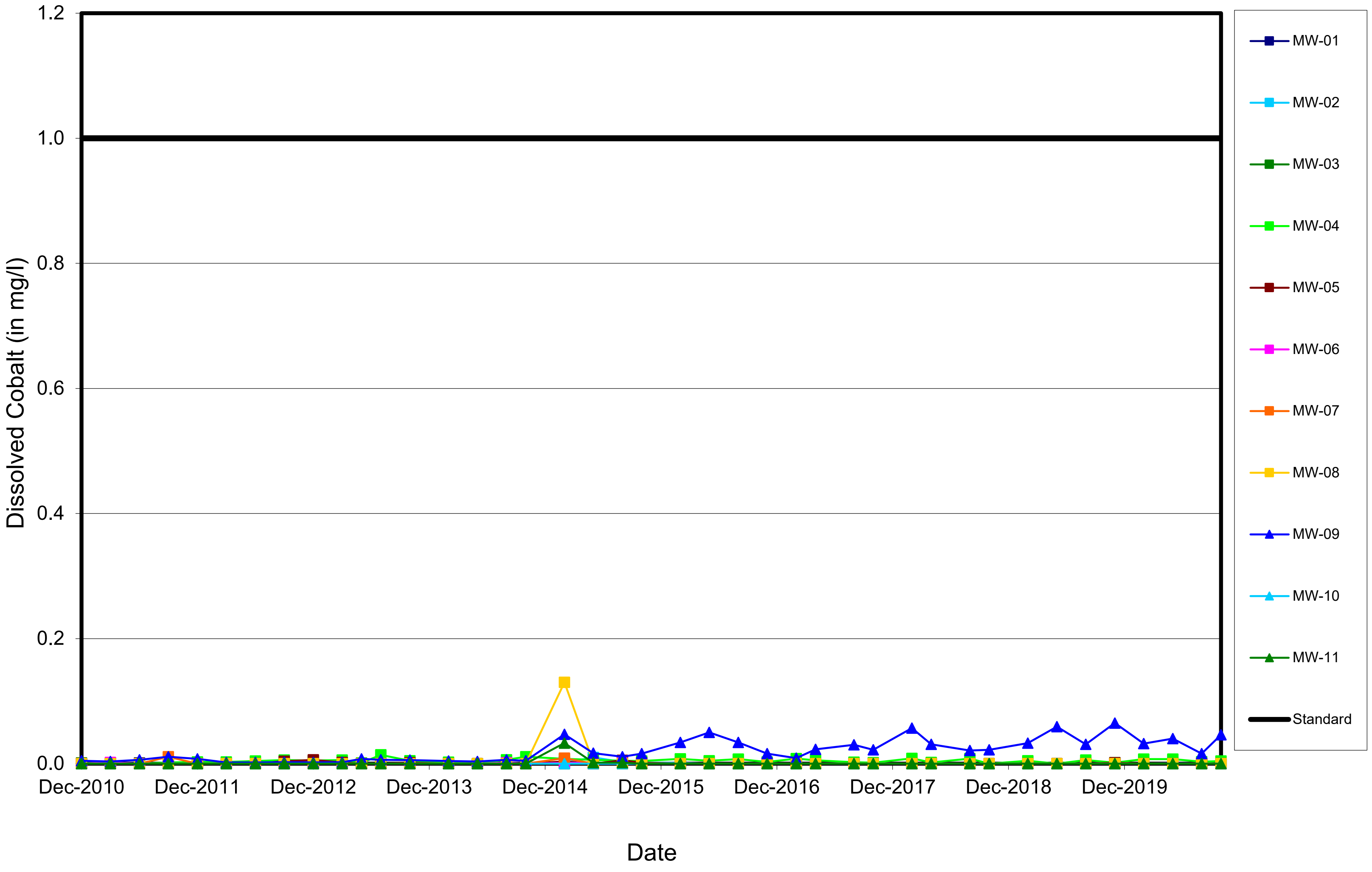
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Chromium vs. Time



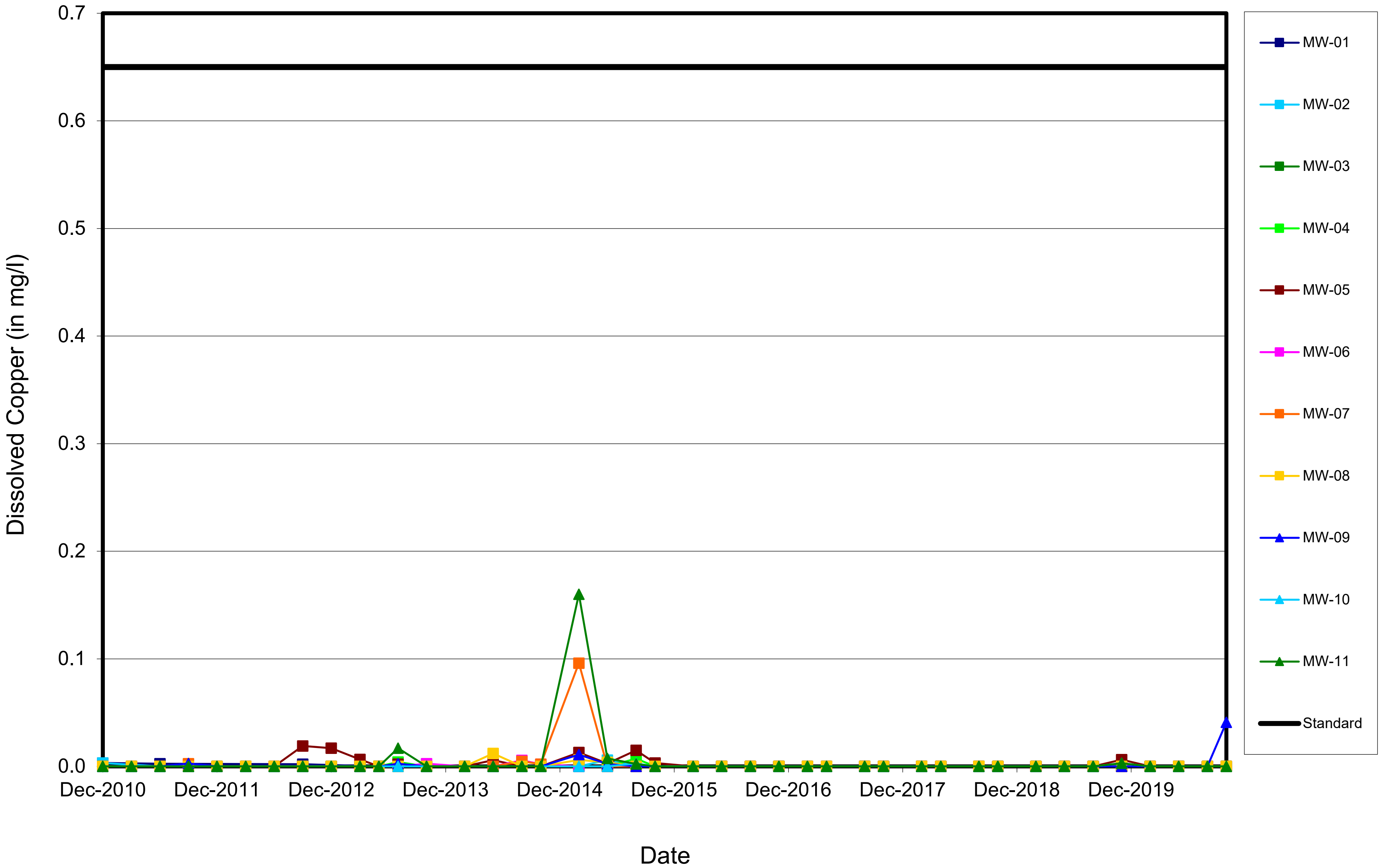
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Cobalt vs. Time



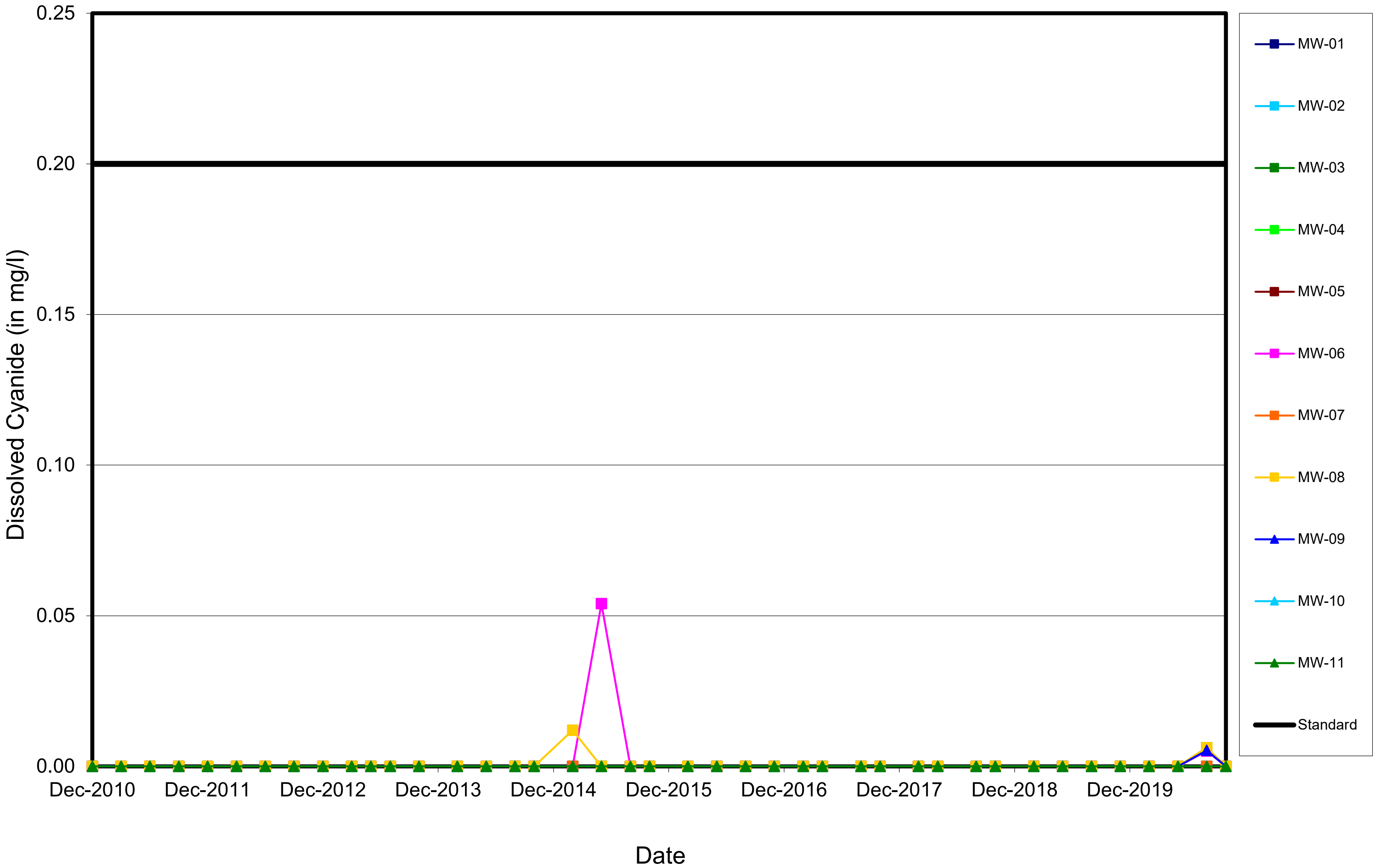
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Copper vs. Time



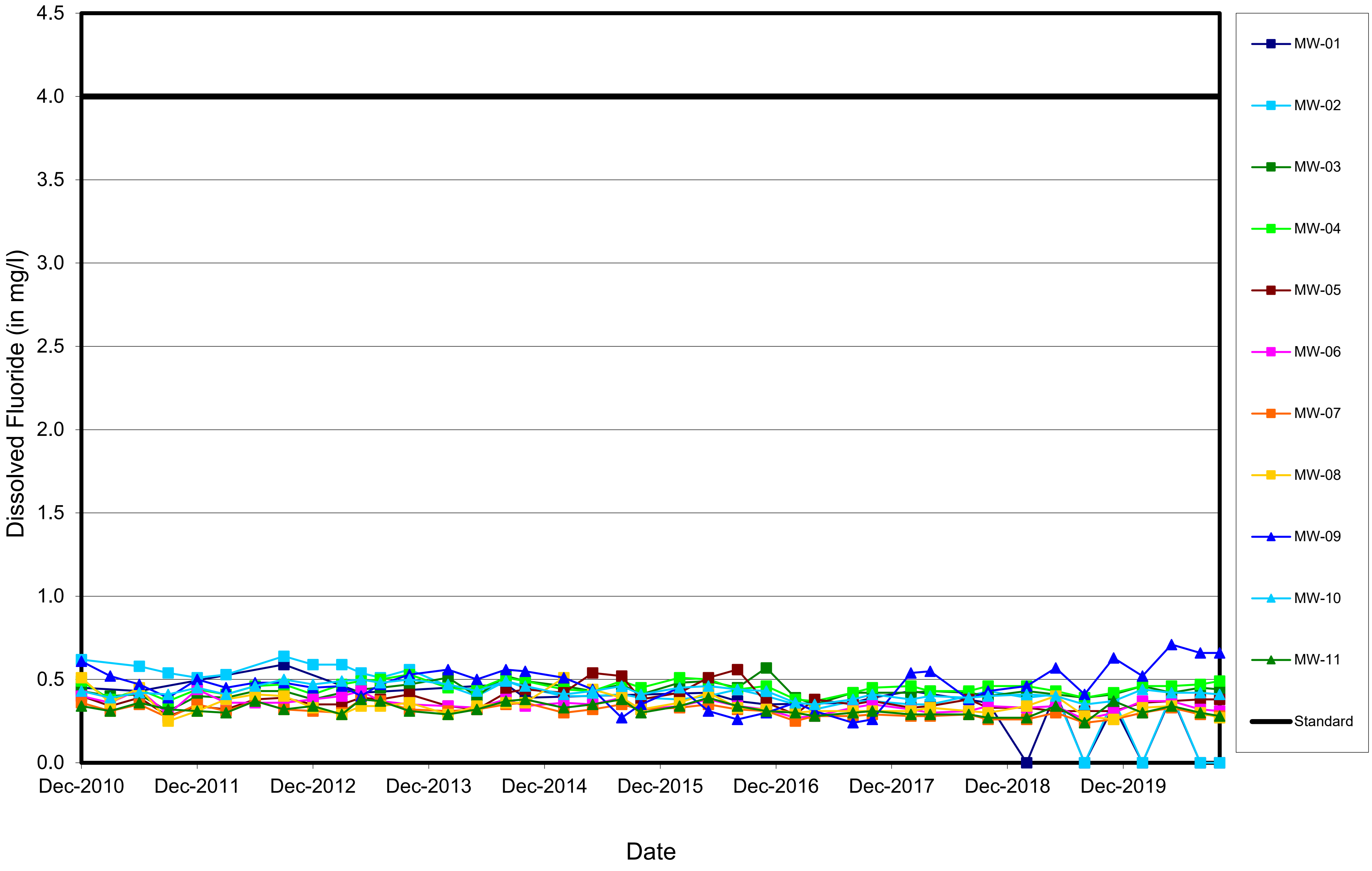
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Cyanide vs. Time



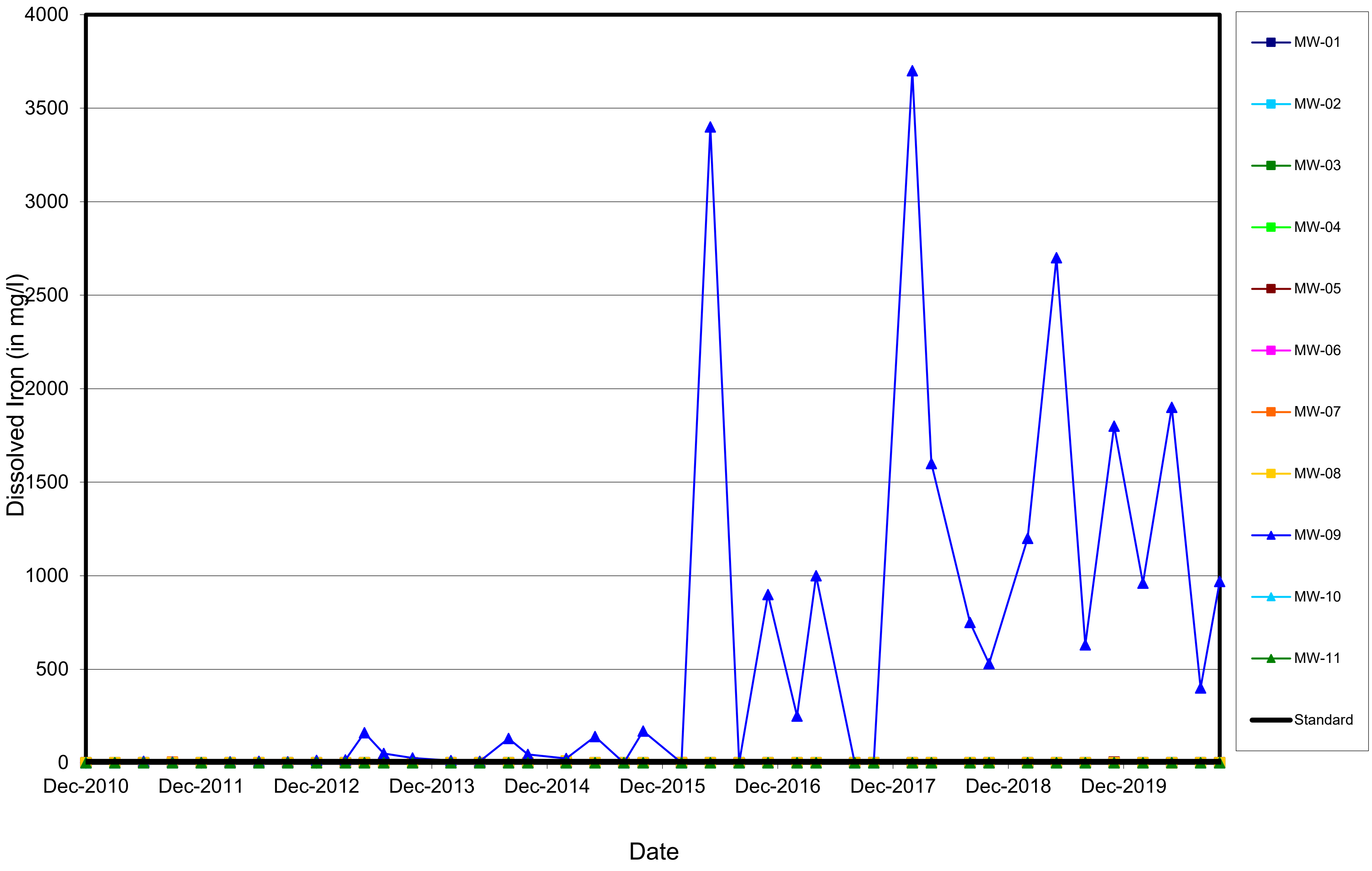
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Fluoride vs. Time



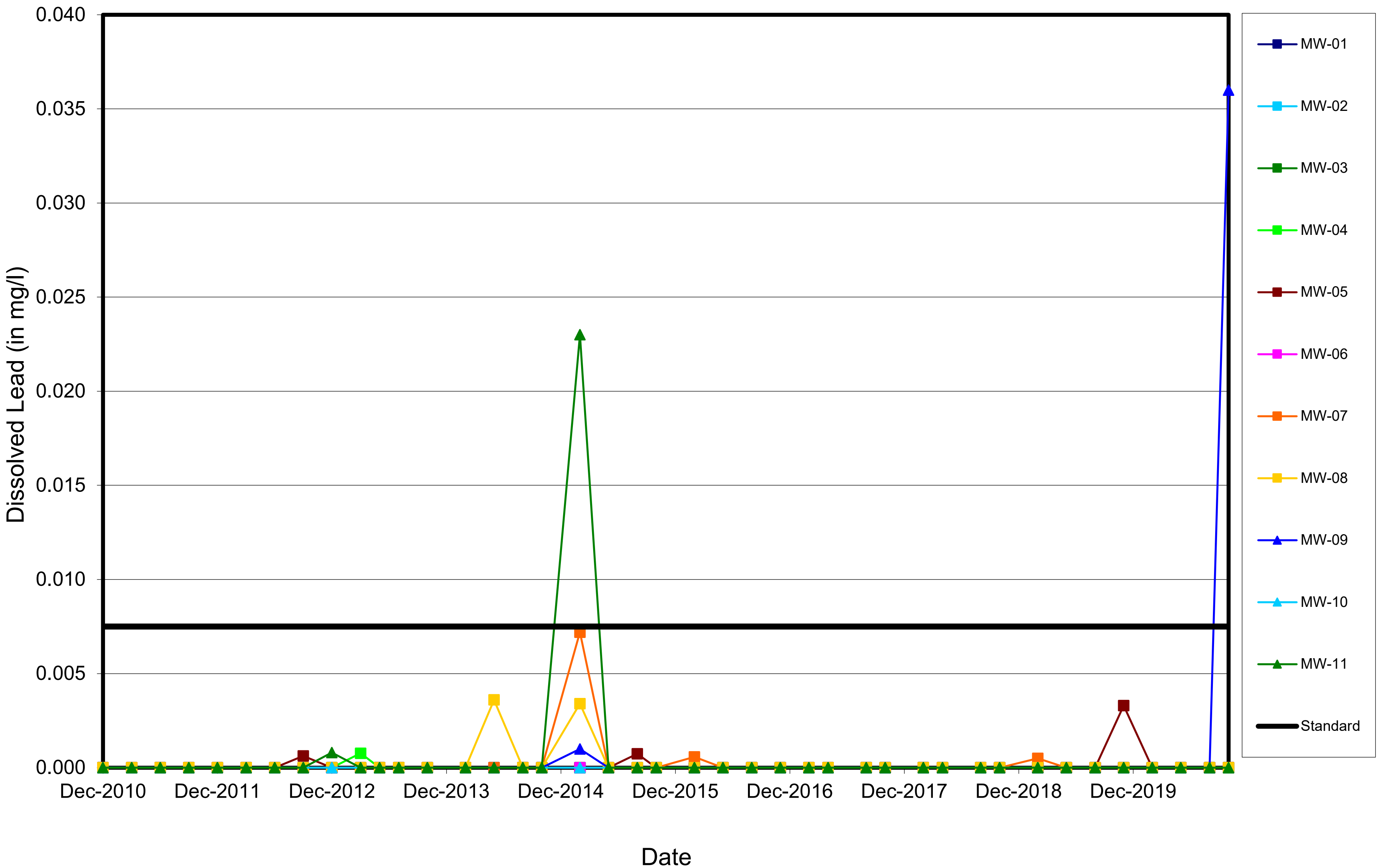
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Iron vs. Time



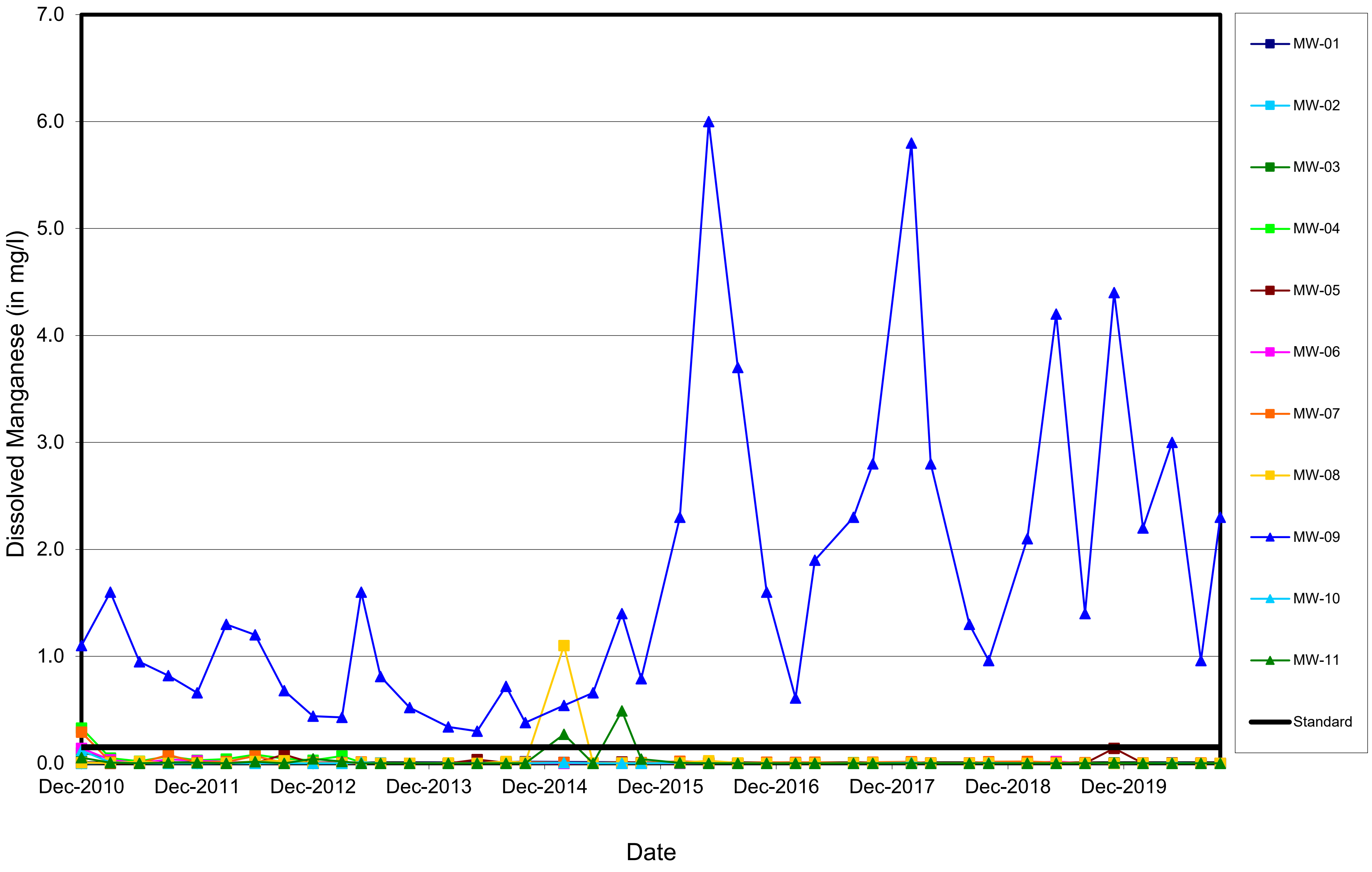
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Lead vs. Time



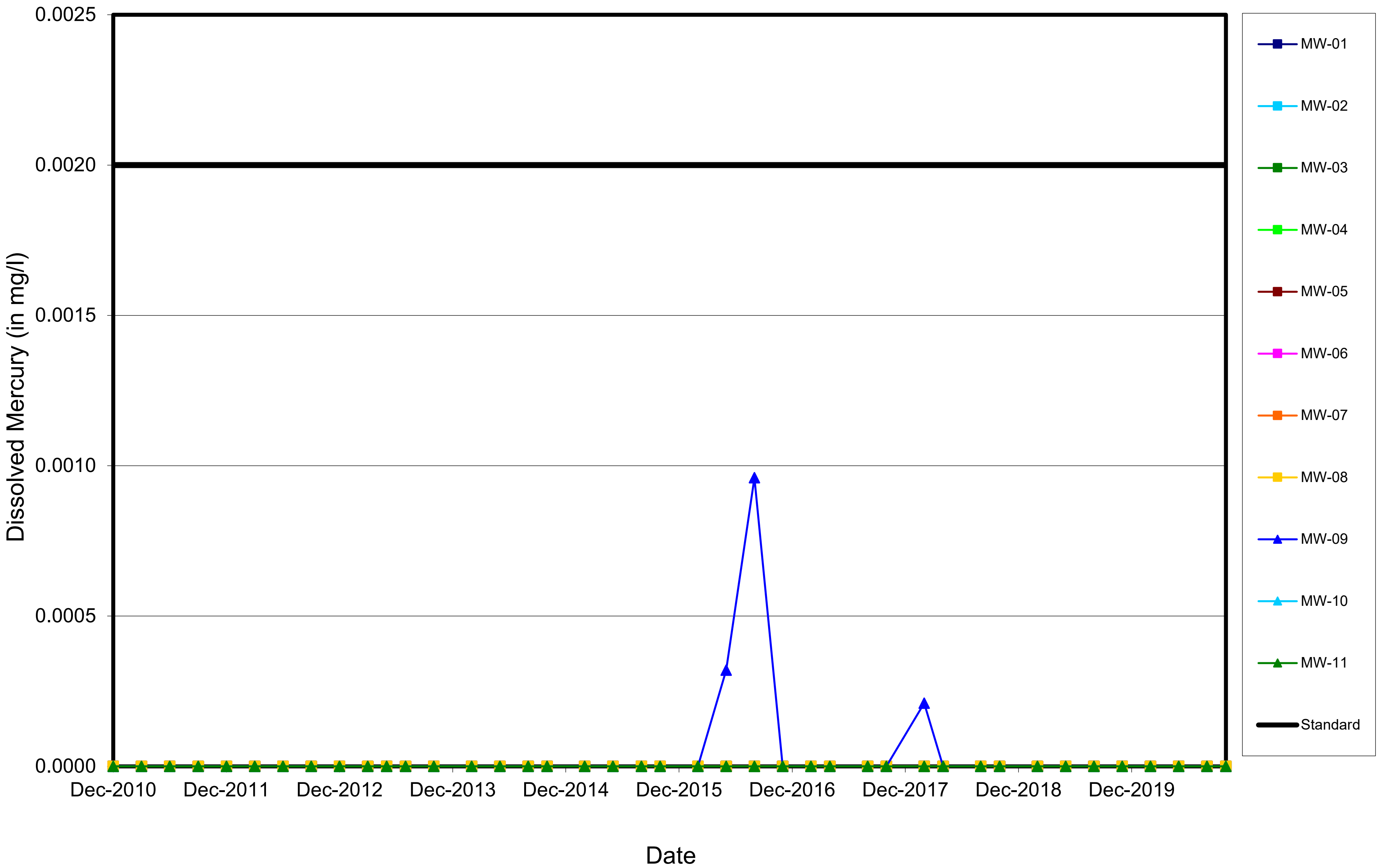
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Manganese vs. Time



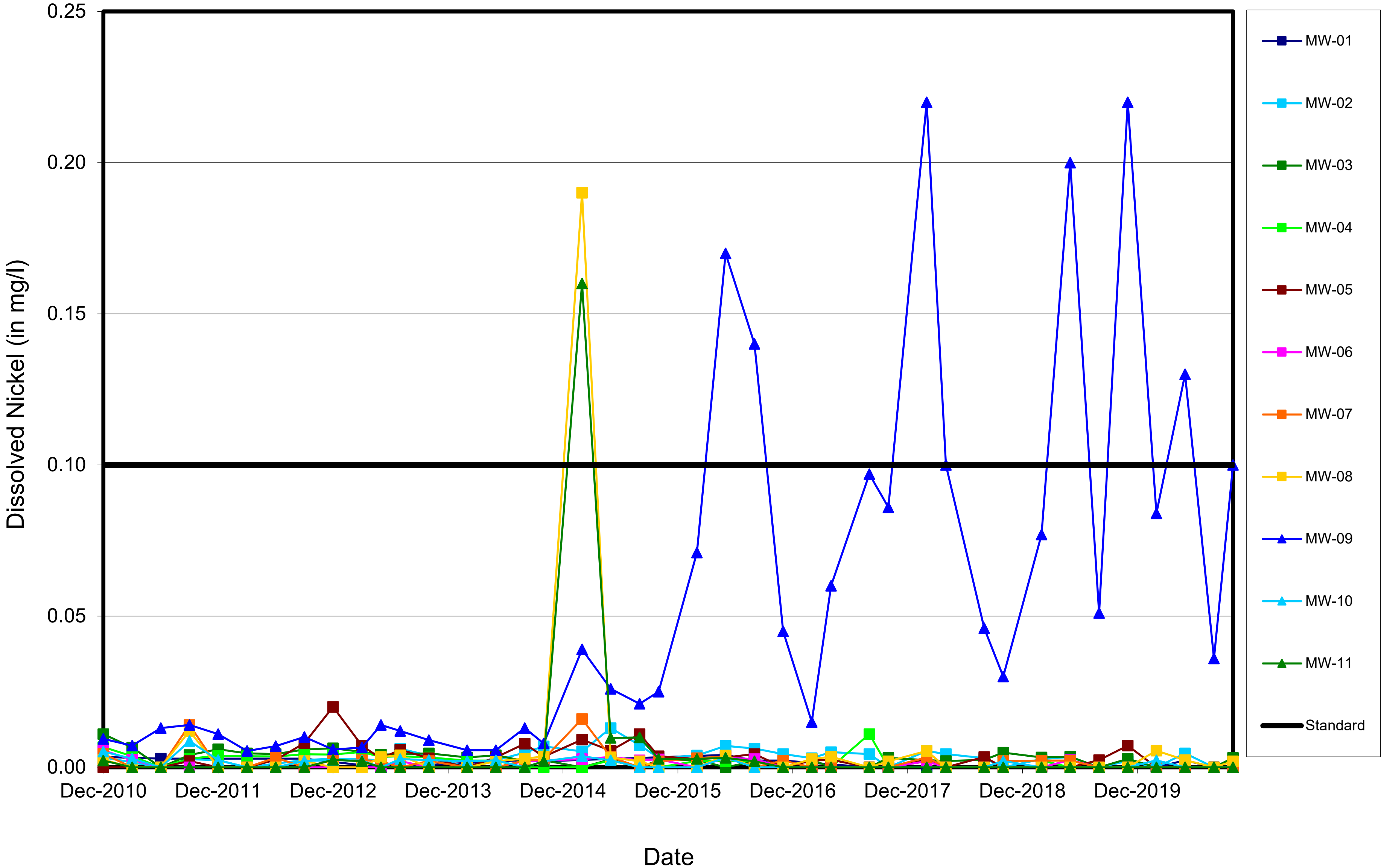
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Mercury vs. Time



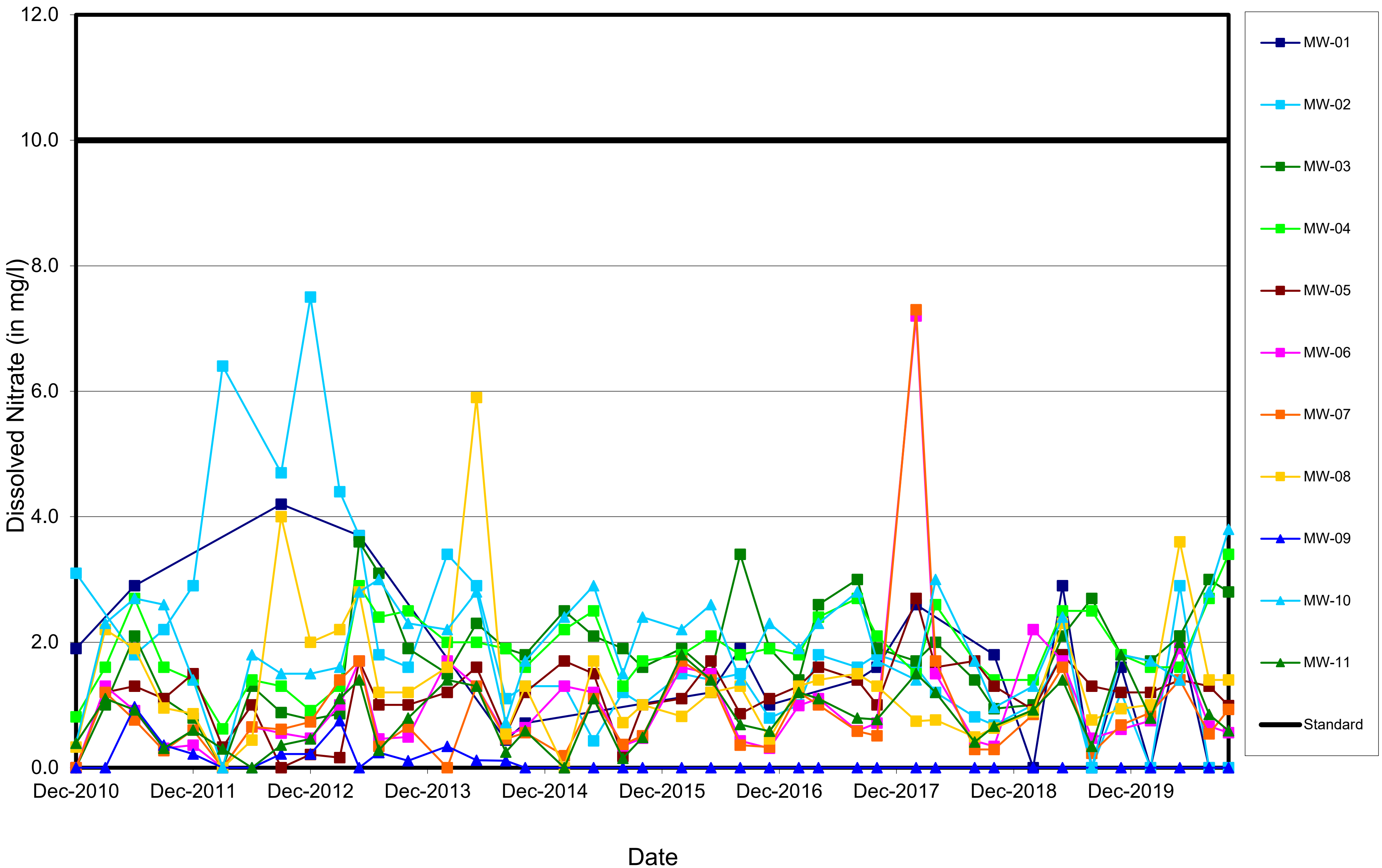
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Nickel vs. Time



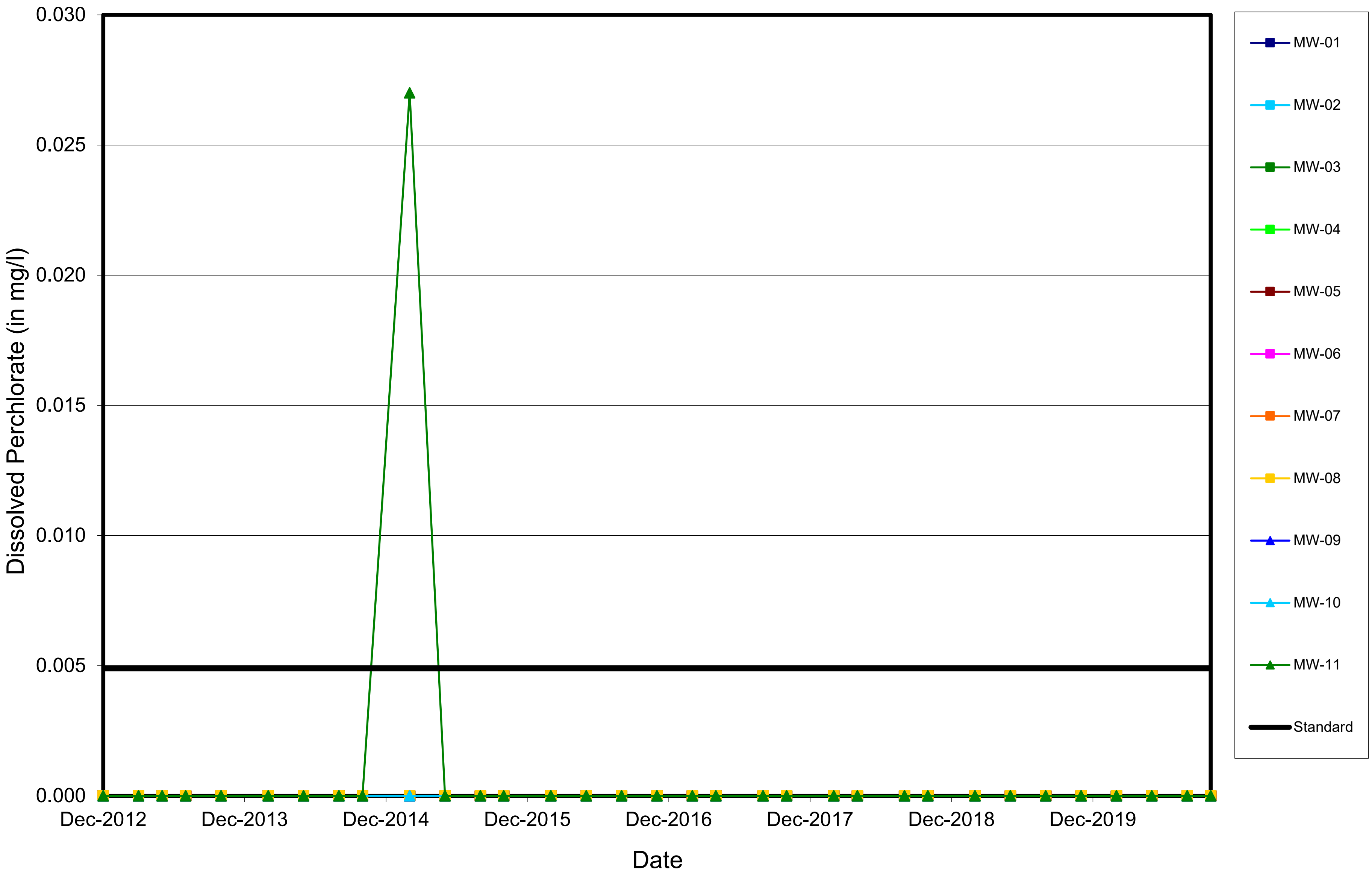
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Nitrate vs. Time



Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Perchlorate vs. Time



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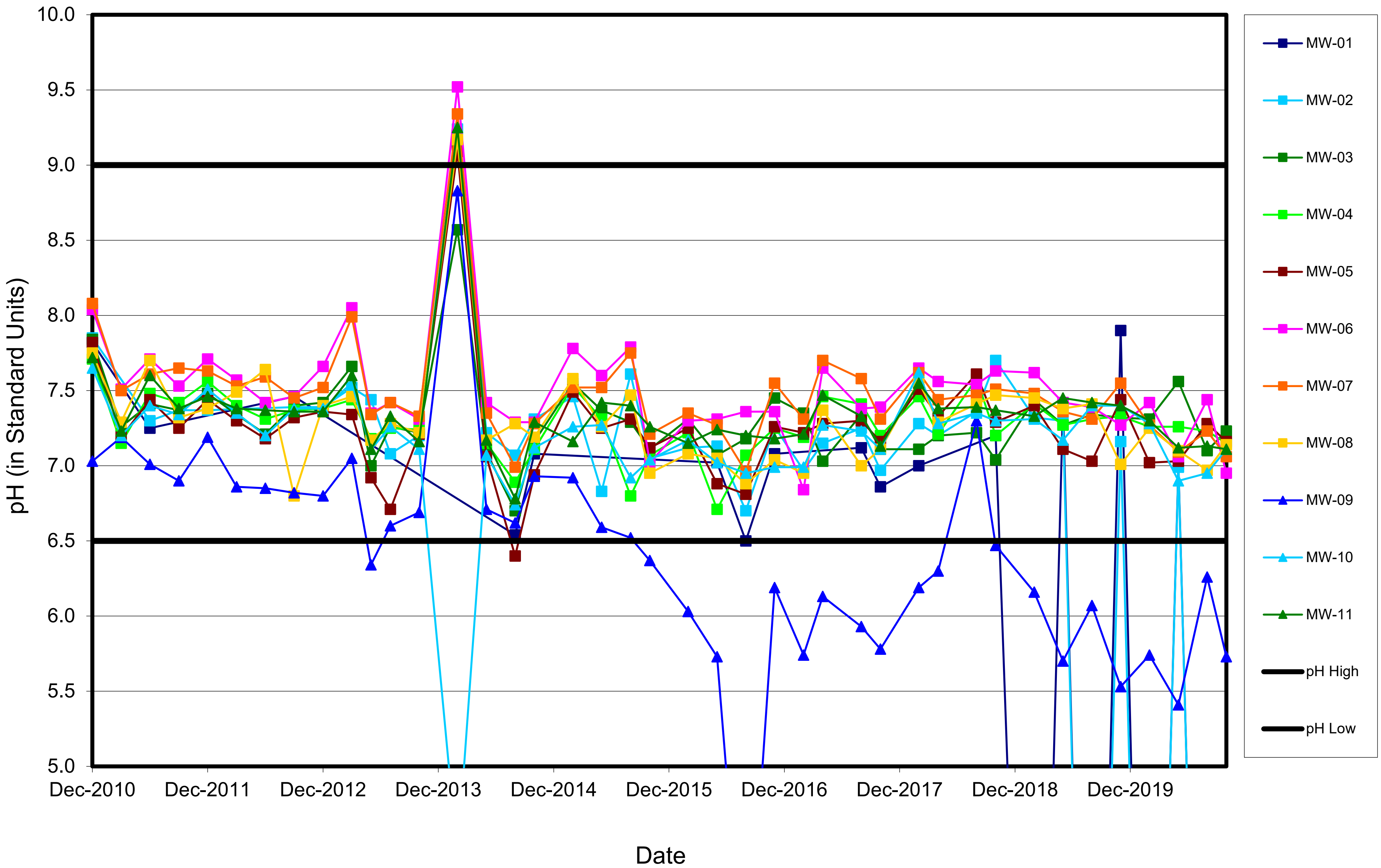
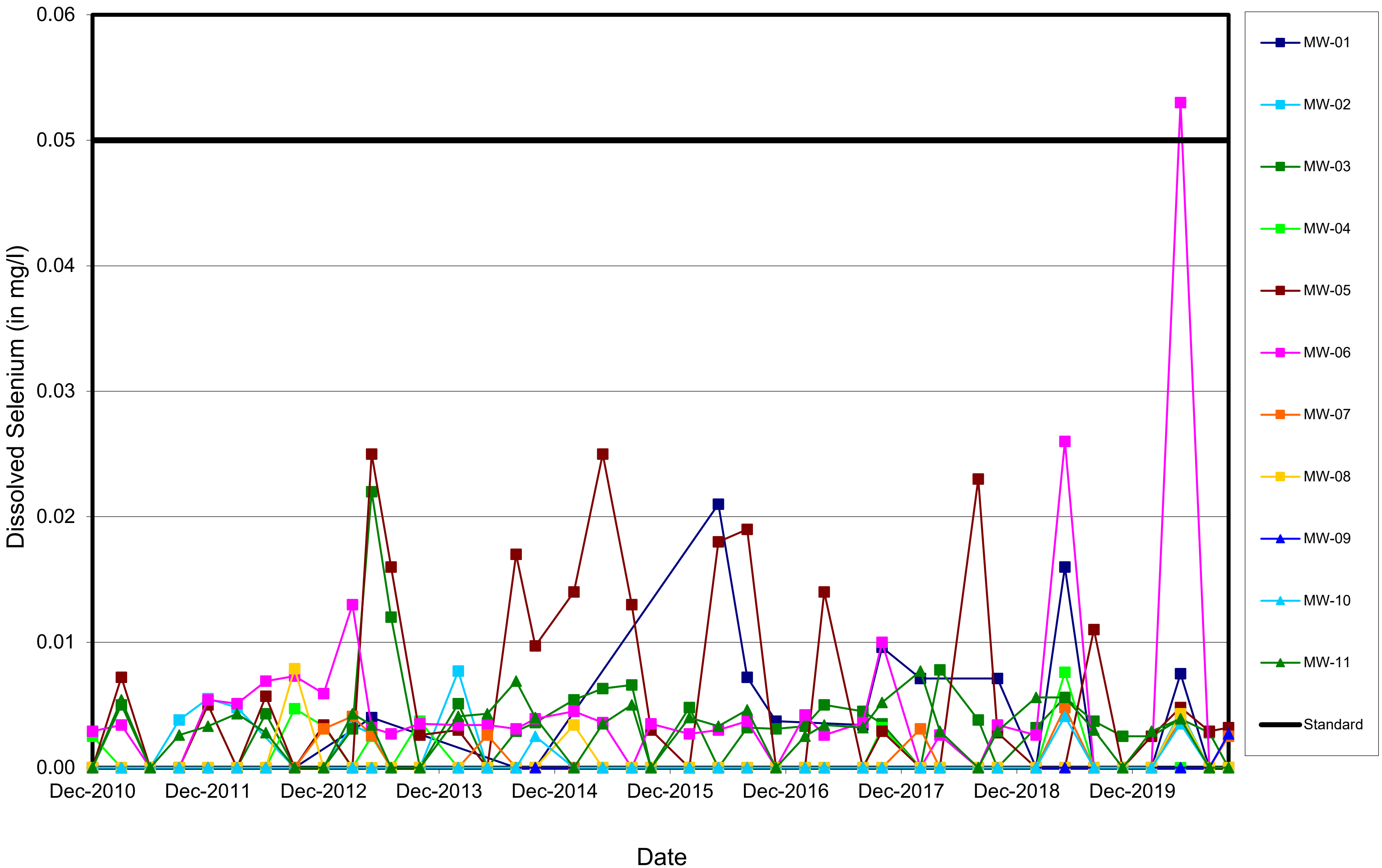
Midwest Generation Joliet Station #29, Joliet, IL

pH vs. Time



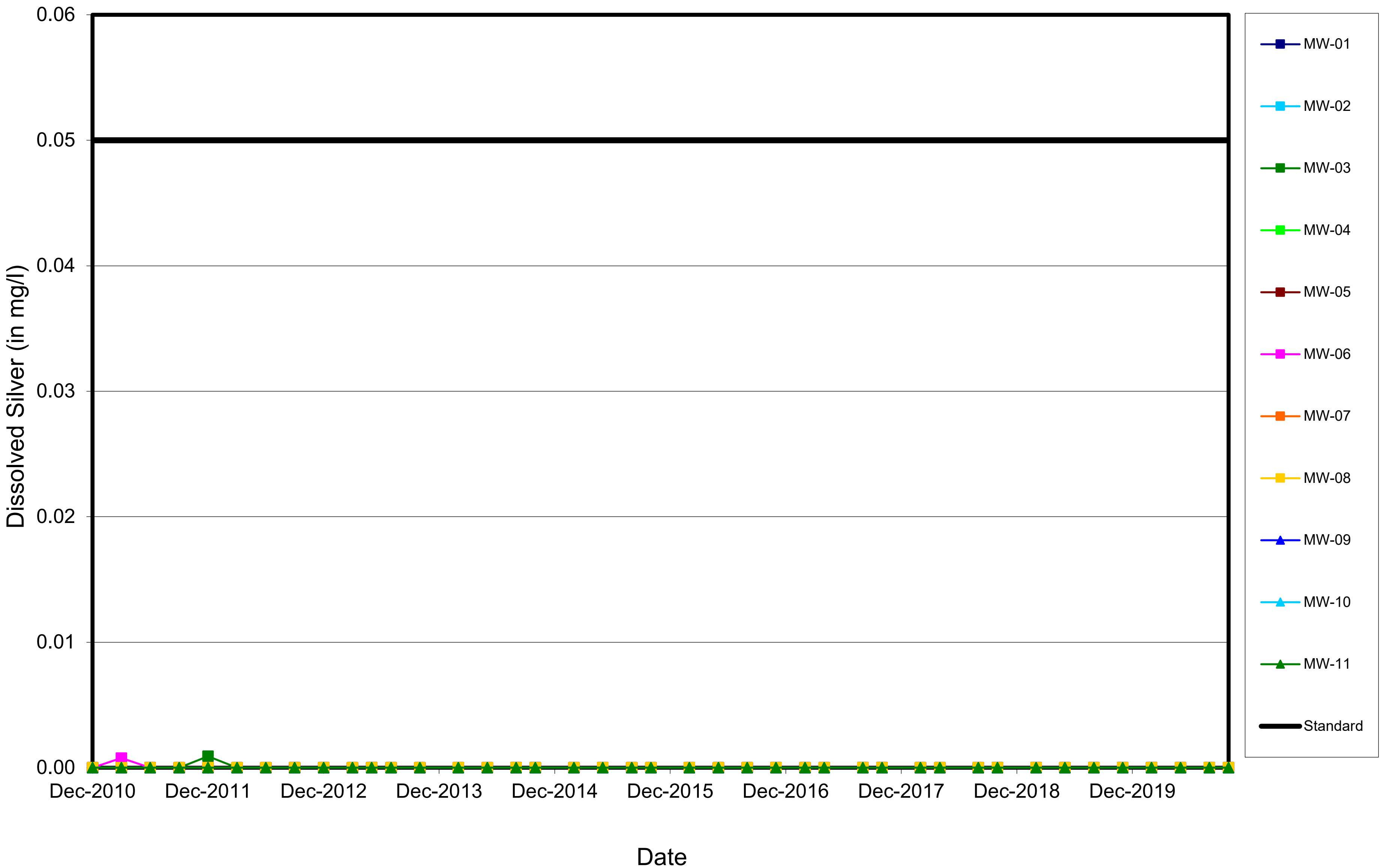
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Selenium vs. Time



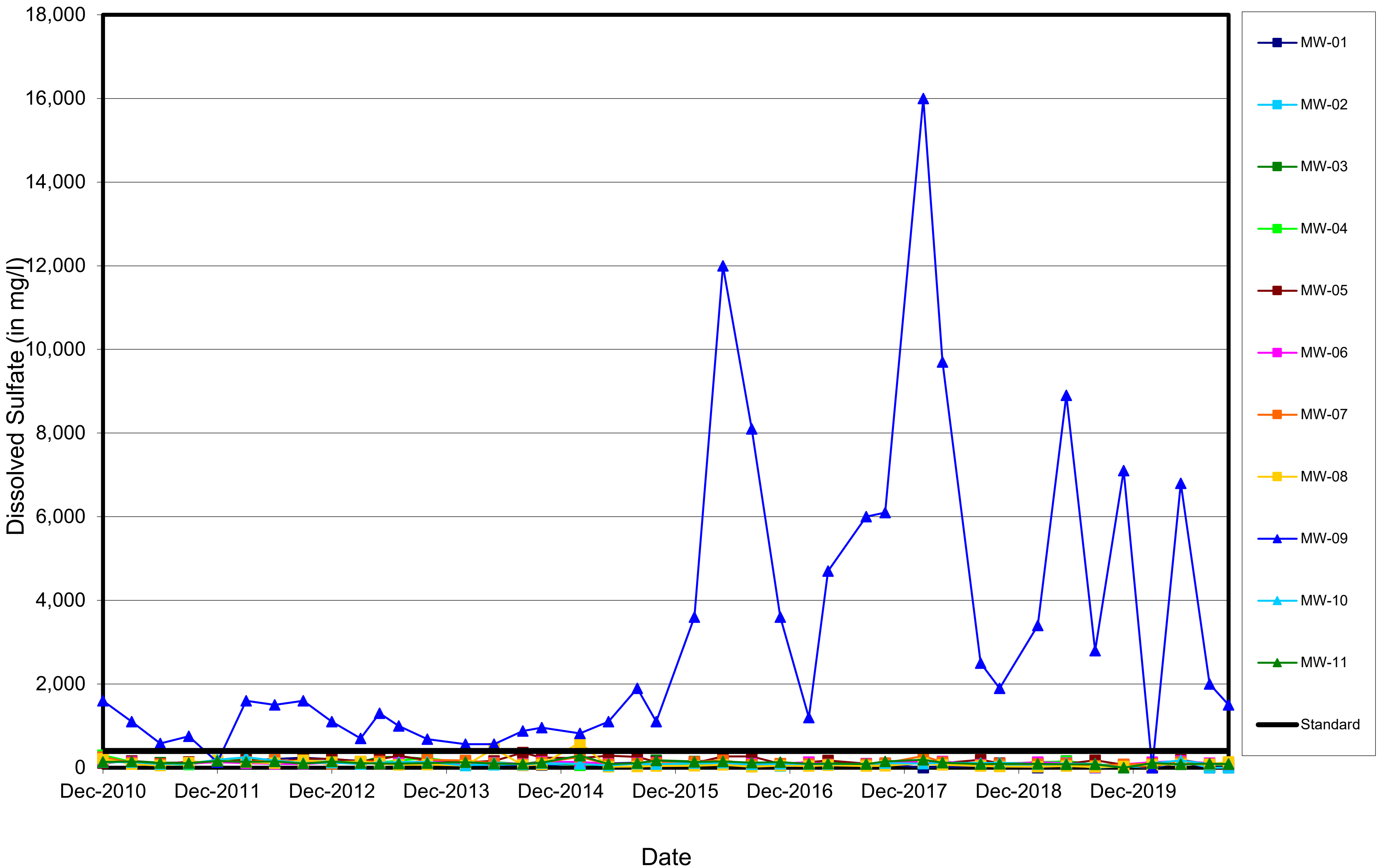
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Silver vs. Time



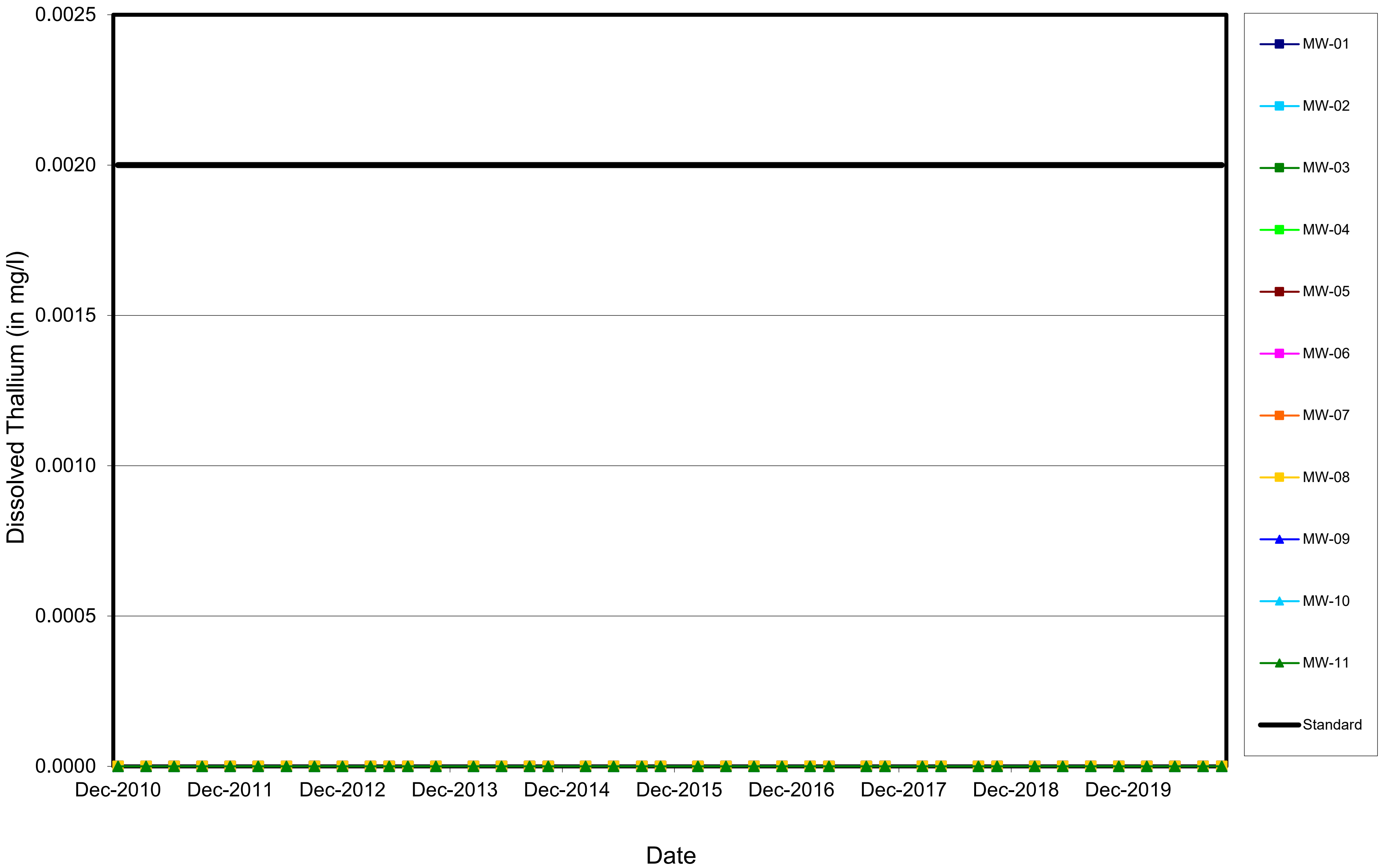
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Sulfate vs. Time



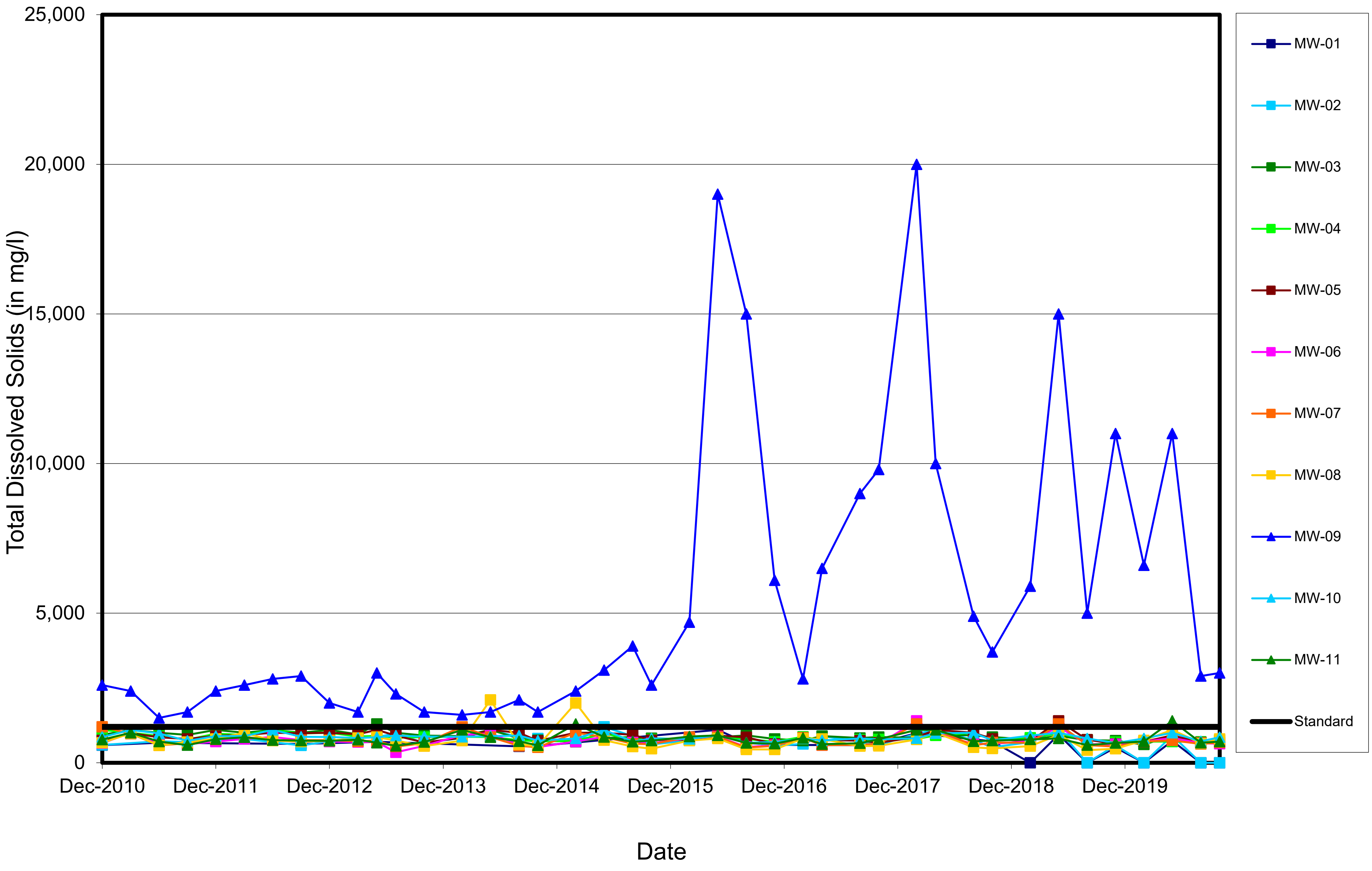
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Thallium vs. Time



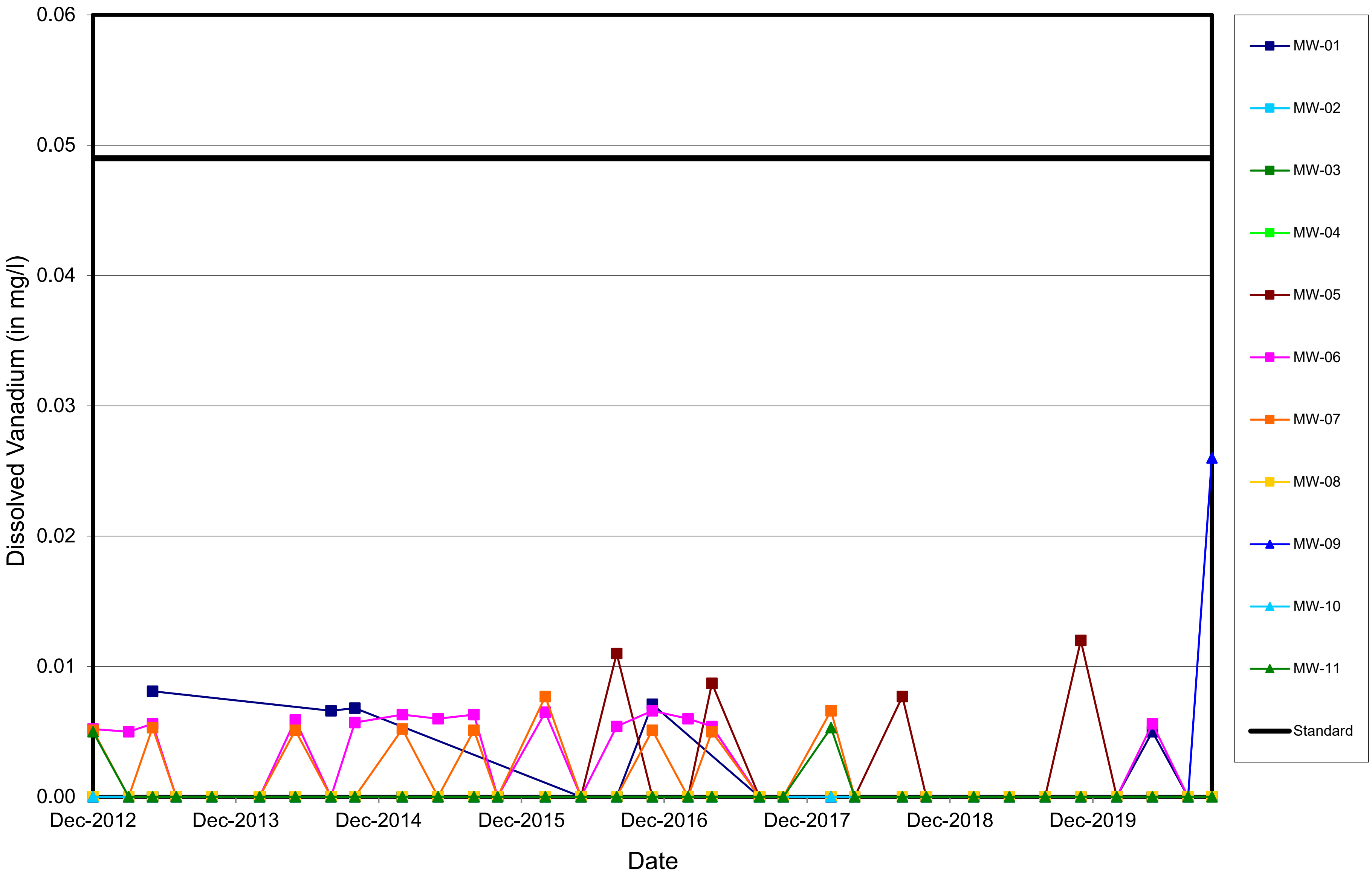
Midwest Generation Joliet Station #29, Joliet, IL

Total Dissolved Solids vs. Time



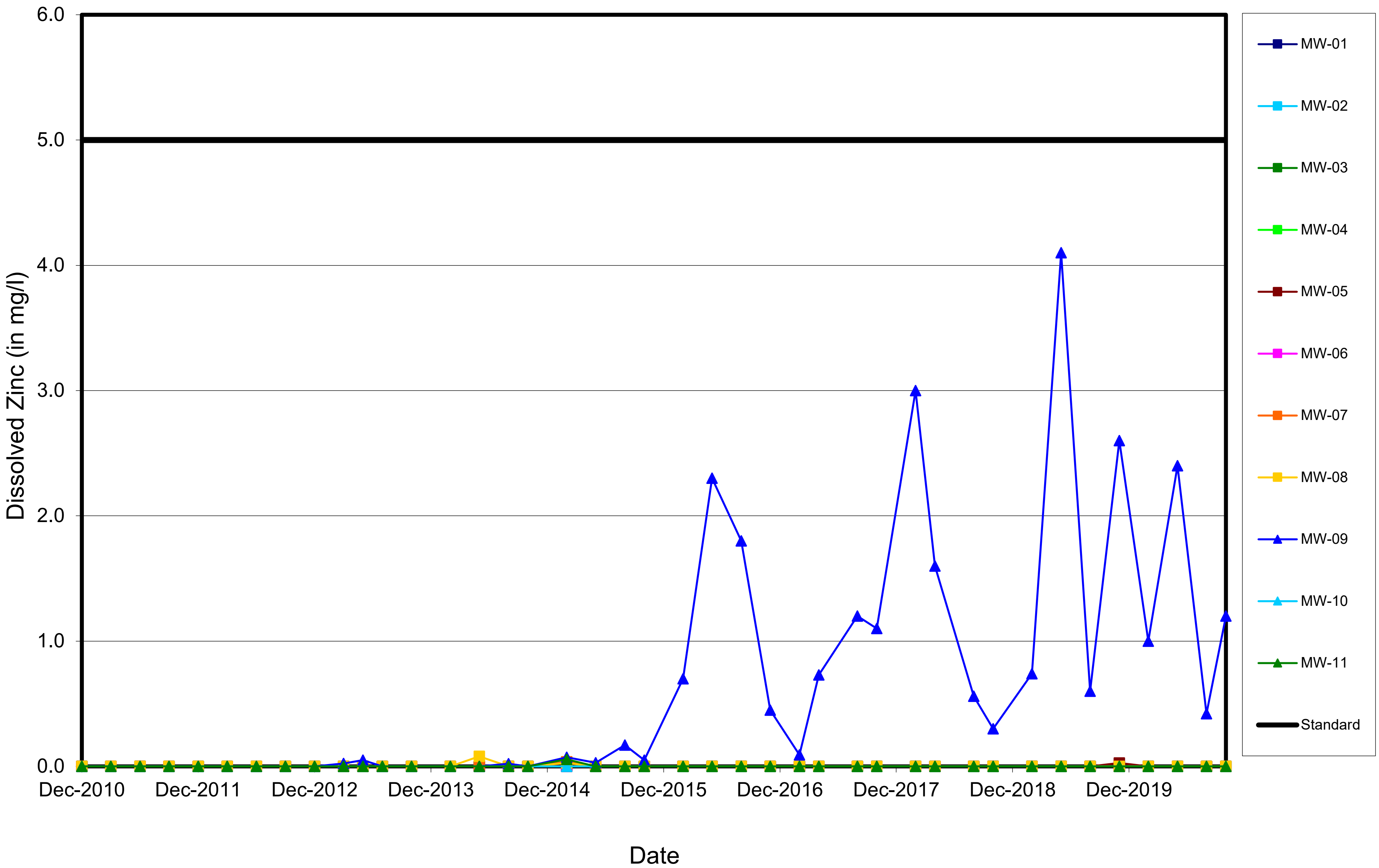
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Vanadium vs. Time



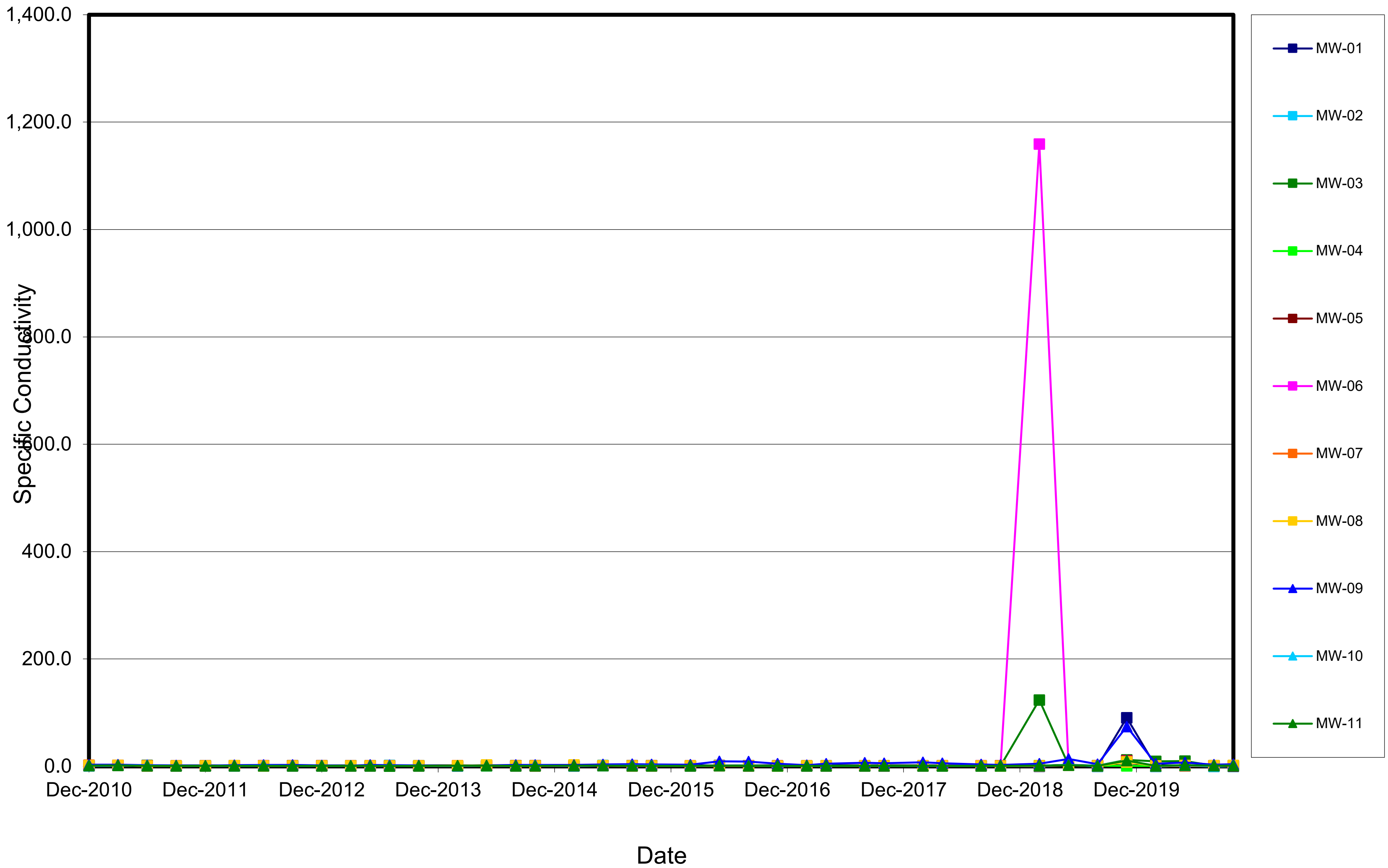
Midwest Generation Joliet Station #29, Joliet, IL

Dissolved Zinc vs. Time



Midwest Generation Joliet Station #29, Joliet, IL

Specific Conductivity vs. Time



ATTACHMENT G

David E Nielson
Curriculum Vitae

DAVID E. NIELSON
Geotechnical Engineer
Sr. Consultant / Sr. Manager

Sargent & Lundy

EDUCATION

Utah State University – B.S. Civil and Environmental Engineering - 1988

REGISTRATIONS

Professional Engineer – Illinois, Indiana, Michigan, Washington, Nevada

Previously Licensed Water Well Driller – Indiana, Tennessee and Louisiana

PROFICIENCIES

- Design of embankments, dikes and containment structures
- Evaluation of existing conditions of dams, dikes, landfills & other earthen structures
- Design and evaluation of production and monitoring well systems
- Selection of design parameters for foundation and earthen structures
- Design of shallow and deep foundation systems
- Design of pavement systems
- Reinforced earth structure design
- Geosynthetics applications in geotechnical and geo-environmental areas
- Geotechnical field and laboratory instrumentation, field testing and data acquisition
- Construction material field and laboratory instrumentation, field testing and data acquisition
- Forensic evaluation of concrete structures and earthen structures

RESPONSIBILITIES

Mr. Nielson is the process owner of geotechnical and groundwater well process in the S&L quality program. He is responsible for the selection of geotechnical design parameters, design and construction monitoring of foundation systems for projects at fossil and nuclear powered electric generating stations. Mr. Nielson performs and reviews examinations of dikes, dams and landfills at both nuclear and coal fired power plants. Additionally, Mr. Nielson actively participates in engineering geology evaluation of potential plant sites and plant structure foundations. Mr. Nielson serves as a committee member on the DFI Auger Cast Pile subcommittee.

EXPERIENCE

Mr. Nielson has over 30 years of experience in geotechnical engineering and construction material testing services. He has successfully performed shallow and deep foundation design for projects in virtually all geologic settings and directed construction material quality control services in over 30 states and over 10 countries. Additionally, he has specified, directed, and performed over one-thousand subsurface exploration programs.

In addition to the design and consultation services on earthen embankments, ponds, lakes and landfills, he supervises and performs annual examination of eight dams, which are up to 8 miles in length with residential properties within 1/8 mile of the dam toe.

He has designed numerous production wells, monitoring well programs, and structure under-drain/dewatering systems to mitigate the effects of groundwater seepage in several construction projects. Moreover, he has provided design and construction recommendations for tunnels under and bridges over Midwestern rivers.

He has served as an expert witness for construction defect litigation in the areas of soil and concrete.

He provides our clients with an unusual perspective and experience. In addition to his design experience, he has worked as a construction laborer on the construction of a large coal fired power plant in Utah, geotechnical driller and geotechnical engineer with design work and quality control services in many of the major physiographic regions of the U.S.

Mr. Nielson's relevant experience with Sargent & Lundy LLC (since 2008) includes:

- **Hydroelectric Dam – Peruvian Andes**
  Before visiting the site, Mr. Nielson reviewed the prior design documents, prior reports, studies and repair designs to aid in our evaluation of the repair of a vertical crack and the general integrity of the confidential hydroelectric dam. The existing dam is an arched concrete gravity structure with an 88-meter maximum height and a crest length of 274 m. Our evaluation of the structure included recommendations for physical repairs of an abutment to improve stability and supplemental monitoring equipment to provide insight into the structure's response to loading (2018).

- **Power Stations – Wyoming**
  Performing conceptual and detailed design of several new impoundments to serve as evaporation and disposal ponds for Coal Combustion Residual waste streams. Dam heights will range up to 50 feet and the total impoundment area will exceed 400 acres. (2017 - 2020)

- **Two Power Stations – Texas**
  The two stations represent over 4400 megawatts of coal fired generating capacity. Served as Owner's Engineer to develop closure plans, hazard classifications, structural stability and annual inspections of coal ash ponds and landfills (2015 - 2018).

- **Power Station – Indiana**
  Performed emergency dam inspection to evaluate damage and recommend repair alternatives for a sand filled dam which experienced significant erosion during beyond design basis storm event. (2012)

- **Power Station – Pennsylvania**
  Formulated of design parameters for shallow spread, drilled piers and deep micropile foundation systems for SCR system constructed above existing precipitators and other plant features (2010-2012).

- **Power Station – Pennsylvania**
  Developed of geotechnical exploration specifications and formulated ACIP foundation design details, specifications, and performance criteria (2009).

- **Power Station – Nebraska**
  Developed specification for geotechnical exploration and formulated design criteria for foundation systems for major emission control project (2008).

- **Generation Project – Upper Midwest**
  Prepared a study of groundwater availability for a new combined cycle generating station (2016).

Mr. Nielson's relevant experience with other firms (1988 - 2008) includes:

- **Elkhart County Jail – Elkhart, Indiana**
  Determination of engineering design parameters for shallow foundations and utility tunnels for 1000-bed, seven building correctional campus. This work included monitoring and designing repairs to control seepage into a major utility tunnel that was constructed with inferior concrete (2004 - 2008).

- **Elkhart County Landfill/Jail – Elkhart, Indiana**
  Mr. Nielson designed extraction, compression and transmission system to remove landfill gas and transport it for beneficial use at the 1000 bed jail (2006 - 2008).

- **Earth Movers Landfill – Elkhart County, Indiana**
  Directed Construction Quality Control and Assurance (CQA/CQC) services to assure state regulators the clay and membrane liners were constructed in accordance with the permit requirements (2007).

- **Prairie View Landfill – St. Joseph County, Indiana**
  Directed Construction Quality Control and Assurance (CQA/CQC) services to assure state regulators the clay and membrane liners were constructed in accordance with the permit requirements (2006).

MEMBERSHIP

Deep Foundation Institute

EXHIBIT 4

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
STANDARDS FOR THE DISPOSAL	)	
OF COAL COMBUSTION RESIDUALS	)	R 2020-019
IN SURFACE IMPOUNDMENTS:	)	(Rulemaking - Water)
PROPOSED NEW 35 ILL. ADM.	)	
CODE 845	)	

<u>PRE-FILED TESTIMONY OF DAVID E. NIELSON, P.E.</u>

Introduction

My name is David E. Nielson I am a Sr. Consultant and Sr. Manager with Sargent & Lundy (S&L). S&L is an Illinois-based engineering firm with over 125 years of history focused on the design of electric power generation and transmission systems. I have over 30 years of professional experience as a geotechnical and civil engineer. I have been a licensed professional engineer (civil) in the state of Illinois in good standing since 1993. My professional career has included services associated with coal combustion residuals (CCR), industrial waste surface impoundments, industrial waste landfills, and municipal solid waste (MSW) landfills in numerous states and regulatory environments since 1990. My curriculum vitae is attached.

I have been retained on behalf of Midwest Generation to review and comment on the Illinois Environmental Protection Agency's (IEPA) proposed Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments (Reference 1, which is referred to herein as the "Proposed Illinois CCR Rule").

My testimony will focus on the following sections of the Proposed Illinois CCR Rule:

- Section 845.420: Leachate Collection and Removal System
- Section 845.770: Retrofitting

COMMENTS ON SECTION 845.420
LEACHATE COLLECTION AND REMOVAL SYSTEM

Leachate Collection & Removal System Requirements

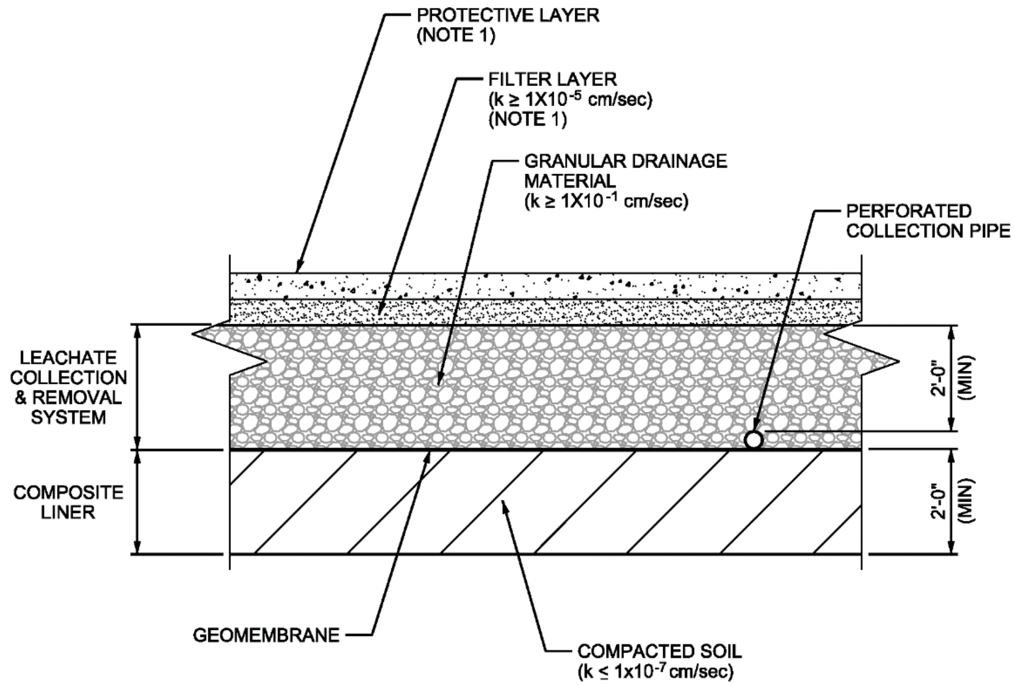
The IEPA has incorporated a leachate collection requirement for new and retrofitted CCR surface impoundments in Section 845.420 of the Proposed Illinois CCR Rule. This essentially requires a drainage layer at the base of new and retrofitted CCR surface impoundments with the purpose of reducing the hydraulic head on the impoundment's composite liner system. Per the IEPA:

> "A new CCR surface impoundment must be designed, constructed, operated and maintained with a leachate collection and removal system. The purpose of this Section is to minimize the amount of head on the liner system which will decrease the potential for the movement of fluids through the liner. The system is similar to leachate collection systems required for solid waste landfills." (Reference 1, Statement of Reason, Part IV [1] ("Regulatory Proposal: Language"), Section 845.420: Leachate Collection and Removal System)

Section 845.420 of the Proposed Illinois CCR Rule details the requirements for leachate collection systems for new and retrofitted CCR surface impoundments. For this testimony, I am focusing on the following excerpts from the Proposed Illinois CCR Rule (paragraph numbering from the rule is preserved for clarity):

a) The leachate collection and removal system must:
   1) be placed above the liner required by Section 845.400 or Section 845.410;
   2) have placed above it a filter layer that has a hydraulic conductivity of no less than 1 $x10^{-5}$ cm/sec;
   4) be constructed of drainage materials with a hydraulic conductivity of 1×10^{-1} cm/sec or more and a thickness of 24 inches or more above the crown of the collection pipe; or constructed of synthetic drainage materials with a transmissivity of 6×10^{-4} m^2/sec or more;
   7) have collection pipes
      A) designed such that leachate is collected at a sump and is pumped or flows out of the CCR surface impoundment;

These requirements are graphically depicted in Figure 1. When a new or retrofitted CCR surface impoundment is operating, the CCR transport water (leachate) will be directly above the protective layer, which would likely be gravel or crushed limestone.



MINIMUM REQUIREMENTS PROPOSED BY ILLINOIS EPA FOR
CCR SURFACE IMPOUNDMENT LINER & LEACHATE COLLECTION & REMOVAL SYSTEM

FIGURE 1

NOTE 1: PROPOSED 35 ILL. ADM. CODE 845.420 DOES NOT SPECIFY THICKNESS REQUIREMENTS FOR THE PROTECTIVE AND FILTER LAYERS.

The Federal CCR Rule (Reference 2) does not require leachate collection and removal systems for the transport water in CCR surface impoundments. During the rulemaking phase of these federal CCR disposal standards, the US EPA evaluated if a leachate collection and removal system should be required for new and retrofitted CCR surface impoundments. In the 2010 proposed rule (Reference 3), the US EPA proposed a leachate collection and removal system be installed between the flexible membrane liner (FML, i.e., geomembrane) and low-permeability soil components of the impoundment's composite liner system. This was a modification of the double liner system required by the US EPA for hazardous waste land disposal units, which was justified by the US EPA's initial CCR risk assessment in which the agency concluded that "composite liners effectively reduce risks from all constituents to below the risk criteria for both landfills and surface impoundments" (Reference 3, p. 35174). The US EPA continued, "[T]he Agency believes a composite liner system would be adequately protective of human health and the environment and a double liner system would be unnecessarily burdensome" (Reference 3, p. 35174).

Following several years of additional research and review of comments on the 2010 proposed rule, in 2015 the US EPA finalized the Federal CCR Rule, in which the agency concluded that it was counterproductive and erroneous to require a leachate collection and removal system between the two component's of a CCR surface impoundment's composite liner system (Reference 2, p. 21369). The agency stated:

> "The proposed requirement for CCR surface impoundments to construct a leachate collection system between the FML and soil components would prevent the direct and uniform contact of the upper and lower components and, therefore, compromise the integrity of the composite liner. For this reason, EPA is not requiring a leachate collection and removal system for new surface impoundments or any lateral expansion of a CCR surface impoundment." (Reference 2, p. 21369)

It is notable that the US EPA did not require a leachate collection and removal system for CCR surface impoundments. The agency could have required the leachate collection and removal system be installed above the impoundment's composite liner system (as the Proposed Illinois CCR Rule), which would maintain the integrity of the liner. However, after performing an exhaustive risk assessment, which included modeling of and reviewing the available data on both proven and potential damage cases , the agency determined that a leachate collection and removal system was not necessary for CCR surface impoundments to be protective of human health and the environment.

Risk Evaluation of CCR Surface Impoundments Without Leachate Collection and Removal Systems

The US EPA performed an exhaustive risk assessment during the development of the Federal CCR Rule. This EPA risk assessment used mathematical models to determine the rate at which chemical constituents may be released from different CCR waste management units, to predict the fate and transport of these constituents through the environment, and to estimate the resulting risks to human and ecological receptors. In addition to extensive sensitivity analysis and as a further method of validation, EPA compared the results of the sensitivity and uncertainty analyses with proven and potential damage cases. Together these analyses and comparisons show that there is a high degree of confidence in the principal findings of the probabilistic analysis.

The findings from this analysis are presented in a detailed public report (Reference 4). The stated purpose of this study was:

> "…to characterize the risks that may result from the current disposal practices for coal combustion residuals (CCRs) and provide a scientific basis for the development of regulations necessary to protect human health and the environment under the Resource Conservation and Recovery Act (RCRA)." (Reference 4, p. ES-1)

One of the conclusions of this risk analysis was:

> "**Composite liners** were the only liner type modeled that **effectively reduced risks** from all pathways and constituents **far below human health and ecological criteria** in every sensitivity analysis conducted." (Bolding added for emphasis) (Reference 4, p. ES-7)

To validate the modeling, the study also compared the results to proven and potential damage cases. This comparison was summarized:

> "Due to the differing nature of these two sources of information, a direct comparison would not be relevant. However, general characteristics and conclusions from the damage cases are relevant to support the findings of the risk assessment, and are discussed below. …**No damage cases were identified for composite-lined units**. This agrees well with the results of the sensitivity analyses, which showed … … that **risks for composite-lined units were far below all cancer and noncancer criteria**." (Bolding added for emphasis) (Reference 4, p. 5-47)

Based on the conclusions made in US EPA's Risk Assessment (Reference 4) and the lack of damage cases for composite-lined CCR surface impoundments, I agree with the US EPA's determination that a leachate collection and removal system is not necessary for CCR surface impoundments to be protective of human health and the environment.

In written questions regarding the US EPA's Risk Assessment (Reference 4) the IEPA was asked, "Has IEPA reviewed that risk assessment?" The IEPA response was "No. The Agency is aware this document exists." (Reference 5, Page 37, Agency's response to Q 3.a). When asked "Did IEPA rely upon U.S. EPA's risk assessment to support its Part 845 proposal?" the agency responded, "Only to the extent that USEPA's risk assessment was used by USEPA to develop the requirements of Part 257." (Reference 5, Page 37, Q 3.b).

As a licensed professional engineer, I believe that valid scientific studies, similar to the US EPA's Risk Assessment, should be the primary basis for environmental regulation, which does not appear to be the case for the leachate collection and removal system requirements in the Proposed Illinois CCR Rule. Understanding that the IEPA and the Illinois Pollution Control Board are on a very short deadline pursuant to the new Section 22.59 of the Illinois Environmental Protection Act, both agencies should look to the thorough study and analysis conducted by the US EPA when they developed the Federal CCR Rule, as well as the recommendations against leachate collection systems in impoundments. Following a thorough review of this information by the IEPA and the Pollution Control Board, I suggest that the Pollution Control Board should not require a leachate collection and removal system for new and retrofitted CCR surface impoundments in Illinois.

Operational Implications of Leachate Collection and Removal from Impoundments

The collection and removal of leachate from MSW landfills is a well-established requirement and an industry standard. However, removing CCR transport water (leachate) from surface impoundments is not an industry standard because it is not practical given the inherent operation of a surface impoundment. In fact, calling the transport water "leachate" is a bit of a misnomer. Leachate from an MSW landfill is very different than transport water used to move CCR from a power station; the volume and purpose of liquid is vastly different. MSW landfill leachate is the combination of precipitation that falls on open cells that percolates through the waste to the leachate collection system and the liquid generated as the solid waste degrades and compresses in the landfill. The flow rate of leachate collected in an MSW landfill is typically less than 1/10th of the typical flow rate of CCR transport water system, which are usually about 3,000 to 5,000 gpm. One additional significant difference in MSW landfill leachate and transport water is that while MSW leachate is a waste product, the transport water is a vital part of the operation of a power plant to cool and move the CCR from a power station to waste treatment unit such as a CCR surface impoundment.

The IEPA's basis for requiring a leachate collection and removal system is to reduce the hydraulic head on an impoundment's liner as a proactive means of protecting groundwater (Reference 1, p. 19). However, the Proposed Illinois CCR Rule does not mandate the removal of leachate or the maximum hydraulic head level on a pond liner system. Moreover, during the August 12, 2020 Hearing, Ms. Gale asked, "So are you saying that under these rules the head should be limited to 30 centimeters?" and Mr. Buscher of the IEPA responded "… no, I don't think that can be done because it's an operational consideration of the CCR impoundment. I think that that might not allow the owner or operator of a CCR impoundment the flexibility they would need to properly operate the impoundment." (Reference 6, p. 141. l. 15 – 24). I concur with Mr. Buscher's opinion regarding mandating a maximum water level above the liner of CCR impoundments in Illinois. In my opinion, the decision whether to install a leachate collection and removal system that will be operated as determined by the Owner/Operator should be made by the Owner/Operator.

Installing a leachate collection and removal system in a CCR surface impoundment is not practical because, if the system was to operate, the pond would likely be dry, causing negative consequences such as fugitive dust emissions.

To better understand the implications of collection and removal of leachate from a pond floor, consider the following hypothetical scenario. The flow rate through the filter layer, which is the most restrictive layer above the leachate collection system, as required by the Proposed Illinois CCR Rule, for a hypothetical 20-acre CCR surface impoundment is calculated using Darcy's Law for flow through porous media. The flow per unit area (Q/A) is:

$Q/A = k \times ((h/t) + 1)$, (Reference 2, p. 21474)

where:
Q = flow rate (cubic feet/second);
A = surface area of the area considered (square feet);
k = hydraulic conductivity of the filter layer (feet/second);
Assume $k = 1 \times 10^{-5}$ cm/sec = 3.28×10^{-7} ft/sec
h = hydraulic head above the filter layer (feet); Assume impoundment water is 20 ft deep; and
t = thickness of the filter layer (feet); Although not specified, assume 6 inches or 0.5 ft..

$Q/A = 3.28 \times 10^{-7}$ ft/sec x $((20/.5) + 1) = 1.3 \times 10^{-5}$ ft/sec = 0.048 ft/hr

Assuming the hydraulic conductivity of the filter layer is the minimum permitted by the Proposed Illinois CCR rule (1×10^{-5} cm/sec $=3.28 \times 10^{-7}$ cm/sec), the water in the pond is 20-feet deep, and the filter layer is 6-in. thick (it is noted that no minimum thickness is specified by the Proposed Illinois CCR Rule), the total flow per hour in the 20-acre pond is:

Q = 20 ac x 43,560 ft^2/ac x 0.048 ft/hr = 42,000 ft^3/hr = 5,300 gpm = 7.5 million gal/day

Since the hydraulic conductivity used in this example was the lowest permeability allowed by the Proposed Illinois CCR Rule, and since the filter layer thickness was assumed to be six inches, the calculated flow could be significantly higher with more permeable or thinner filter materials. It is noted that in my experience with CCR sluice systems, the flow rate into the pond is typically on the order of 3,000 to 5,000 gpm. Thus, this hypothetical CCR surface impoundment would not be able to contain significant free water since the flow rate into the leachate collection and removal system would be effectively equal to the flow rate of CCR into the impoundment. Consequently, this hypothetical pond would generally be dry, which would result in a higher likelihood of fugitive dust risks to the environment.

The IEPA clarified that water collected by a leachate collection and removal system could be returned to the impoundment (Reference 5, p. 16, Agency's Answer to Question 36.a). But that creates other issues, including the impracticality of having one pump system designed to remove water from the leachate collection system and return it to the pond, and a second pump system to reuse the water that is typically impounded as the source for the CCR sluicing system, which is the typical process flow for sluice water system. If these two systems are operated simultaneously, they would require "tank like" water storage for the sluice water return system to operate. Additionally, when the sluice system is not operational, the leachate collection and removal system is not really what its name suggests; instead it is a filtration system that constantly circulates the transport water without serving any other purpose.

Alternatively, the Proposed Illinois CCR Rule could suggest that the leachate collection and removal system would not operate until the closure of the CCR surface impoundment. However, I do not believe the Illinois CCR Rule should require installation of a leachate control and removal system that would be idle until closure, since other dewatering options are available. The installation of a leachate collection and removal system in the hypothetical 20-acre surface impoundment presented earlier is expected to require the mining, transportation, and placement of over 70,000 cubic yards (3,500 to 4,500 truckloads) of free-draining gravel, which may not be considered to be a prudent use of natural resources, given the US EPAs position on the adequacy of composite liners without leachate collection.

Approved State CCR Rules and Leachate Collection & Removal Systems for CCR Surface Impoundments

To date, two states (Oklahoma and Georgia) have obtained US EPA approval of their CCR programs. Neither of these states have a requirement to install a leachate collection and removal system in a CCR surface impoundment. Also, I am not aware of any other state requiring (or proposing to require) a leachate collection and removal system in a CCR surface impoundment

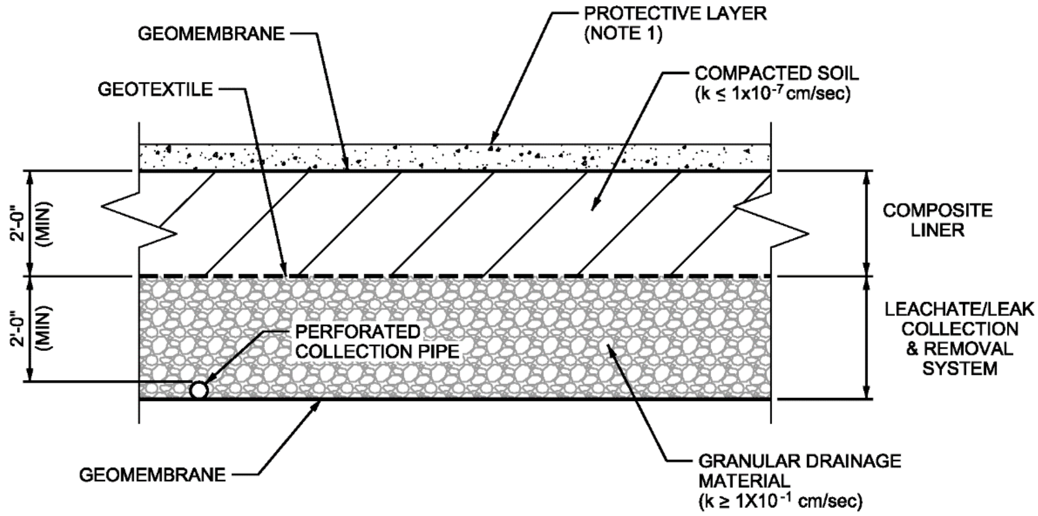
Groundwater Protection

Since the IEPA's stated reason for this leachate collection and removal system is to "minimize the amount of head on the liner system which will decrease the potential for the movement of fluids through the liner," protection of the groundwater is further considered. The Federal CCR Rule and the Proposed Illinois CCR Rule both require a system of groundwater monitoring wells near the waste boundary of a CCR surface impoundment (Reference 1, Section 845.630.a.2), which is effectively an early leak detection system and thus allow any required remedial actions to be implemented before offsite groundwater impacts.

Alternate Leachate Collection System

Based on the preceding discussions, I do not believe that a leachate collection and removal system is necessary in a CCR surface impoundment to protect human health and the environment. Further, I do not agree that the one design as mandated by IEPA should be to only acceptable "one size fits all option" in the event leachate collection remains within this rule.

I recognize that the IEPA is seeking a more proactive measure in protecting groundwater than the protection provided by the composite liner system and regular groundwater monitoring. Given my concerns with the system described in the Proposed Illinois CCR Rule, I suggest the Illinois Pollution Control Board should allow an alternative method of leachate collection that is at least as protective as the system required by the Proposed Illinois CCR Rule. For example, a collection system similar to that shown in Figure 2 would provide a proactive means of protecting groundwater since the lower geomembrane liner would impede the flow of any leakage from the primary composite liner and direct the flow to the leachate pumping system. The leachate collection and removal system in this case would effectively act as a leak detection system, which would provide immediate notice to the owner or operator that the surface impoundment's liner is leaking. Conversely, leaks through the CCR surface impoundment design specified in the Proposed Illinois CCR Rule would not be detected until the next groundwater monitoring well sampling event. Finally, this alternative system also has the advantage of requiring less energy to operate relative to the system proposed by the IEPA since the composite liner would significantly limit the flow into the leachate collection and removal system.



POSSIBLE ALTERNATE LINER FOR CCR SURFACE IMPOUNDMENTS WITH PROACTIVE LEAK COLLECTION SYSTEM IN LIEU OF LEACHATE COLLECTION SYSTEM

FIGURE 2

NOTE 1: PROPOSED 35 ILL. ADM. CODE 845.420 DOES NOT SPECIFY THICKNESS REQUIREMENTS FOR THE PROTECTIVE LAYER.

Conclusions

The Federal CCR Rule was based on an exhaustive risk analysis performed by the US EPA, and it does not require leachate collection and removal systems for CCR surface impoundments. This risk assessment notes that CCR surface impoundments with composite liners, as required by the Federal CCR Rule as well as the Proposed Illinois CCR Rule (without leachate collection system) provide a level of protection “that effectively [reduce] risks from all pathways and constituents far below human health and ecological criteria in every sensitivity analysis.” Moreover, when evaluating proven and potential damage cases, the US EPA’s analysis concluded, “No damage cases were identified for composite-lined units.” Thus, I conclude that the use of composite liners in CCR surface impoundments, without leachate collection, is appropriately protective of human health and the environment. As a licensed professional engineer, I believe that valid scientific studies should be the basis for environmental regulation, which does not appear to be the case for the leachate collection and removal requirements in the Proposed Illinois CCR Rule.

If the proposal to require a leachate collection and removal system for a new or retrofitted CCR surface impoundment is not modified, any operation of the system, will result in very large flow rates and significant water management challenges for Illinois power plants. Any proposed requirement to attempt to reduce the hydrostatic pressure on a liner system through operation of a leachate collection and removal system is burdensome and, based on the US EPA risk assessment, provides no material long term benefit to the protection of human health or the environment relative to the burden placed on Illinois power plants.

A properly designed and monitored system of groundwater monitoring wells can identify future failures in a CCR surface impoundment's composite liner system. When identified early (i.e., when impacted water is at the edge of waste), a remedial program can be implemented to protect the offsite groundwater quality.

I encourage the Pollution Control Board to implement pond design requirements that are identical to those in the Federal CCR Rule. The Federal CCR Rule is the result of many thousands of hours of thoughtful work by scientists, engineers, and regulators of the US EPA and other interested parties, which in my opinion, is an appropriate regulation for the protection of human health and the environment. Specifically, I encourage the Illinois Pollution Control Board to remove Section 845.420 of the Proposed Illinois CCR Rule along with any references to leachate collection and removal systems.

Alternatively, if the Board concludes that more proactive measures are required for protecting groundwater than those prescribed by the Federal CCR Rule, I suggest that the Board include language in 845.420 that would allow an entity to install an alternative leachate collection system that is at least as protective as the system required in 845.420(a).

COMMENTS ON SECTION 845.770
RETROFITTING

Background

The Federal CCR Rule uses the term retrofit as the process of removing CCR and contaminated soils and sediments from the CCR surface impoundments to allow relining in accordance with the current regulation. Thus, retrofitting is a method to allow existing impoundments to be improved to allow ongoing use of the CCR surface impoundment. The Proposed Illinois CCR Rule, Section 845.120 (Reference 1) defines retrofit as:

> "Retrofit" means to remove all CCR and contaminated soils and sediments from the CCR surface impoundment, and to ensure the surface impoundment complies with the requirements in Section 845.410."

Although the Illinois definition of retrofit essentially matches the Federal CCR Rule, Section 845.770(a)(1) of the Proposed Illinois CCR Rule (Reference 1) requires that any liners be removed when an impoundment is retrofitted.

Evaluation

The Proposed Illinois CCR Rule does not clearly define the type of liners that would require removal. This testimony is based on responses provided by the IEPA in the August 25 Hearing that the IEPA intends for any existing geomembrane liners to be removed as well as any clay liners.

In answer to why the Agency required removal of a liner, "The Agency would consider the liner system to be contaminated with CCR" (Reference 5, p. 32, Agency's Answer to Question 84), yet gave no other explanation. The responses provided by the IEPA in the August 25, 2020 Hearing indicate that the Agency believes that all liners are considered contaminated.

Geomembrane liners are flexible membranes that are manufactured of resins such as polyethylene (HDPE, LLDPE, LDPE) and polyvinyl chloride (PVC), which are energy intensive to manufacture and very low permeability. ASTM International defines geomembrane "an essentially impermeable geosynthetic composed of one or more synthetic sheets." (Reference 7, p. 3)

I assume the Agency believes that a geomembrane liner would become saturated with CCR constituents such that it would allow these constituents to migrate into the environment. While this may be true of clay liners, there is no basis to conclude that it is true of geomembrane liners, such as

HDPE. In fact, I am not aware of a study that shows that polymer liners become saturated with CCR constituents. Accordingly, there is no basis to conclude that a geomembrane liner would be saturated with CCR constituents such that the only method of decontamination is removal.

It is recognized that the existing geomembrane liner cannot be considered as a component of a new compliant composite liner system. Although not incorporated into the composite liner system, it is my opinion that allowing existing, effective liners to stay in place could add an additional level of protection of the environment. It is certainly a better alternative than requiring removal of a decontaminated liner and transporting it to a solid waste landfill, which in my opinion is not in compliance the reuse and energy conservation concepts that are fundamental to environmental stewardship.

Conclusion

I recommend that the language of section 845.770 be modified to allow existing geomembrane liners to be decontaminated, similar to the Federal CCR Rule requirements. The decontamination could include cleaning with high-pressure water washes, visual inspections for any damage, repair if damage was a result of the removal of CCR, and reuse as a supplemental layer below a new composite liner as suggested in Figure 2.

REFERENCES

1. IEPA, 2020 – Proposed New 35 ILL. ADM. CODE 845, "Standards For The Disposal of Coal Combustion Residuals in Surface Impoundments", as published March 2020 (referred to as the "Proposed Illinois CCR Rule")
2. US EPA, 2015 – 40 CFR Part 257 Subpart D, "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments", as published April 17, 2015 (herein referred to as "Federal CCR Rule")
3. US EPA, 2010 – "Hazardous and Solid Waste Management System; Identification and Listing of Special Wastes; Disposal of Coal Combustion Residuals From Electric Utilities," 75 Fed. Reg. 35128, June 21, 2010.
4. US EPA 2014 – "Human and Ecological Risk Assessment of Coal Combustion Residuals", December 2014, Regulation Identifier Number: 2050-AE81
5. IEPA, 2020 – "FIRST SUPPLEMENT TO IEPA'S PRE-FILED ANSWER" filed with the Clerk's Office August 5, 2020 by Christine Zeivel.
6. Illinois Pollution Control Board, 2020 – "REPORT OF THE PROCEEDINGS … … before Hearing Officer Vanessa Horton, called by the Illinois Pollution Control Board, taken by Steven Brickey, CSR, RMR, for the State of Illinois … … on the 12th day of August 2020, commencing at the hour of 8:01 a.m."
7. ASTM International Standard Terminology for Geosynthetics, ASTM D4439 - 20, January 2020

Thank you, this concludes my pre-filed testimony .

David E. Nielson, P.E.

August 27, 2020

DAVID E. NIELSON

Geotechnical Engineer
Sr. Consultant / Sr. Manager

Sargent & Lundy

EDUCATION

Utah State University – B.S. Civil and Environmental Engineering - 1988

REGISTRATIONS

Professional Engineer – Illinois, Indiana, Michigan, Washington, Nevada

Previously Licensed Water Well Driller – Indiana, Tennessee and Louisiana

PROFICIENCIES

- Design of embankments, dikes and containment structures
- Evaluation of existing conditions of dams, dikes, landfills & other earthen structures
- Design and evaluation of production and monitoring well systems
- Selection of design parameters for foundation and earthen structures
- Design of shallow and deep foundation systems
- Design of pavement systems
- Reinforced earth structure design
- Geosynthetics applications in geotechnical and geo-environmental areas
- Geotechnical field and laboratory instrumentation, field testing and data acquisition
- Construction material field and laboratory instrumentation, field testing and data acquisition
- Forensic evaluation of concrete structures and earthen structures

RESPONSIBILITIES

Mr. Nielson is the process owner of geotechnical and groundwater well process in the S&L quality program. He is responsible for the selection of geotechnical design parameters, design and construction monitoring of foundation systems for projects at fossil and nuclear powered electric generating stations. Mr. Nielson performs and reviews examinations of dikes, dams and landfills at both nuclear and coal fired power plants. Additionally, Mr. Nielson actively participates in engineering geology evaluation of potential plant sites and plant structure foundations. Mr. Nielson serves as a committee member on the DFI Auger Cast Pile subcommittee.

EXPERIENCE

Mr. Nielson has over 30 years of experience in geotechnical engineering and construction material testing services. He has successfully performed shallow and deep foundation design for projects in virtually all geologic settings and directed construction material quality control services in over 30 states and over 10 countries. Additionally, he has specified, directed, and performed over one-thousand subsurface exploration programs.

In addition to the design and consultation services on earthen embankments, ponds, lakes and landfills, he supervises and performs annual examination of eight dams, which are up to 8 miles in length with residential properties within 1/8 mile of the dam toe.

He has designed numerous production wells, monitoring well programs, and structure under-drain/dewatering systems to mitigate the effects of groundwater seepage in several construction projects. Moreover, he has provided design and construction recommendations for tunnels under and bridges over Midwestern rivers.

He has served as an expert witness for construction defect litigation in the areas of soil and concrete.

He provides our clients with an unusual perspective and experience. In addition to his design experience, he has worked as a construction laborer on the construction of a large coal fired power plant in Utah, geotechnical driller and geotechnical engineer with design work and quality control services in many of the major physiographic regions of the U.S.

Mr. Nielson's relevant experience with Sargent & Lundy LLC (since 2008) includes:

- **Hydroelectric Dam – Peruvian Andes**
  Before visiting the site, Mr. Nielson reviewed the prior design documents, prior reports, studies and repair designs to aid in our evaluation of the repair of a vertical crack and the general integrity of the confidential hydroelectric dam. The existing dam is an arched concrete gravity structure with an 88-meter maximum height and a crest length of 274 m. Our evaluation of the structure included recommendations for physical repairs of an abutment to improve stability and supplemental monitoring equipment to provide insight into the structure's response to loading (2018).

- **Power Stations – Wyoming**
  Performing conceptual and detailed design of several new impoundments to serve as evaporation and disposal ponds for Coal Combustion Residual waste streams. Dam heights will range up to 50 feet and the total impoundment area will exceed 400 acres. (2017 - 2020)

- **Two Power Stations – Texas**
  The two stations represent over 4400 megawatts of coal fired generating capacity. Served as Owner's Engineer to develop closure plans, hazard classifications, structural stability and annual inspections of coal ash ponds and landfills (2015 - 2018).

- **Power Station – Indiana**
  Performed emergency dam inspection to evaluate damage and recommend repair alternatives for a sand filled dam which experienced significant erosion during beyond design basis storm event. (2012)

- **Power Station – Pennsylvania**
  Formulated of design parameters for shallow spread, drilled piers and deep micropile foundation systems for SCR system constructed above existing precipitators and other plant features (2010-2012).

- **Power Station – Pennsylvania**
  Developed of geotechnical exploration specifications and formulated ACIP foundation design details, specifications, and performance criteria (2009).

- **Power Station – Nebraska**
  Developed specification for geotechnical exploration and formulated design criteria for foundation systems for major emission control project (2008).

- **Generation Project – Upper Midwest**
  Prepared a study of groundwater availability for a new combined cycle generating station (2016).

Mr. Nielson's relevant experience with other firms (1988 - 2008) includes:

- **Elkhart County Jail – Elkhart, Indiana**
  Determination of engineering design parameters for shallow foundations and utility tunnels for 1000-bed, seven building correctional campus. This work included monitoring and designing repairs to control seepage into a major utility tunnel that was constructed with inferior concrete (2004 - 2008).

- **Elkhart County Landfill/Jail – Elkhart, Indiana**
  Mr. Nielson designed extraction, compression and transmission system to remove landfill gas and transport it for beneficial use at the 1000 bed jail (2006 - 2008).

- **Earth Movers Landfill – Elkhart County, Indiana**
  Directed Construction Quality Control and Assurance (CQA/CQC) services to assure state regulators the clay and membrane liners were constructed in accordance with the permit requirements (2007).

- **Prairie View Landfill – St. Joseph County, Indiana**
  Directed Construction Quality Control and Assurance (CQA/CQC) services to assure state regulators the clay and membrane liners were constructed in accordance with the permit requirements (2006).

MEMBERSHIP

Deep Foundation Institute

EXHIBIT 5

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
Standards for the Disposal	)	No. R20-19
of Coal Combustion	)	(Rulemaking - Land)
Residuals in Surface	)	
Impoundments: Proposed new	)	
35 Ill. Adm. Code 845	)	

REPORT OF THE PROCEEDINGS held in the above entitled cause before Hearing Officer Vanessa Horton, called by the Illinois Pollution Control Board, taken by Pamela L. Cosentino, Certified Shorthand Reporter for the State of Illinois, at James R. Thompson Center, 100 West Randolph Street, Room 9-040, Chicago, Illinois, on the 30th day of September, 2020, commencing at the hour of 9:00 a.m.

Electronic Filing: Received, Clerk's Office 05/11/2021

a visual clarification, visual classification, in particular, to remove.

I think it would be reasonable for the Agency to consider visual. I think it would be reasonable for the Agency to require a swab, an occasional swab test to be submitted for analytical testing.

But these are very low-permeability plastic products that are nonabsorptive, and I'm confident that the professionals of the Agency and the professionals working for industry can come to a reasonable meeting of the mind during the permitting process.

Q. And you say some states use visual. Can you name those states for me that you are aware of?

A. The very first clean closure I did following the implementation of the CCR Rules in Minnesota and visual was the criteria.

Q. Is Minnesota the only one that comes to mind?

A. I can think of two others, but since there's a question on one, I'm going to hold off. So Minnesota is the one I'm willing to share.

Q. All right. Thank you.

How would an owner or operator demonstrate that a liner is not contaminated?

EXHIBIT 6

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
STANDARDS FOR THE DISPOSAL OF COAL COMBUSTION RESIDUALS IN SURFACE IMPOUNDMENTS: PROPOSED NEW 35 ILL. ADM. CODE 845	)	R 20-19 (Rulemaking – Land)
	)	

MIDWEST GENERATION LLC'S PRE-FILED ANSWERS

Midwest Generation, L.L.C. ("Midwest Generation" or "MWG"), by and through its attorneys, Nijman Franzetti, LLP, submits the following Pre-filed Answers on behalf of its witnesses Sharene Shealey, Richard Gnat, and David Nielson in response to Pre-filed Questions submitted by the Illinois Pollution Control Board, the Illinois Environmental Protection Agency ("Illinois EPA"), and the "Environmental Group" (collectively the Environmental Law and Policy Center, Prairie Rivers Network, and Sierra Club).

I. Sharene Shealey's Answer to the Illinois Pollution Control Board's Question

17. On page 15, you state, "[r]emoval and replacement of a competent liner that is not contaminated with CCR constituents adds even more unnecessary costs for retrofitting a CCR surface impoundment without any added benefit or protection. Accordingly, MWG recommends that the Board remove the phrase "including any liners" from 845.770(a)(1) so that existing liners that are not contaminated and in fact may be protective can remain in place for retrofitting." Please comment on whether it would be acceptable to MWG, if the Board were to revise Section 845.770(a)(1) to specify "including any contaminated liners."

Answer: Yes, that proposed modification is acceptable to MWG.

II. Sharene Shealey's Answers to the Environmental Group's Questions

1. On page 3 of your testimony, you state "Since MWG began operating the Stations in 1999, the coal ash ponds have been used only for temporary storage of coal ash until the material is removed from the ponds for beneficial reuse."
   a. Is this statement true about operations prior to MWG's ownership?

Answer: MWG objects to the question to the extent it requests site specific information. The Hearing Officer has limited questioning to general questions, and has held that site-specific information is outside the scope of the rulemaking. *See* 8/13/20 Tr., PCB20-19, pp. 17:7-10, 215:23-216:3; *See also Public*

The system proposed as a possible alternate in my testimony has the following advantages:

- If any leak occurs through the composite system, which is unlikely, it detects and collects leaks as they occur.
- It has a significantly lower impact on parasitic load (*i.e.* - power requirements to operate the equipment at generating stations) and plant operations.
- Is not likely to become fouled by fly ash and FGD waste streams.
- It does not increase the risk of fugitive dust throughout the operating life of the surface impoundment.
- It does not require the construction of very large tanks to hold and manage the transport water for re-use in the closed loop ash transport system.
- It allows a CCR surface impoundment to conduct its primary function, which is to separate the ash and slurry water, as well as store the ash transport water which is recycled in the closed loop system.

13. Does reduction of hydraulic head on the composite liner reduce the potential for the migration of contaminants through the composite liner? If not, why?

Response:

See my responses to the following questions by the IL EPA 8.c., 8.d., 9.b., and 10.

14. In your testimony regarding Section 845.770, you discuss the potential of decontaminating liners.

a. Do synthetic liners have holes and imperfections?

Response:

There are numerous types of synthetic liners used for various purposes. Depending on the use, installation process including the quality assurance and quality control ("QA/QC"), and quality of a liner, it is possible that there may be holes and imperfections. If a properly designed and installed geomembrane liner is installed following proper QA/QC measures, then the likelihood of imperfections and holes is minimized. Moreover, if a liner is somehow compromised during operations, such as a hole, then there are methods to repair the liner such that the seal of the liner is restored.

It is also noted that the Risk Assessment assumed small holes in the geomembrane liner element of composite lined systems and still did not identify any risk to human health or the environment. The Risk Assessment (p. 4-1) was conducted using the EPA Composite Model for Leachate Migration with

Transformation Products (EPACMTP). The 2003 version of the EPACMTP Technical Background Document, which is reference EPA 2003a in the Risk Assessment p. A-1 states:

> "For composite-lined Sis [surface impoundments], we used the Bonaparte (1989) equation to calculate the infiltration rate assuming circular (pin-hole) leaks with a uniform leak size of 6 mm^2 , and using the distribution of leak densities (number of leaks per hectare) assembled from the survey of composite-lined units (TetraTech, 2001).

Therefore, I conclude that the Risk Assessment accounted for potential holes in the geomembrane component of composite liners and the Risk Assessment did not identify statistically significant risks to health and the environment for composite lined CCR surface impoundments.

b. Could the heavy equipment that is likely to be used for removing CCR damage the liner?

Response:

If the operators are aware and focused on avoiding damage, then the likelihood of damage to a liner is diminished. Due to the possibility of damage to a liner during CCR removal, I suggested an inspection and repair in the final paragraph of my pre-filed testimony. *See* D. Nielson Pre-filed Testimony, p. 13

c. Could tears too small to see compromise the integrity of the liner?

Response:

While that may be true, my testimony is supporting the reuse of the liner as a supplemental liner system or as part of a different process entirely, and would not be in contact with CCR. If a decontaminated existing geomembrane liner is reused as a supplemental liner system, in addition to the regulatory mandated composite liner system, the combined liners would be more protective than the Federal CCR Rule or any other state rule requirement. *See* response to Illinois EPA Question 14.a.

d. How do you believe an owner or operator would assure the clay portion of a composite liner was decontaminated, which you agree can become saturated with CCR constituents, without removing the synthetic?

Response:

MWG objects to the question as a mischaracterization of Mr. Nielson's Pre-filed testimony. In no part of the testimony did I suggest that the clay portion of a composite liner system (*i.e.* had a geomembrane liner *and* a clay liner) could become saturated with CCR constituents. In fact, I stated the opposite. I stated that there was no basis to conclude that a geomembrane liner could become saturated with CCR constituents. D. Nielson Pre-filed Testimony, pp. 12-13. It appears that Illinois EPA misread this section, because in the sentence before I stated that clay-liners *alone* may become saturated with CCR constituents. *Id*. However, I then distinguished the clay-liners to the geomembrane liners, which are one part of the composite liner system. *Id*. As stated in my testimony, I am not aware of any study showing that a geomembrane liner may become saturated with CCR constituents. *Id*. By extension, I am not aware of a composite liner system that became saturated with CCR constituents. Additionally, as stated in my Answer to Illinois Pollution Control Board Question 18.b., there has been no damage case found for a CCR surface impoundment with a composite liner – a geomembrane liner with a clay-liner underneath.

e. Have you ever been involved with or overseen a project where the decontamination of a composite liner in a CCR surface impoundment has been performed? If so, please provide a summary of the site(s), the liners, and the processes used.

Response:

I am not personally aware of any instance where a composite lined CCR impoundment has been taken out of service.

f. Have you read or researched about a project where the decontamination of a composite liner in a CCR surface impoundment has been performed? If so, please provide a summary of the site(s), the liners, and the processes used.

Response:

See my response to question 14.e.

g. For what purpose would the allegedly decontaminated liner be reused?

Response:

MWG objects to the question because it is premised on the assumption that a geomembrane liner may not be decontaminated. I am not aware of any study showing that a geomembrane liner becomes saturated with CCR constituents. I am also not aware of any study or information demonstrating that a geomembrane liner may not become decontaminated. Moreover, no party to this rulemaking has entered into the record any study or information showing that a geomembrane liner may not be decontaminated. In fact, for retrofitting a CCR surface impoundment, the Federal CCR rule does not require removal of a liner system, but instead only requires removal of any contaminated soils and sediments. 40 CFR 257. 102(k)(i).

Because of the absence of such studies or information, I do not believe HDPE will become contaminated with CCR constituents such that decontamination methods will be ineffective.

As stated in my testimony, the possible purposes of reuse for a decontaminated liner are:

> "It is recognized that the existing geomembrane liner cannot be considered as a component of a new compliant composite liner system. Although not incorporated into the composite liner system, it is my opinion that allowing existing, effective liners to stay in place could add an additional level of protection of the environment. It is certainly a better alternative than requiring removal of a decontaminated liner and transporting it to a solid waste landfill…"
>
> "I recommend that the language of section 845.770 be modified to allow existing geomembrane liners to be decontaminated, similar to the Federal CCR Rule requirements. The decontamination could include cleaning with high-pressure water washes, visual inspections for any damage, repair if damage was a result of the removal of CCR, and reuse as a supplemental layer below a new composite liner as suggested in Figure 2." D. Nielson Pre-filed Testimony, p. 13.

Additionally, a decontaminated liner could be used for holding process waters at a generating station.

I have had an opportunity to review the suggested language by the Illinois Pollution Control Board in its Question 17 to Sharene Shealey. I believe the Board's suggested revision to Section 845.770(a)(1) to state "including any contaminated liners" will resolve the concerns expressed in my testimony.

IX. David E. Nielson's Answers to the Environmental Group's Questions

1. On Page 2 of your testimony, you state: "This essentially requires a drainage layer at the base of new and retrofitted CCR surface impoundments with the purpose of reducing the hydraulic head on the impoundment's composite liner system." As used in this quoted sentence:

   a. What does "drainage layer" mean?

      Response:

      A drainage layer is a layer in the engineered system, that is specifically designed and constructed to allow rapid drainage (removal) of water (leachate) from an impoundment (pond).

   b. What does "hydraulic head" mean?

      Response:

      In static (minimal flow or movement) conditions, hydraulic head is the vertical measurement from the surface of the water or another fluid to the point of

EXHIBIT 7

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	R 2020-019
STANDARDS FOR THE DISPOSAL	)	
OF COAL COMBUSTION RESIDUALS	)	(Rulemaking - Water)
IN SURFACE IMPOUNDMENTS:	)	
PROPOSED NEW 35 ILL. ADM.	)	
CODE 845	)	

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY'S FINAL POST-HEARING COMMENTS

NOW COMES the Illinois Environmental Protection Agency ("Illinois EPA" or "Agency"), by and through one if its attorneys, and hereby submits its Final Post Hearing Comments as directed by the Hearing Officer Orders entered on October 4 and 20, 2020 in the above captioned rulemaking.

I. Procedural Background

On March 31, 2020, the Illinois EPA filed its proposed rulemaking for coal combustion residual surface impoundments pursuant to Section 22.59 of the Illinois Environmental Protection Act, along with a Statement of Reasons ("SOR") in support. On April 24, 2020 the Illinois Pollution Control Board ("Board") accepted Illinois EPA's proposal for hearing and set prehearing deadlines. On June 2, 2020, Illinois EPA filed with the Board pre-filed testimony of eight witnesses: Lynn Dunaway, Darin LeCrone, Melinda Shaw, William Buscher, Lauren Martin, Amy Zimmer, Chris Pressnall, and Robert Mathis (Hrg, Ex. 1). Illinois EPA filed Answers to Pre-Filed Questions from the Board, Little Village Environmental Justice Organization, the Environmental Law and Policy Center, Prairie Rivers Network, and Sierra Club ("Environmental Groups," collectively), Springfield City Water, Light, and Power, the Illinois Environmental Regulatory Group, Ameren, Midwest Generation, and Dynegy on August 3 (Hrg. Ex. 2), August 5 (Hrg. Ex.

1. Proposed Part 845, filed by the Agency on March 30, 2020, incorporated requirements that had been proposed by USEPA in 85 Fed. Reg. (Mar. 3, 2020), 12456, but have not yet been adopted by USEPA. Among other things, the proposed changes to Part 257 addressed closure by removal (referred to as "Part B"). The current version of Part 257 treats closure by removal and all associated corrective action as a single process, with closure not being complete until all corrective action has been completed. Hrg. Ex. 8 as amended by 85 Fed. Reg. 53516, (Aug. 28, 2020). The USEPA proposal divides closure by removal into a two-step process. The first step is the physical removal of all CCR, containment systems and related structures, while the second step is the completion of any necessary groundwater corrective action.

The Agency had testified that it believed Part 845 would have to be revised, if USEPA had not adopted the "Part B" requirements. Hrg. Ex. 2, p. 139. However, upon reexamination of the "Part B" requirements, the Agency concludes they are more protective and comprehensive than Part 257 as it currently exists. For example, "Part B" requires a deed notation until corrective action is complete. The requirement for a deed notation is not required by the current version of Part 257, but the Agency included the requirement for a deed notation in Part 845 as proposed. Part 845 requires financial assurance for corrective action, thereby affording additional protection of public funds should an owner or operator default. Also "Part B" specifies that in addition to meeting groundwater protection standards to terminate groundwater corrective action after closure by removal has been completed, compliance with the groundwater protection standards must be demonstrated for three consecutive years, prior to terminating groundwater corrective action and the associated groundwater monitoring. These requirements are also included in Part 845 as drafted. However, Section 845.740(a) as drafted contains the generalized language that removal and decontamination of areas affected by releases must be completed for closure by removal. Therefore, as shown below, the Agency has proposed a revision to Section 845.740(a) using specific language from the "Part B" proposal describing how to complete closure by removal and an additional statement that closure by removal must be completed before groundwater corrective action.

> a) Closure by removal of CCR. An owner or operator may elect to close a CCR surface impoundment by removing all CCR and removing and decontaminating all areas affected by releases of CCR from the CCR surface impoundment. CCR removal and decontamination of the CCR surface impoundment are complete when all CCR and CCR residues, containment system components such as the impoundment liner and contaminated subsoils, and CCR impoundment structures and ancillary equipment have been removed. Closure by removal shall be completed before the completion of a groundwater corrective action pursuant to Subpart F. ~~the CCR in the surface impoundment and any areas affected by releases from the CCR surface impoundment have been removed.~~

2. The Agency proposed a revision to Section 845.700(d), and a corresponding requirement for a new subsection 845.800(d)(19), relative to Part 257.103. The Agency has also proposed a revision to Section 845.770(a)(3), required to clarify that owners and operators seeking extensions to retrofit a CCR surface impoundment must submit a preliminary retrofit plan to make the Agency aware of their intent to retrofit a CCR surface impoundment. Those proposed revisions required the renumbering of Section 845.800(d) cross-references in subsections (d), (e) and (f) of 845.740.

> d) At the end of each month where CCR is being removed from a CCR surface impoundment, the owner or operator must prepare a report that describes the weather, precipitation amounts, the amount of CCR removed from the CCR surface impoundment, the amount and location of CCR being stored on-site, the amount of CCR transported offsite, the implementation of good housekeeping procedures required by Section 845.740(c)(4)(C), the implementation of dust control measures, and documents worker safety measures implemented. The owner or operator of the CCR surface impoundment must place the monthly report in the facility's operating record as required by Section 845.800(d)(~~22~~23).

EXHIBIT 8

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
STANDARDS FOR THE DISPOSAL OF	)	
COAL COMBUSTION RESIDUALS IN	)	**R20-19**
SURFACE IMPOUNDMENTS: PROPOSED	)	**(Rulemaking – Water)**
35 ILL.ADM. CODE PART 845	)	

MIDWEST GENERATION, LLC'S RESPONSE TO POST-HEARING COMMENTS

I. Introduction

Midwest Generation, LLC ("Midwest Generation" or "MWG") appreciates the opportunity to provide a response to certain post-hearing comments submitted in this rulemaking proceeding for the Illinois Pollution Control Board's ("Board") consideration. MWG generally supports the post-hearing comments filed by Dynegy and the City of Springfield d/b/a City Water, Light, and Power. MWG also supports certain sections of the post-hearing comments filed by the Illinois Environmental Protection Agency ("Illinois EPA" or "Agency"), however, as described herein, MWG disagrees with other sections. Additionally, MWG provides responses to the final comments and suggested modifications by the Sierra Club, Prairie Rivers Network, Environmental Law and Policy Center and Little Village Environmental Justice Organization (collectively the "Environmental Group").

II. The Board Should Not Adopt the Sections of the Proposed CCR Rule That Are Not Supported by the Record.

MWG objects to Illinois EPA's substantial, substantive proposed changes to the closure by removal requirements in Section 847.770. Agency Final Comment, pp. 86-87. These significant changes come at the eleventh hour without any basis or explanation and without any opportunity for stakeholders to present rebuttal evidence or testimony. If significant changes to proposed rules are first presented in a final post-hearing Agency comment, it essentially nullifies the due process rights of stakeholders like Midwest Generation that a rulemaking proceeding is intended to afford and protect. There is no meaningful opportunity now to evaluate and respond to the Agency's proposed changes. The Board should reject the change and implement the language Illinois EPA originally proposed.

Illinois EPA also has failed to provide technical or scientific support for its proposed inclusion of a leachate collection system requirement for coal combustion residual ("CCR") surface impoundments. Not only does this proposal conflict with the requirements of the Federal Coal Combustion Residual Rule ("Federal CCR Rule"), it is unnecessary, particularly for smaller surface impoundments that close by removal. At most, any leachate collection system requirement should only apply to CCR surface impoundments that are larger than 20 acres. This approach would be consistent with the Agency's underlying rationale that such systems are only needed to assist in dewatering impoundments during closure in place activities and their subsequent post-closure care. The hearing testimony showed not only that small CCR surface impoundments predominantly close by removal, not closure in place, and that dewatering and removing CCR in these impoundments is not difficult and does not require the assistance of a leachate collection system to complete the dewatering process.

The Board should not adopt the Agency's position that a single detection above the groundwater protection standards of one constituent in one quarter is a "confirmed exceedance." As the hearing testimony of Richard Gnat clearly showed, single detection anomalies can and do occur. Owners or operators should not be denied the limited opportunity to determine if the single detection of an exceedance is an anomaly. The rule should instead allow for a second sampling event to confirm that the exceedance is a real value before requiring an owner or operator to expend further resources to address it. The very limited additional time to confirm that an exceedance in fact has occurred will not endanger either human health or the environment. It will, however, prevent investigations of single detection exceedances that really don't exist.

Similarly, a requirement to develop background concentrations in only six months is unreasonable. The hearing testimony shows that the development of accurate background data requires evaluation of the seasonal changes in the groundwater and also samples taken sufficiently spaced apart in time to assure independent data - neither of which can be accomplished in six months' time. Finally, MWG submits that the final rule should allow an owner or operator to reduce the constituents evaluated where the data collected shows that certain constituents do not require further evaluation.

a. The Board Should Reject Illinois EPA's New Language for Closure by Removal

For the first time and without any prior indication or explanation, the Agency presents new requirements for closure by removal in its post-hearing comments. Agency Final Comment, pp.

86-87. The original language for closure by removal in the proposed Disposal of Coal Combustion Residuals ("CCR") in Surface Impoundments Rule (the "Proposed CCR Rule") states that:

> An owner may close by removing and decontaminating all areas affected by releases from the CCR surface impoundment. CCR removal and decontamination of the CCR surface impoundment are complete when the CCR in the surface impoundment and any areas affected by releases from the CCR surface impoundment have been removed.
> Proposed 35 Ill. Adm. Code 845.740(a).

This is the same language that is in the federal CCR Rule. 40 CFR 257.102(c). Ex. 8, 483. Now, the Agency is suddenly and belatedly proposing a wholesale revision of that section. The Agency's new language states that for closure by removal, an owner/operator must also remove "containment system components such as the impoundment liner and contaminated subsoils, and CCR impoundment structures and ancillary equipment." Agency Final Comment, p. 87. The Agency provided no explanation or technical support to show that the containment system components associated with the CCR surface impoundment must be removed.

The Agency has not provided any information on the technical feasibility nor the economic reasonableness of removing the containment equipment associated with a CCR surface impoundment for closure by removal. Section 27(a) of the Act sets out the procedures the Board must follow to enact regulations, including a requirement to take into account the technical feasibility and economic reasonableness of measuring or reducing the particular type of pollution. 415 ILCS 5/27(a). If the Board fails to follow the procedures under Section 27(a), then the rule is invalid. *See Waste Mgmt. of Ill., Inc. v. Pollution Control Bd.,* 231 Ill. App. 3d 278, 288-289, 172 Ill. Dec. 501, 508, (1st Dist. 1992). (Court found Board regulation requiring certain air monitoring of chemicals invalid because the record contained no evidence concerning the technical feasibility and economic reasonableness of measuring the chemicals.)

Here, the Agency has provided no information to show that its proposed change to Section 845.740(a) is technically feasible or economically reasonable. The Agency claims the revision is necessary to be consistent with the Federal Part B Rule, that was proposed on March 3, 2020 and is attached here as Attachment A. But the Agency's proposed language is inconsistent with the proposed Part B regulation. The March 3, 2020 proposed federal CCR rule for closure by removal states:

> "Closure by removal activities include removing ***or*** *decontaminating* all CCR and CCR residues, containment system components such as the unit liner, contaminated subsoils, contaminated groundwater, and CCR unit structures and ancillary equipment."
> Proposed 40 CFR 257.102(c) (emphasis added)

The proposed Part B regulation does not require removal of the containment systems. The Agency does not explain why it significantly deviated from the federal March 3, 2020 proposed language. The Agency's proposed change also diverges from its own admonition that as "frequently reminded" by the U.S.EPA, the Agency's goal was "to keep the language and function of Part 257 as similar as possible." Agency Final Comment, p. 10. By failing to replicate the proposed Part B language, the Agency is failing to follow the U.S.EPA's direct instructions.

The Agency has created – without explanation and for the first time in its final comments – new language requiring removal not only of the CCR, but all of the equipment and liners associated with the CCR surface impoundment regardless of its condition. There is nothing in the record here to demonstrate that the equipment and the liner associated with CCR is so contaminated that it may not be decontaminated. Instead, the testimony demonstrates precisely the opposite. Mr. Nielson testified that a synthetic liner (or "geomembrane liner") is not likely to be contaminated with CCR constituents merely because it was in contact with CCR. Ex. 54, p. 12-13. Geosynthetic liners are nonabsorptive and can be decontaminated so that they are suitable to reuse as part of a CCR surface impoundment retrofit. Ex. 54, p. 12-13; ASTM D4439; 9/30/2020 Tr., p. 199:7-8. The Illinois EPA admits that it is simply assuming that liners become contaminated and cannot be decontaminated without providing any other basis, including any scientific studies or analysis, to support that assumption. 8/25/2020 Tr., pp. 73:20-23, 76:14-17.

Turning to the other components that the Agency now proposes also must be removed, it again fails to explain why it believes that these components cannot be decontaminated. Because the record is closed, MWG and any other affected party, is foreclosed from providing additional evidence and expert opinion explaining why the components associated with a CCR surface impoundment may be decontaminated such that their removal is not required. It is unfair, unreasonable, and arbitrary to substantially change the scope of the requirements for closure by removal at such a late stage in this proceeding when the record is closed, and affected parties do not have an opportunity to present evidence demonstrating that the Agency's proposal is flawed.

It appears the Agency's impetus for recommending this substantial change is a sentence in the preamble to the proposed March 3, 2020 federal rule that refers to removal of all of the equipment regardless of whether it can be decontaminated. Ex. 1, p. 12469-12470. But such reliance is both inconsistent and contrary to the Agency's testimony that it rejects the preamble language, and instead prefers "to utilize regulation as opposed to utilizing the preamble." 8/11/20 Tr. p. 70: 12-14, p. 71:8-10. The Agency explained that it preferred to use the regulation language, because Part 257 has changed over time, thus the preference "is to utilize the regulation." 8/11/20 Tr. p. 71:10-11.

The federal March 3, 2020 proposal regarding closure by removal is only a proposal. It has not been adopted by the U.S.EPA. On October 15, 2020, USEPA finalized a part of the March 2020 proposed regulation. U.S.EPA, Hazardous and Solid Waste Management System: Disposal of Coal Combustion Residuals from Electric Utilities: Final Rule (pre-publication, October 15, 2020). The sections that the U.S.EPA adopted related to 40 CFR 257.102(d) and the alternative final cover system design. The U.S.EPA stated that the other provisions from the proposed rule (including closure by removal activities) "will be addressed in a subsequent rulemaking action." *Id.*, p. 7. As the Illinois EPA stated at hearing, the USEPA has changed the rule often, so there is no basis to believe that their proposed rule, and their statements in the preamble, will remain the same.

An isolated and unjustified preamble statement in a *proposed Federal rule* is an insufficient basis for including a requirement to remove every piece of equipment connected to CCR regardless of its condition. The Federal CCR Rule - which the Agency otherwise follows – states only that the equipment must be decontaminated. 40 CFR 257.102. Neither the preamble nor the Agency's post-hearing comments provides any technical basis supporting either equipment removal or the inability to decontaminate it. The record here shows exactly the opposite - - that the liners used for CCR surface impoundments can be decontaminated. Based on the record, the Board should reject the Agency's proposed language, and use the language that the Illinois EPA originally proposed, which is based upon and similar in function to Section 257.102(c) of the current Federal CCR Rule and on which the stakeholders have had an opportunity to comment. Ex. 8, p. 483.

EXHIBIT 9

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:)
)
Standards for the Disposal) No. R20-19
of Coal Combustion) (Rulemaking - Land)
Residuals in Surface)
Impoundments: Proposed new)
35 Ill. Adm. Code 845)

REPORT OF THE PROCEEDINGS held in the above entitled cause before Hearing Officer Vanessa Horton, called by the Illinois Pollution Control Board, taken by Pamela L. Cosentino, Certified Shorthand Reporter for the State of Illinois, at James R. Thompson Center, 100 West Randolph Street, Room 9-040, Chicago, Illinois, on the 25th day of August, 2020, commencing at the hour of 9:15 a.m.

things at least in play for leaving a liner in place during removal, any time you remove ash, generally, you're using machinery and you're on the liner. There will be damage. Could be significant damage.

The other possibility is there could be impacts to groundwater beneath the liner, whatever levels they may be. So there could be -- those are two reasons that we believe the liner needs to be removed.

MS. GALE: Okay. And to be clear, I'm talking about polymer liners here, which are plastic HDPE, to make sure we're just on the same baseline.

So the Agency doesn't think a polymer liner cannot be decontaminated by a washing, a plastic liner?

MS. ZIMMER: Amy Zimmer. Once again, any type of liner could be damaged, probably would be damaged by removing the ash and fully cleaning it during ash removal.

MS. GALE: So that's an assumption you're making?

MS. ZIMMER: Amy Zimmer. Based on information and belief.

MS. GALE: And also, the basis of my question

MS. GALE: Did the Agency consider the volume of material that would go into landfills even though the groundwater protection standards are established, instead of reusing the material?

MS. ZIMMER: Amy Zimmer. No.

MS. GALE: Okay. Considering the energy and manufacturing impacts associated with manufacturing of plastic HDPE liners, isn't it more environmentally responsible to reuse this resource if it's able to be cleaned?

MS. ZIMMER: Amy Zimmer. That would require the Agency to speculate because we don't know what the next use would be.

MS. GALE: Well, you've already speculated that the liner has leaks in it, right? You have made that assumption?

MS. ZIMMER: Yes. Amy Zimmer.

MS. GALE: So you can't speculate this way as well?

MS. ZEIVEL: The question was asked and answered.

MS. GALE: Okay.

HEARING OFFICER HORTON: I hate to interrupt, but could we pause here for lunch?

EXHIBIT 10

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

1021 NORTH GRAND AVENUE EAST, P.O. BOX 19276, SPRINGFIELD, ILLINOIS 62794-9276 • (217) 782-3397
BRUCE RAUNER, GOVERNOR   ALEC MESSINA, ACTING DIRECTOR

217/782-0610   MAJOR

July 6, 2016

Midwest Generation, LLC
13082 East Manito Rd.
Pekin, IL 61554

Re: Midwest Generation, LLC
Powerton Generating Station
NPDES Permit No. IL0002232
Final Permit

Gentlemen:

The Illinois Environmental Protection Agency has reviewed the request for modification of the above-referenced NPDES Permit and issued a public notice based on that request. The final decision of the Agency is to modify the Permit as follows:

1600 gpd of Trona Mill Wash Water and an intermittent discharge of Trona Mill Building Roof Drains were added as subwastestreams 6(h) and (i) for outfall 001 on page 2 of the permit.

The permittee address was changed as requested in your letter of September 9, 2015.

An incidental take statement pursuant to 40 CFR 125.98(b)(1) was added to Special Condition 15.

Enclosed is a copy of the modified Permit. 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 Jaime Rabins at 217/782-0610.

Sincerely,

Alan Keller, P.E.
Manager, Permit Section
Division of Water Pollution Control

SAK:JAR:15071701

Attachments: Modified Permit

cc: Compliance Assurance Section
Records Unit
Peoria FOS
US EPA
Billing

NPDES Permit No. IL0002232

MAJOR

Illinois Environmental Protection Agency

Division of Water Pollution Control

1021 North Grand Avenue East

Post Office Box 19276

Springfield, Illinois 62794-9276

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

Modified (NPDES) Permit

Expiration Date: May 31, 2020

Issue Date: May 22, 2015
Effective Date: June 1, 2015
Modification Date: July 6, 2016

Name and Address of Permittee:
Midwest Generation, LLC
13082 East Manito Rd.
Pekin, IL 61554

Facility Name and Address:
Powerton Generating Station
13082 East Manito Rd.
Pekin, IL 61554
(Tazewell County)

Discharge Number and Name:	Receiving Waters:
001 Ash Treatment System Effluent	Illinois River
A01 Metal Cleaning Waste Treatment System Effluent	
002 Cooling Pond Emergency Overflow	Unnamed tributary to the Illinois River
A02 Coal Pile Runoff Treatment System Effluent	
B02 West Yard Treatment System Effluent	
004 RBC Sewage Treatment Plant Effluent	Illinois River
006 Treated Asbestos Contaminated Stormwater	Illinois River

In compliance with the provisions of the Illinois Environmental Protection Act, Title 35 of Ill. Adm. Code, Subtitle C and/or Subtitle D, Chapter 1, and the Clean Water Act (CWA), 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.

Alan Keller

Alan Keller, P.E.
Manager, Permit Section
Division of Water Pollution Control

SAK:JAR:15071701

Modification Date: July 6, 2016

NPDES Permit No. IL0002232

Effluent Limitations and Monitoring

From the modification date of this permit until the expiration date, the effluent of the following discharge(s) shall be monitored and limited at all times as follows:

	LOAD LIMITS lbs/day DAF (DMF)		CONCENTRATION LIMITS mg/l			
PARAMETER	30 DAY AVERAGE	DAILY MAXIMUM	30 DAY AVERAGE	DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE

Outfall: 001 Ash Treatment System Effluent (DAF = 7.33 MGD)*

This discharge consists of:

	Approximate Flow
1. Bottom Ash and Economizer Ash Sluice Wastewater	10.9 MGD
2. Alternate Route for Boiler Room Sump	Intermittent
3. Intermittent Route for Boiler Room Floor and Roof Drains	Intermittent
4. Slag Tank Overflow Sump Wastes; Tripper Room Dust Extractor; Tail End and Tripper Room Washdown; Alternate Route for Boiler Room Floor Drains; Alternate Route for RO Reject and Cleaning Wastes	6.2 MGD
5. Demineralizer Sand Filter Backwash	0.1 MGD
6. East Yard Runoff Basin Effluent	Intermittent
a. East Yard Area Runoff	1.0 MGD
b. Units 1-4 Roof and Yard Drains	Intermittent
c. Boiler Room Sump Wastes	0.3 MGD
d. Boiler Room Roof and Building Drains	Intermittent
e. Polymer Building Floor Drains	0.01 MGD
f. Scrubber and Limestone Building Area Drains	0.01 MGD
g. Condensate Storage Tank	Intermitten
h. Trona Mill Wash Water	1600 GPD
i. Trona Mill Building Roof Drains	Intermittent
7. Demineralizer Regenerant and RO Wastes to South Equalization Basin; Alternate Route direct to Ash Treatment	0.3 MGD
8. Metal Cleaning Wastes Treatment System Effluent	0.50 MGD

PARAMETER	30 DAY AVERAGE	DAILY MAXIMUM	30 DAY AVERAGE	DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE
Flow (MGD)	See Special Condition 1				1/Week	24 Hour Total
pH	See Special Condition 2				1/Week	Grab
Total Suspended Solids			15	30	2/Month	24 Hour Composite
Oil and Grease			15	20	2/Month	Grab

*See Special Condition 16.

Effluent Limitations and Monitoring

From the modification date of this permit until the expiration date, the effluent of the following discharge(s) shall be monitored and limited at all times as follows:

PARAMETER	LOAD LIMITS lbs/day DAF (DMF) 30 DAY AVERAGE	LOAD LIMITS lbs/day DAF (DMF) DAILY MAXIMUM	CONCENTRATION LIMITS mg/l 30 DAY AVERAGE	CONCENTRATION LIMITS mg/l DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE

Outfall: A01 Metal Cleaning Waste Treatment System Effluent (DAF = 0.5 MGD)

This discharge consists of:	Approximate Flow
1. Boiler and Air Heater, Precipitator, and Economizer Wash Water; (Gas Side Boiler Wash Water)	Intermittent
2. Water Side Boiler Cleaning Water	Intermittent
3. Alternate Route for Demineralizer Regenerant Waste and RO Reject and Cleaning Wastes	Intermittent

PARAMETER	LOAD 30 DAY AVERAGE	LOAD DAILY MAXIMUM	CONC. 30 DAY AVERAGE	CONC. DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE
Flow (MGD)	See Special Condition 1				Daily	24 Hour Total
Total Suspended Solids			30	100	2/Week	24 Hour Composite
Oil and Grease			15	20	2/Week	Grab
Iron			1.0	1.0	2/Week	24 Hour Composite
Copper			0.5	1.0	2/Week	24 Hour Composite

Effluent Limitations and Monitoring

From the modification date of this permit until the expiration date, the effluent of the following discharge(s) shall be monitored and limited at all times as follows:

PARAMETER	LOAD LIMITS lbs/day DAF (DMF) 30 DAY AVERAGE	DAILY MAXIMUM	CONCENTRATION LIMITS mg/l 30 DAY AVERAGE	DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE

Outfall: 002 Cooling Pond Emergency Overflow (Intermittent Discharge)

This discharge consists of:	Approximate Flow
1. Condenser Cooling Water	497 MGD/Unit
2. House Service Water	Intermittent
3. Intermittent Ash Treatment System Effluent (Approximately 15%)	7.33 MGD
4. Coal Pile Runoff System Effluent	1.64 MGD
5. West Yard Runoff System Effluent	1.14 MGD
6. Pond Intake Screen Backwash	Intermittent
7. Boiler Drains	Intermittent
8. RO Reject	0.14 MGD

PARAMETER	30 DAY AVERAGE	DAILY MAXIMUM	30 DAY AVERAGE	DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE
Flow (MGD)	See Special Condition 1				Daily When Discharging	Estimate
pH	See Special Condition 3				Daily When Discharging	Grab
Temperature	See Special Condition 5				Daily When Discharging	Measure

Effluent Limitations and Monitoring

From the modification date of this permit until the expiration date, the effluent of the following discharge(s) shall be monitored and limited at all times as follows:

PARAMETER	LOAD LIMITS lbs/day DAF (DMF) 30 DAY AVERAGE	LOAD LIMITS lbs/day DAF (DMF) DAILY MAXIMUM	CONCENTRATION LIMITS mg/l 30 DAY AVERAGE	CONCENTRATION LIMITS mg/l DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE

Outfall: A02 Coal Pile Runoff Treatment System Effluent (Intermittent Discharge)*

This discharge consists of:

	Approximate Flow
1. Crusher Building Area Runoff	Intermittent
2. East & West Coal Pile Runoff	2.0 MGD
3. Equipment Building Area Runoff	Intermittent
4. Reclaim Hopper and Car Dumper Sumps	Intermittent
5. Fuel Oil Tank Area Runoff	Intermittent
6. Treated Asbestos Contaminated Stormwater	1.44 MGD

PARAMETER	30 DAY AVERAGE (lbs/day)	DAILY MAXIMUM (lbs/day)	30 DAY AVERAGE (mg/l)	DAILY MAXIMUM (mg/l)	SAMPLE FREQUENCY	SAMPLE TYPE
Flow (MGD)	See Special Condition 1				Daily	24 Hour Total
Total Suspended Solids			15	30	1/Week	24 Hour Composite
Oil and Grease			15	20	1/Week	Grab

*See Special Condition 16.

Effluent Limitations and Monitoring

From the modification date of this permit until the expiration date, the effluent of the following discharge(s) shall be monitored and limited at all times as follows:

PARAMETER	LOAD LIMITS lbs/day DAF (DMF) 30 DAY AVERAGE	LOAD LIMITS lbs/day DAF (DMF) DAILY MAXIMUM	CONCENTRATION LIMITS mg/l 30 DAY AVERAGE	CONCENTRATION LIMITS mg/l DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE

Outfall: B02 West Yard Runoff Treatment System Effluent (DAF = 1.14 MGD)

This discharge consists of:

		Approximate Flow
1.	West Yard Area Runoff	0.115 MGD
2.	North and South 345kV Switchyard Oil Separator Effluents	0.377 MGD
3.	Oil Tank Area Oil Separator Effluent	0.205 MGD
4.	Crib House Roof and Floor Drains	0.09 MGD
5.	Units 5 and 6 Turbine Room Roof and Floor Drains to Oil Separators	0.134 MGD
6.	Units 1-4 Area Runoff	0.115 MGD
7.	138kV Switchyard Area Runoff	0.176 MGD
8.	Condenser Pit Oil Separator Effluents	Intermittent
9.	Parking Area Runoff	0.39 MGD
10.	Administration Building Roof and Area Drains	Intermittent

PARAMETER	30 DAY AVERAGE	DAILY MAXIMUM	30 DAY AVERAGE	DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE
Flow (MGD)	See Special Condition 1				Daily	24 Hour Total
Total Suspended Solids			15	30	2/Month	24 Hour Composite
Oil and Grease			15	20	2/Month	Grab

Modification Date: July 6, 2016

NPDES Permit No. IL0002232

Effluent Limitations and Monitoring

From the modification date of this permit until the expiration date, the effluent of the following discharge(s) shall be monitored and limited at all times as follows:

	LOAD LIMITS lbs/day DAF (DMF)		CONCENTRATION LIMITS mg/l			
PARAMETER	30 DAY AVERAGE	DAILY MAXIMUM	30 DAY AVERAGE	DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE
Outfall: 004 RBC Sewage Treatment Plant Effluent (DAF = 0.036 MGD)						
Flow (MGD)	See Special Condition 1				Continuous	
pH	See Special Condition 2				1/Week	Grab
Total Suspended Solids	10	20	30	60	2/Month	24 Hour Composite
BOD_5	10	20	30	60	2/Month	24 Hour Composite
Total Residual Chlorine	See Special Condition 4				Daily When Chlorinating	Grab

NPDES Permit No. IL0002232

Effluent Limitations and Monitoring

From the modification date of this permit until the expiration date, the effluent of the following discharge(s) shall be monitored and limited at all times as follows:

	LOAD LIMITS lbs/day DAF (DMF)		CONCENTRATION LIMITS mg/l			
PARAMETER	30 DAY AVERAGE	DAILY MAXIMUM	30 DAY AVERAGE	DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE
Outfall: 006 Treated Asbestos Contaminated Stormwater (DAF = 1.44 MGD)						
Flow (MGD)	See Special Condition 1				Weekly When Discharging	Single Reading
Asbestos				7 million fibers/L	Weekly When Discharging	Grab

Special Conditions

SPECIAL CONDITION 1. Flow shall be measured in units of Million Gallons per Day (MGD) and reported as a monthly average and a daily maximum value on the monthly Discharge Monitoring Report.

SPECIAL CONDITION 2. The pH shall be in the range 6.0 to 9.0 for the discharge from outfalls 001 and 004. The monthly minimum and monthly maximum values shall be reported on the DMR form.

SPECIAL CONDITION 3. The pH shall be in the range 6.5 to 9.0 for the discharge from outfall 002. The monthly minimum and monthly maximum values shall be reported on the DMR form.

SPECIAL CONDITION 4. All samples for TRC shall be grab samples and analyzed by an applicable method contained in 40 CFR 136, equivalent in accuracy to low-level amperometric titration. Any analytical variability of the method used shall be considered when determining the accuracy and precision of the results obtained.

SPECIAL CONDITION 5. This facility meets the allowed mixing criteria for thermal discharges from outfall 002 pursuant to 35 IAC 302.102. No reasonable potential exists for the discharge to exceed thermal water quality standards. The permittee shall monitor the flow and temperature of the discharge prior to entry into the receiving water body. Monitoring results shall be reported on the monthly DMR. This permit may be modified to include formal temperature limitations should the results of the monitoring show that there is a reasonable potential to exceed a thermal water quality standard. Modification of this permit shall follow public notice and opportunity for comment.

SPECIAL CONDITION 6. Debris collected on river make-up intake screens is prohibited from being discharged back to the pond. Debris does not include living fish or other living aquatic organisms.

SPECIAL CONDITION 7. The Agency has determined that the effluent limitations in this permit constitute BAT/BCT for storm water which is treated in the existing treatment facilities for purposes of this permit reissuance, and no pollution prevention plan will be required for such storm water. In addition to the chemical specific monitoring required elsewhere in this permit, the permittee shall conduct an annual inspection of the facility site to identify areas contributing to a storm water discharge associated with industrial activity, and determine whether any facility modifications have occurred which result in previously-treated storm water discharges no longer receiving treatment. If any such discharges are identified the permittee shall request a modification of this permit within 30 days after the inspection. Records of the annual inspection shall be retained by the permittee for the term of this permit and be made available to the Agency on request.

SPECIAL CONDITION 8. There shall be no discharge of polychlorinated biphenyl compounds

SPECIAL CONDITION 9. The bypass provisions of 40 CFR 122.41(m) and upset provisions of 40 CFR 122.41(n) are hereby incorporated by reference.

SPECIAL CONDITION 10. Samples taken in compliance with the effluent monitoring requirements of outfalls 001, 002, 004 and 006 shall be taken at a point representative of the discharge, but prior to entry into the receiving stream.

Samples taken in compliance with the effluent monitoring requirements of outfalls A01, A02 and B02 shall be taken at a point representative of the discharge, but prior to comingling with other wastestreams.

SPECIAL CONDITION 11. The Permittee shall record monitoring results on Discharge Monitoring Report (DMR) Forms using one such form for each outfall each month.

In the event that an outfall does not discharge during a monthly reporting period, the DMR Form shall be submitted with no discharge indicated.

The Permittee may choose to submit electronic DMRs (NetDMR) instead of mailing paper DMRs to the IEPA. More information, including registration information for the NetDMR program, can be obtained on the IEPA website, http://www.epa.state.il.us/water/net-dmr/index.html.

The completed Discharge Monitoring Report forms shall be submitted to IEPA no later than the 28th day of the following month, unless otherwise specified by the permitting authority.

Special Conditions

Permittees not using NetDMR shall mail Discharge Monitoring Reports with an original signature to the IEPA at the following address:

Illinois Environmental Protection Agency
Division of Water Pollution Control
1021 North Grand Avenue East
Post Office Box 19276
Springfield, Illinois 62794-9276

Attention: Compliance Assurance Section, Mail Code # 19

SPECIAL CONDITION 12. The effluent, alone or in combination with other sources, shall not cause a violation of any applicable water quality standard outlined in 35 Ill. Adm. 302.

SPECIAL CONDITION 13. The use or operation of this facility shall be by or under the supervision of a Certified Class K operator.

SPECIAL CONDITION 14. In the event that the permittee shall require a change in the use of water treatment additives, the permittee must request a change in this permit in accordance with the Standard Conditions – Attachment H.

SPECIAL CONDITION 15. In accordance 40 CFR 125.3 it is the Agency's Best Professional Judgment that the intake structure is considered the Best Technology Available for minimizing adverse environmental impact because utilization of a closed-cycle recirculating system was considered the best technology available for minimizing adverse environmental impact under the now remanded rule of 40 CFR 125.94(a)(1)(i). Furthermore, the Illinois River intake structure design intake velocity is less than 0.5 feet per second which is considered the best technology available for minimizing adverse environmental impact. This permit may also be revised or modified in accordance with any laws, regulations, or judicial orders issued pursuant to Section 316(b) of the Clean Water Act.

However, the Permittee shall comply with the requirements of the Cooling Water Intake Structure Existing Facilities Rule as found at 40 CFR 122 and 125. Any application materials and submissions required for compliance with the Existing Facilities Rule, shall be submitted to the Agency no later than 4 years from the effective date of this permit.

Nothing in this permit authorizes take for the purpose of a facility's compliance with the Endangered Species Act.

SPECIAL CONDITION 16. The Permittee shall monitor the effluent from outfalls 001 and A02 for the following parameters on a semi-annual basis. This Permit may be modified with public notice to establish effluent limitations if appropriate, based on information obtained through sampling. The sample shall be a 24-hour effluent composite except as otherwise specifically provided below and the results shall be submitted to the address in special condition 11 in June and December. The parameters to be sampled and the minimum reporting limits to be attained are as follows:

STORET CODE	PARAMETER	Minimum reporting limit
01002	Arsenic	0.05 mg/L
01007	Barium	0.5 mg/L
01022	Boron	0.1 mg/L
01027	Cadmium	0.001 mg/L
00940	Chloride	0.1 mg/L
01032	Chromium (hexavalent) (grab)	0.01 mg/L
01034	Chromium (total)	0.05 mg/L
01042	Copper	0.005 mg/L
00718	Cyanide (grab) (available *** or amendable to chlorination))	5.0 ug/L
00720	Cyanide (grab not to exceed 24 hours) (total)	5.0 ug/L
00951	Fluoride	0.1 mg/L
01045	Iron (total)	0.5 mg/L
01046	Iron (Dissolved)	0.5 mg/L
01051	Lead	0.05 mg/L
01055	Manganese	0.5 mg/L
71900	Mercury (grab)**	1.0 ng/L*
01067	Nickel	0.005 mg/L
00556	Oil (hexane soluble or equivalent) (Grab Sample only)	5.0 mg/L
32730	Phenols (grab)	0.005 mg/L
01147	Selenium	0.005 mg/L
00945	Sulfate	0.1 mg/L
01077	Silver (total)	0.003 mg/L
01092	Zinc	0.025 mg/L

Unless otherwise indicated, concentrations refer to the total amount of the constituent present in all phases, whether solid, suspended or

Special Conditions

dissolved, elemental or combined, including all oxidation states.

*1.0 ng/L = 1 part per trillion.
**Utilize USEPA Method 1631E and the digestion procedure described in Section 11.1.1.2 of 1631E. Mercury shall be monitored monthly for the first two years and quarterly thereafter. This Permit may be modified with public notice to establish effluent limitations if appropriate, based on information obtained through sampling. The quarterly monitoring results shall be submitted on the March, June, September and December DMRs.
***USEPA Method OIA-1677

SPECIAL CONDITION 17. A zone of initial dilution (ZID) is recognized for ammonia, with dimensions of 1.0 feet outward across the river from the point where the canal/ditch receiving the effluent from outfall 004 flows into the Illinois River, and 1.0 feet downstream from this point. Within the ZID 11:1 dilution is afforded. A mixing zone is recognized with dimensions of 1.2 feet outward across the river from the outfall and 1.2 feet downstream from this point. Within the mixing zone 88:1 dilution is afforded.

SPECIAL CONDITION 18. A plan of study must be submitted to IEPA no later than 30 days from the effective date of the permit for a bacteria die-off demonstration. Fecal coliform bacteria must be measured at the end of the treatment process for Outfall 004 (the usual sampling location) and at points in the canal receiving the effluent leading to the Illinois River. The sampling for this demonstration must occur on at least three occasions, at least one week apart, during the months of July, August and/or September, 2015. A final report on the results of the study is due to the IEPA no later than October 15, 2015. IEPA will use the results of this demonstration to determine if the year-round disinfection exemption remains valid for this Outfall. If the IEPA finds that the Illinois River receives water at fecal coliform concentrations above the water quality standard (geometric mean of 200 cells per 100 mL) a modified permit will be issued that revokes the year-round exemption and requires seasonal disinfection.

SPECIAL CONDITION 19. An alternate discharge location for the reverse osmosis reject, which is currently discharged to the cooling pond tributary to outfall 002, shall be evaluated for discharge into the Illinois River. If this alternative proves reasonable, an antidegradation assessment with modification request to relocate the reverse osmosis reject discharge from the cooling pond to the Illinois River, shall be submitted to the Agency within 90 days of the effective date of the permit.

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.

EXHIBIT 11

ENVIRONMENTAL CONSULTATION & REMEDIATION

KPRG

KPRG and Associates, inc.

414 Plaza Drive, Suite 106 Westmont, Illinois 60559 Telephone 630-325-1300 Facsimile 630-325-1593

14665 West Lisbon Road, Suite 2B Brookfield, Wisconsin 53005 Telephone 262-781-0475 Facsimile 262-781-0478

CCR MONITORING WELL SITE MAP	
POWERTON STATION PEKIN, ILLINOIS	
Scale: 1" = 350'	Date: December 19, 2018
KPRG Project No. 12313.1	FIGURE 1

EXHIBIT 12

LOG NUMBERS: 2748-09

PERMIT NO.: 2009-EB-2748

FINAL PLANS, SPECIFICATIONS, APPLICATION AND SUPPORTING DOCUMENTS
PREPARED BY: Natural Resource Technology Group

DATE ISSUED: NOV 13 2009

SUBJECT: MIDWEST GENERATION LLC - Powerton Generating Station - Metal Cleaning Basin Liner Replacement - Discharge Tributary to the Illinois River

PERMITTEE TO CONSTRUCT AND OPERATE

Midwest Generation, LLC
235 Remington Blvd., Suite A
Bolingbrook, IL 60440

Permit is hereby granted to the above designated permittee(s) to construct and operate water pollution control facilities described as follows:

The Metal Cleaning Basin at the Powerton Generating Station located at 13082 East Manito Rd. in Pekin, Illinois will undergo a liner upgrade by the addition of a 60 mil HDPE geomembrane liner. At the base, a 12 inch thick sand or limestone cushion layer and a 6 inch coarse aggregate warning layer will be placed on top of the new HDPE liner.

Once complete the liner system will consist of the existing chlorosulfonated polyethylene liner and the new 60 mil HDPE geomembrane liner. The DMF of 1.19 MGD and working volume of 5.4 million gallons at 3 to 6 feet of freeboard for the Metal Cleaning Basin will remain unchanged.

This operating permit expires on September 30, 2014.

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

SPECIAL CONDITION 1: The Permittee to Construct shall be responsible for obtaining an NPDES Storm Water Permit prior to initiating construction if the construction activities associated with this project will result in the disturbance of one (1) or more acres total land area.

An NPDES Storm Water Permit may be obtained by submitting a properly completed Notice of Intent (NOI) form by certified mail to the Agency's Division of Water Pollution Control - Permit Section.")

SPECIAL CONDITION 2: The operational portion of this permit shall be governed by NPDES Permit No. IL0002232.

SPECIAL CONDITION 3: All sludges generated on site shall be disposed of at a site and in a manner acceptable to the Agency.

SPECIAL CONDITION 4: The existing Midwest Generation waste storage lagoon shall adhere to the following groundwater protection elements:

THE STANDARD CONDITIONS OF ISSUANCE INDICATED ON THE REVERSE SIDE MUST BE COMPLIED WITH IN FULL. READ ALL CONDITIONS CAREFULLY.

SAK:JAR:2748-09.docx

DIVISION OF WATER POLLUTION CONTROL

Alan Keller by AEL

Alan Keller, P.E.
Manager, Permit Section

cc: EPA-Peoria FOS
Natural Resource Technology Group
Records - Industrial
Binds

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY
WATER POLLUTION CONTROL PERMIT

LOG NUMBERS: 2748-09 **PERMIT NO.:** 2009-EB-2748

FINAL PLANS, SPECIFICATIONS, APPLICATION AND SUPPORTING DOCUMENTS
PREPARED BY: Natural Resource Technology Group

DATE ISSUED: NOV 13 2009

SUBJECT: MIDWEST GENERATION LLC - Powerton Generating Station - Metal Cleaning Basin Liner Replacement - Discharge Tributary to the Illinois River

1. A minimum of three monitoring wells must be installed around the waste storage lagoon, no more than 25 feet from the outermost edge of the waste storage lagoon. At least one of the monitoring wells must be located down gradient of the waste storage lagoon. The monitoring wells should be screened in the upper most water bearing materials. Provide drillers logs and well completion reports, and an updated monitoring well location map after well completion.

2. At least six groundwater samples must be collected from each monitoring well within one year, to establish a statistically valid representation of existing (background) concentrations.

3. Sample monitoring wells for the chemical parameters listed in 35 IAC 620.410(a) and (d). The sampling plan will be required as part of the permit. The following parameters listed below should also be sampled.

   Specific Conductance
   Temperature
   Depth to Water (bls)
   Depth to Water (bmp)
   Elevation of MP
   Elevation of GW Surface

4. After a background concentration for each constituent is determined, monitoring will be conducted and reported monthly during waste storage lagoon use.

5. In the event that any Class I: Potable Resource Groundwater Quality Standards are exceeded in any potable water supply well, and is attributable to the operation of the waste storage lagoon, an alternative water supply shall be supplied with all costs of providing the alternative supply being borne by the owner of waste storage lagoon.

6. A corrective action plan is required, if monitoring well analysis indicates impacted groundwater from the waste storage lagoon.

7. The liner must be protected from degradation.

8. Copies of the groundwater monitoring well sample analysis shall be submitted to the following addresses:

Illinois EPA
Division of Water Pollution Control
Compliance Assurance Section
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9276

Illinois EPA
DWPC - Peoria Region
5415 North University Ave.
Peoria, Illinois 61614

Illinois EPA
Hydrogeology and Compliance Unit
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9276

READ ALL CONDITIONS CAREFULLY:
STANDARD CONDITIONS

The Illinois Environmental Protection Act (Illinois Revised Statutes Chapter 111-12. Section 1039) grants the Environmental Protection Agency authority to impose conditions on permits which it issues.

1. Unless the construction for which this permit is issued has been completed, this permit will expire (1) two years after the date of issuance for permits to construct sewers or wastewater sources or (2) three years after the date of issuance for permits to construct treatment works or pretreatment works.

2. The construction or development of facilities covered by this permit shall be done in compliance with applicable provisions of Federal laws and regulations, the Illinois Environmental Protection Act, and Rules and Regulations adopted by the Illinois Pollution Control Board.

3. There shall be no deviations from the approved plans and specifications unless a written request for modification of the project, along with plans and specifications as required, shall have been submitted to the Agency and a supplemental written permit issued.

4. The permittee shall allow any agent duly authorized by the Agency upon the presentations of credentials:

    a. to enter at reasonable times, the permittee's premises where actual or potential effluent, emission or noise sources are located or where any activity is to be conducted pursuant to this permit;

    b. to have access to and copy at reasonable times any records required to be kept under the terms and conditions of this permit;

    c. to inspect at reasonable times, including during any hours of operation of equipment constructed or operated under this permit, such equipment or monitoring methodology or equipment required to be kept, used, operated, calibrated and maintained under this permit;

    d. to obtain and remove at reasonable times samples of any discharge or emission of pollutants;

    e. to enter at reasonable times and utilize any photographic, recording, testing, monitoring or other equipment for the purpose of preserving, testing, monitoring, or recording any activity, discharge, or emission authorized by this permit.

5. The issuance of this permit:

    a. shall not be considered as in any manner affecting the title of the premises upon which the permitted facilities are to be located;

    b. does not release the permittee from any liability for damage to person or property caused by or resulting from the construction, maintenance, or operation of the proposed facilities;

    c. does not release the permittee from compliance with other applicable statutes and regulations of the United States, of the State of Illinois, or with applicable local laws, ordinances and regulations;

    d. does not take into consideration or attest to the structural stability of any units or parts of the project;

    e. in no manner implies or suggests that the Agency (or its officers, agents or employees) assumes any liability, directly or indirectly, for any loss due to damage, installation, maintenance, or operation of the proposed equipment or facility.

6. Unless a joint construction/operation permit has been issued, a permit for operating shall be obtained from the agency before the facility or equipment covered by this permit is placed into operation.

7. These standard conditions shall prevail unless modified by special conditions.

8. The Agency may file a complaint with the Board for suspension or revocation of a permit:

    a. upon discovery that the permit application contained misrepresentations, misinformation or false statement or that all relevant facts were not disclosed; or

    b. upon finding that any standard or special conditions have been violated; or

    c. upon any violation of the Environmental Protection Act or any Rules or Regulation effective thereunder as a result of the construction or development authorized by this permit.

EXHIBIT 13

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY
WATER POLLUTION CONTROL PERMIT

LOG NUMBERS: 1213-13

PERMIT NO.: 2013-EB-1213

FINAL PLANS, SPECIFICATIONS, APPLICATION AND SUPPORTING DOCUMENTS
PREPARED BY: Natural Resource Technology Group

DATE ISSUED: February 25, 2013

SUBJECT: MIDWEST GENERATION, LLC – Powerton Generating Station – Liner Replacement – Discharge Tributary to the Illinois River

PERMITTEE TO CONSTRUCT AND OPERATE

Midwest Generation, LLC
13082 E. Manito Road
Pekin, IL 61554

Permit is hereby granted to the above designated permittee(s) to construct and operate water pollution control facilities described as follows:

A new 60 mil HDPE geomembrane liner, a 12-inch cushion layer, and a 6-inch warning layer will be installed at the Ash Surge Basin. The side-slopes will be reshaped as necessary to maintain a 3 to 1 slope and may require removal of the existing chlorosulfonated polyethylene liner. The DMF of 19.2 MGD and working volume of 21 million gallons at 3 feet of freeboard will remain unchanged.

This operating permit expires on December 31, 2017.

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

SPECIAL CONDITION 1: The Permittee to Construct shall be responsible for obtaining an NPDES Storm Water Permit prior to initiating construction if the construction activities associated with this project will result in the disturbance of one (1) or more acres total land area.

An NPDES Storm Water Permit may be obtained by submitting a properly completed Notice of Intent (NOI) form by certified mail to the Agency's Division of Water Pollution Control Permit Section.")

SPECIAL CONDITION 2: The discharge from Ash Surge Basin shall be governed by NPDES Permit No. IL0002232.

SPECIAL CONDITION 3: The existing Midwest Generation waste storage lagoon shall adhere to the following groundwater protection elements:

a. A minimum of three monitoring wells must be installed around Ash Surge Basin to demonstrate compliance with 35 IAC 620. At least one monitoring well must be down gradient of the pond. Pursuant to 35 IAC 620.505, compliance

THE STANDARD CONDITIONS OF ISSUANCE INDICATED ON THE REVERSE SIDE MUST BE COMPLIED WITH IN FULL. READ ALL CONDITIONS CAREFULLY.

SAK:JAR:1213-13.docx

DIVISION OF WATER POLLUTION CONTROL

Alan Keller by DEL

Alan Keller, P.E.
Manager, Permit Section

cc: EPA-Peoria FOS
Natural Resource Technology Group
Records - Industrial
Binds

FZ Water - CONB

READ ALL CONDITIONS CAREFULLY:
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2. The construction or development of facilities covered by this permit shall be done in compliance with applicable provisions of Federal laws and regulations, the Illinois Environmental Protection Act, and Rules and Regulations adopted by the Illinois Pollution Control Board.

3. There shall be no deviations from the approved plans and specifications unless a written request for modification of the project, along with plans and specifications as required, shall have been submitted to the Agency and a supplemental written permit issued.

4. The permittee shall allow any agent duly authorized by the Agency upon the presentations of credentials:

   a. to enter at reasonable times, the permittee's premises where actual or potential effluent, emission or noise sources are located or where any activity is to be conducted pursuant to this permit;

   b. to have access to and copy at reasonable times any records required to be kept under the terms and conditions of this permit;

   c. to inspect at reasonable times, including during any hours of operation of equipment constructed or operated under this permit, such equipment or monitoring methodology or equipment required to be kept, used, operated, calibrated and maintained under this permit;

   d. to obtain and remove at reasonable times samples of any discharge or emission of pollutants;

   e. to enter at reasonable times and utilize any photographic, recording, testing, monitoring or other equipment for the purpose of preserving, testing, monitoring, or recording any activity, discharge, or emission authorized by this permit.

5. The issuance of this permit:

   a. shall not be considered as in any manner affecting the title of the premises upon which the permitted facilities are to be located;

   b. does not release the permittee from any liability for damage to person or property caused by or resulting from the construction, maintenance, or operation of the proposed facilities;

   c. does not release the permittee from compliance with other applicable statutes and regulations of the United States, of the State of Illinois, or with applicable local laws, ordinances and regulations;

   d. does not take into consideration or attest to the structural stability of any units or parts of the project;

   e. in no manner implies or suggests that the Agency (or its officers, agents or employees) assumes any liability, directly or indirectly, for any loss due to damage, installation, maintenance, or operation of the proposed equipment or facility.

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   a. upon discovery that the permit application contained misrepresentations, misinformation or false statement or that all relevant facts were not disclosed; or

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   c. upon any violation of the Environmental Protection Act or any Rules or Regulation effective thereunder as a result of the construction or development authorized by this permit.

groundwater monitoring requires the down gradient monitoring wells to be located approximately 25 feet from the toe of the ash impoundment berms.

b. The monitoring wells should be constructed using local conditions as a guide, but must be screened and constructed to allow the collection of representative groundwater samples. In general, the monitoring wells should be cased to at least 10 feet below grade, with a screen that intersects the water table surface.

c. Midwest Generation must collect an adequate number of samples to establish a statistically valid representation of water quality (background) that has not been impacted by this unit or other units at this facility.

d. The contaminants for which background and compliance groundwater monitoring must be completed are listed in 35 IAC 620.410(a) and (d), not including radium 226 or radium 228. Static groundwater elevation must be collected before each monitoring event.

e. Groundwater samples must be analyzed and reported at least quarterly. Copies of the groundwater monitoring well sample analysis shall be submitted during the months of April, July, October, and January for the preceding three month period, to the following addresses:

Illinois EPA
Division of Water Pollution Control
Compliance Assurance Section
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9276

Illinois EPA
DWPC – Peoria Region
5415 North University Ave.
Peoria, Illinois 61614

Illinois EPA
Hydrogeology and Compliance Unit
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9276

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   a. to enter at reasonable times, the permittee's premises where actual or potential effluent, emission or noise sources are located or where any activity is to be conducted pursuant to this permit;

   b. to have access to and copy at reasonable times any records required to be kept under the terms and conditions of this permit;

   c. to inspect at reasonable times, including during any hours of operation of equipment constructed or operated under this permit, such equipment or monitoring methodology or equipment required to be kept, used, operated, calibrated and maintained under this permit;

   d. to obtain and remove at reasonable times samples of any discharge or emission of pollutants;

   e. to enter at reasonable times and utilize any photographic, recording, testing, monitoring or other equipment for the purpose of preserving, testing, monitoring, or recording any activity, discharge, or emission authorized by this permit.

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   b. does not release the permittee from any liability for damage to person or property caused by or resulting from the construction, maintenance, or operation of the proposed facilities;

   c. does not release the permittee from compliance with other applicable statutes and regulations of the United States, of the State of Illinois, or with applicable local laws, ordinances and regulations;

   d. does not take into consideration or attest to the structural stability of any units or parts of the project;

   e. in no manner implies or suggests that the Agency (or its officers, agents or employees) assumes any liability, directly or indirectly, for any loss due to damage, installation, maintenance, or operation of the proposed equipment or facility.

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   a. upon discovery that the permit application contained misrepresentations, misinformation or false statement or that all relevant facts were not disclosed; or

   b. upon finding that any standard or special conditions have been violated; or

   c. upon any violation of the Environmental Protection Act or any Rules or Regulation effective thereunder as a result of the construction or development authorized by this permit.

EXHIBIT 14

NATURAL RESOURCE TECHNOLOGY

ENVIRONMENTAL CONSULTANTS

23713 W. PAUL ROAD, SUITE D
PEWAUKEE, WI 53072
(P) 262.523.9000
(F) 262.523.9001

Mr. Mark Kelly
Midwest Generation, LLC
Powerton Station
13082 East Manito Road
Pekin, IL 61554

June 27, 2011
(1965)

RE: Construction Documentation Transmittal
Metal Cleaning Basin and Bypass Basin Liner Replacement

Dear Mr. Kelly:

Natural Resource Technology, Inc., (NRT) has prepared this correspondence to transmit construction record documents for the liner replacement of the Metal Cleaning Basin and the Bypass Basin at the Powerton Station. The following information is enclosed:

- Select submittals from Contractor:

Attachment	Table 2 Submittal Item[a]		Submittal Description
	Bypass Basin	Metal Cleaning Basin	
A1	6&12	6&11	Warning Layer and Cushion Layer Gradation Reports
A2	14	12	Geomembrane Resin Test Results
A3	NA	19	Reinforcement Steel Shop Drawings
A4	NA	20	Concrete Accessories and Admixtures Manufacturer's Certificate and Literature
A5	NA	21&22	Concrete Quality Control Tests
A6	20-22	23-25	Geosynthetic Product Information
A7	24	27	Geomembrane Installer's Daily Logs and QC Documentation
A8	25	28	Geomembrane Installer's Subgrade Acceptance
A9	26	29	Geomembrane Installation Certificate
A10	26	29	Geomembrane Installation Warranties
A11	26	29	Geomembrane As-Built Panel Layout
A12	31	34	Leak Location Survey Report

- Drawings updated to reflect Contractor's documentation survey of the liner subgrade and warning layer topography (Attachment B); and
- NRT Construction Quality Assurance (CQA) Daily Field Reports (Attachment C).

[a] Refer to Table 2 from the respective Technical Specifications for the metals cleaning basin and bypass basin.

Please contact NRT if you have any questions or comments regarding this transmittal. It has been a pleasure working with Midwest Generation on this project, and we look forward to working with you again in the future.

Sincerely,

NATURAL RESOURCE TECHNOLOGY, INC.

Heather M. Simon, PE
Project Manager

Encls.: Attachment A: Contractor Submittals
Attachment B: Documentation Survey
Attachment C: NRT CQA Daily Field Reports

[1965 Construction Documentation 110627.doc]

ATTACHMENT A

CONTRACTOR SUBMITTALS

Table 2 - List of Submittals
Metal Cleaning Basin Liner Replacement Specifications
Midwest Generation – Powerton Power Station

	Submittal	From	To	Time Frame	Reviewer	Technical Specification	
						Section	Part
1	Subcontractor List	Contractor	Owner and/or Engineer	**With bid documents**	Owner		
2	Baseline Construction Schedule	Contractor	Owner and/or Engineer	**With bid documents** and update within 10 calendar days of the date of the Contract award	Owner and/or Engineer		
3	Name and Location of Recycling / Disposal Facility	Contractor	Owner and/or Engineer	**With bid documents**	Owner and/or Engineer	02300	1.06B
4	Leak Location Contractor's Work Plan	Contractor	Owner and/or Engineer	**With bid documents**	Owner and/or Engineer	02600	1.05B
5	Supplier and Location of Cushion Material Source	Contractor	Owner and/or Engineer	**With bid documents**	Owner and/or Engineer	02300	1.06C
6	Cushion Material Grain Size Distribution Test Results	Contractor	Owner and/or Engineer	**With bid documents**	Owner and/or Engineer	02300	1.06E
7	Construction Start Date	Contractor	Owner and/or Engineer	5 Working days prior to construction start	Owner and/or Engineer	02300	1.06D
8	IEPA Water Pollution Control Construciton Permit	Owner through Engineer	Contractor	Prior to project start	Contractor		
9	Site Superintendant/Foreman's Name & Phone Number	Contractor	Owner and/or Engineer	Prior to project start	Owner and/or Engineer		
10	Location of Off-site Fill Material Sources	Contractor	Owner and/or Engineer	Prior to project start	Owner and/or Engineer	02300	1.06C
11	Off-site Fill Material Certificates/Test Results	Contractor	Owner and/or Engineer	Prior to project start	Owner and/or Engineer	02300	1.06E
12	Resin Supplier, Address, Brand Name, Product Number and Test Results	Contractor	Owner and/or Engineer	Prior to project start	Owner and/or Engineer	02600	1.05A
13	Source and nature of additives	Contractor	Owner and/or Engineer	Prior to project start	Owner and/or Engineer	02600	1.05A

Table 2 - List of Submittals
Metal Cleaning Basin Liner Replacement Specifications
Midwest Generation – Powerton Power Station

	Submittal	From	To	Time Frame	Reviewer	Technical Specification	
						Section	Part
14	Geomembrane Installer's Information, Layout Diagram, Schedule, Seaming Equipment	Contractor	Owner and/or Engineer	Prior to project start	Owner and/or Engineer	02600	1.05A
15	Accident Reports, Work Stoppage/Dispute Records, Contractor Invoices, Schedule of Values, Test Report Records, and Equipment Check Records	Contractor	Owner and/or Engineer	As Necessary	Owner and/or Engineer		
16	Proposed Concrete Mix	Contractor	Owner and/or Engineer	At least 35 days prior to placing of concrete	Owner and/or Engineer	03300	1.04E
17	Cushion Material Representative Sample	Contractor	Owner and/or Engineer	Two weeks prior to delivery	Owner and/or Engineer	02300	2.03
18	Warning Layer Representative Sample	Contractor	Owner and/or Engineer	Two weeks prior to delivery	Owner and/or Engineer	02300	2.04
19	Reinforcement Steel Shop Drawings	Contractor	Owner and/or Engineer	Two weeks prior to delivery	Owner and/or Engineer	03300	1.04A
20	Concrete Accessories and Admixtures Manufacturere's Certificate and Literature	Contractor	Owner and/or Engineer	Two weeks prior to delivery	Owner and/or Engineer	03300	1.04B
21	Concrete Delivery Tickets	Contractor	Owner and/or Engineer	Each day of delivery	Owner and/or Engineer	03300	1.04C
22	Concrete Quality Control Tests	Contractor	Owner and/or Engineer	As Necessary	Owner and/or Engineer	03300	1.04D
23	Geomembrane Manufacture's Certification-PGI Standards	Contractor	Owner and/or Engineer	5 working days prior to delivery to site	Owner and/or Engineer	02600	1.05A
24	Geotextile - Product Information	Contractor	Owner and/or Engineer	5 working days prior to delivery to site	Owner and/or Engineer	02600	1.05A

Table 2 - List of Submittals
Metal Cleaning Basin Liner Replacement Specifications
Midwest Generation – Powerton Power Station

	Submittal	From	To	Time Frame	Reviewer	Technical Specification	
						Section	Part
25	Geomembrane Manufacturer's Certification - Product Information	Contractor	Owner and/or Engineer	5 working days prior to delivery to site	Owner and/or Engineer	02600	1.05A
26	Certification of Geomembrane Manufacturer's Quality Control Plan	Contractor	Owner and/or Engineer	5 working days prior to delivery to site	Owner and/or Engineer	02600	1.05A
27	Geomembrane Installer's Daily Logs and Quality Control Documentation	Contractor	Owner and/or Engineer	During geomembrane installation	Owner and/or Engineer	02600	1.05C
28	Geomembrane Installer's Subgrade Acceptance	Contractor	Owner and/or Engineer	Each day prior to geomembrane installation	Owner and/or Engineer	02600	1.05C 3.02A
29	Geomembrane Installation Certificate, As-Builts, and Warranties	Contractor	Owner and/or Engineer	Within 10 working days of geomembrane installation completion	Owner and/or Engineer	02600	1.05D
30	Written Certification for Project	Contractor	Owner and/or Engineer	Upon completion of work	Owner and/or Engineer	01700	1.03B & C
31	Conditional and/or Final Geomembrane Installation Acceptance	Owner and/or Engineer	Contractor	Upon completion of geomembrane installation and submittals	Contractor	2600	1.05F
32	Record Documents	Contractor	Owner and/or Engineer	Prior to submittal of final invoice	Owner and/or Engineer	01700	1.04
33	Survey Data	Contractor	Owner and/or Engineer	Within 4 days following completion of survey	Owner and/or Engineer	01050	1.05
34	Final Leak Location Survey Report	Contractor	Owner and/or Engineer	Within 14 days following completion of leak location survey	Owner and/or Engineer	02600	1.05G

Table 2 - List of Submittals
Bypass Basin Liner Replacement Specifications
Midwest Generation – Powerton Power Station

	Submittal	From	To	Time Frame	Reviewer	Technical Specification	
						Section	**Part**
1	Subcontractor List	Contractor	Owner and/or Engineer	**With bid documents**	Owner		
2	Baseline Construction Schedule	Contractor	Owner and/or Engineer	**With bid documents** and update within 10 calendar days of the date of the Contract award	Owner and/or Engineer		
3	Name and Location of Recycling / Disposal Facility	Contractor	Owner and/or Engineer	**With bid documents**	Owner and/or Engineer	02300	1.06B
4	Leak Location Contractor's Work Plan	Contractor	Owner and/or Engineer	**With bid documents**	Owner and/or Engineer	02600	1.05B
5	Supplier and Location of Cushion Material Source	Contractor	Owner and/or Engineer	**With bid documents**	Owner and/or Engineer	02300	1.06C
6	Cushion Material Grain Size Distribution Test Results	Contractor	Owner and/or Engineer	**With bid documents**	Owner and/or Engineer	02300	1.06E
7	Construction Start Date	Contractor	Owner and/or Engineer	5 Working days prior to construction start	Owner and/or Engineer	02300	1.06D
8	IEPA Water Pollution Control Construciton Permit	Owner through Engineer	Contractor	Prior to project start	Contractor		
9	General Permit for Storm Water Discharges from Construction Site Activities	Owner through Engineer	Contractor	Prior to project start	Contractor		
10	Site Superintendant/Foreman's Name & Phone Number	Contractor	Owner and/or Engineer	Prior to project start	Owner and/or Engineer		
11	Location of Off-site Fill Material Sources	Contractor	Owner and/or Engineer	Prior to project start	Owner and/or Engineer	02300	1.06C
12	Off-site Fill Material Certificates/Test Results	Contractor	Owner and/or Engineer	Prior to project start	Owner and/or Engineer	02300	1.06E
13	Laboratory Test Results - Excavated Bank Soils	Contractor	Owner and/or Engineer	14 days prior to start of bank reconstruction	Owner and/or Engineer	02300	1.06F

Table 2 - List of Submittals
Bypass Basin Liner Replacement Specifications
Midwest Generation – Powerton Power Station

	Submittal	From	To	Time Frame	Reviewer	Technical Specification	
						Section	Part
14	Resin Supplier, Address, Brand Name, Product Number, and Test Results	Contractor	Owner and/or Engineer	Prior to project start	Owner and/or Engineer	02600	1.05A1
15	Geomembrane Installer's Personnel and Information	Contractor	Owner and/or Engineer	Prior to project start	Owner and/or Engineer	02600	1.05A5 & A6
16	Geomembrane Panel Layout Drawing	Contractor	Owner and/or Engineer	Prior to project start	Owner and/or Engineer	02600	1.05A7
17	Cushion Material Representative Sample	Contractor	Owner and/or Engineer	Two weeks prior to delivery	Owner and/or Engineer	02300	2.03
18	Warning Layer Representative Sample	Contractor	Owner and/or Engineer	Two weeks prior to delivery	Owner and/or Engineer	02300	2.04
19	Field Test Results	Contractor and/or Field Technician	Engineer	Within 24 hours of test completion	Engineer	02300	1.06G
20	Geomembrane Manufacture's Certification-PGI Standards	Contractor	Owner and/or Engineer	5 working days prior to delivery to site	Owner and/or Engineer	02600	1.05A2
21	Geotextile Manufacture's Certification	Contractor	Owner and/or Engineer	5 working days prior to delivery to site	Owner and/or Engineer	02600	1.05A4
22	Geomembrane Manufacturer's Certification - Production Information includes QC Plan	Contractor	Owner and/or Engineer	5 working days prior to delivery to site	Owner and/or Engineer	02600	1.05A3
23	Seed mix and application rate	Contractor	Owner and/or Engineer	5 days prior to delivery to site	Owner and/or Engineer	02930	1.03
24	Geomembrane Installer's Daily Logs and Quality Control Documentation	Contractor	Owner and/or Engineer	During geomembrane installation	Owner and/or Engineer	02600	1.05C1
25	Geomembrane Installer's Subgrade Acceptance	Contractor	Owner and/or Engineer	Each day prior to geomembrane installation	Owner and/or Engineer	02600	1.05C2 3.02A

Table 2 - List of Submittals
Bypass Basin Liner Replacement Specifications
Midwest Generation – Powerton Power Station

	Submittal	From	To	Time Frame	Reviewer	Technical Specification	
						Section	Part
26	Geomembrane Installation Certificate, As-Builts, and Warranties	Contractor	Owner and/or Engineer	Within 10 working days of geomembrane installation completion	Owner and/or Engineer	02600	1.05D
27	Written Certification for Project	Contractor	Owner and/or Engineer	Upon completion of work	Owner and/or Engineer	01700	1.03B & C
28	Conditional and/or Final Geomembrane Installation Acceptance	Owner and/or Engineer	Contractor	Upon completion of geomembrane installation and submittals	Contractor	2600	1.05F
29	Record Documents	Contractor	Owner and/or Engineer	Prior to submittal of final invoice	Owner and/or Engineer	01700	1.04
30	Survey Data	Contractor	Owner and/or Engineer	Within 4 days following completion of survey	Owner and/or Engineer	01050	1.05
31	Final Leak Location Survey Report	Contractor	Owner and/or Engineer	Within 14 days following completion of leak location survey	Owner and/or Engineer	02600	1.05G

ATTACHMENT A1

WARNING LAYER AND CUSHION LAYER GRADATION REPORTS

ILLINOIS DEPARTMENT OF TRANSPORTATION

MISTIC ID

AGGREGATE GRADATION REPORT

FA-6 - Cushion Layer

Inspector No.:	940000000	Insp. Name:	Sara Kacir	Date Sampled:	10/14/2010
Mix Plant No.:		Mix Plant:		Sequence No.:	4
Resp. Loc.:	94	Contract No.:		Job Number:	
Lab:	PP	Lab Name:	Scharf	Source Name:	Cam Scharf Materials
				Source Location:	Pekin, IL

Source Number	Material Code	Type Insp.	Original Test ID	Spec.	Article	Sampled From	Wash Dry
51790-39	016FA06 Gradation #1	PRO		Standard		SP	W

CA	3	2.5	2	1.75	1.5	1	3/4	5/8	1/2	3/8	1/4	#4	#8	#16	#30	#40	#50	#100	#200
Percent Passing						100			100	100		93	71	48	30		17	12	9.8

Wash 200	Test Results	Remarks
8.7	APPR	

Sieve (English)	12" Overload	Individual Weight Retained	Cumul. Weight Retained	Cumul. Percent Retained	Percent Passing	Spec. Range % Pass	In/Out	Overload
3	12600							
2.5	10600							
2	8400							
1.75	7500							
1.5	6300							
1	4200	0.0	0.0	0.0	100.0	100		
3/4	3200							
5/8	2700							
1/2	2100	0.0	0.0	0.0	100.0			
3/8	1600	1.0	1.0	0.1	99.9			
1/4	1100							
#4	800	49.0	50.0	6.9	93.1	50-100		
#8	470	159.5	209.5	29.1	70.9			
#16	470	168.8	378.3	52.5	47.5			
#30	470	126.4	504.7	70.1	29.9			
#40	470							
#50	470	95.4	600.1	83.4	16.6			
#100	470	33.1	633.2	88.0	12.0	0-40		
#200	470	16.2	649.4	90.2	9.8	0-12		
Pan		7.3	656.7					
Total Dry Weight:		719.9						
Total Washed Weight:		657.3						
Diff. (-#200):		62.6						

Master Band Target: #N/A

Orig. Wet Weight: grams | Moisture %:

Plasticity Index Ratio (#200/#40):
Plasticity Index Test Results:

% Washed - #200: 8.7

Mix Plant Only
Lot:
Bin:

Authorized By: Sara Kacir
Tested By: Sara Kacir
Agency/Company: Cam Scharf Materials

Copies to: Materials Inspector
District Materials
Producer

Validity Check OK
/FOR DTY03504
MI504QC
(This is a Field/Laboratory Report for MISTIC Input)

Signature

Date

ILLINOIS DEPARTMENT OF TRANSPORTATION

AGGREGATE GRADATION REPORT

MISTIC ID

Inspector No.:	930000000	Insp. Name:	JOSH RICH	Date Sampled:	4/23/2010	Sequence No.:	
Mix Plant No.:		Mix Plant:					
Resp. Loc.:	93	Contract No.:		Job Number:		Source Name:	Prairie Material
Lab:	PP	Lab Name:	Prairie			Source Location:	Ocoya, IL

Source Number	Material Code	Type Insp.	Original Test ID	Spec.	Article	Sampled From	Wash Dry
51052-09	042CM06 Gradation #1	PRO		Standard		SP	W

CA	3	2.5	2	1.75	1.5	1	3/4	5/8	1/2	3/8	1/4	#4	#8	#16	#30	#40	#50	#100	#200
Percent Passing					100	100	97	87	75	58	54	47	31	22		15			10.1

Wash 200	Test Results	Remarks	
8.5	APPR		overloads, if any, were split and hand-shaken.. JER

Sieve (English)	12" Overload	Individual Weight Retained	Cumul. Weight Retained	Cumul. Percent Retained	Percent Passing	Spec. Range % Pass	In/Out	Overload
3	12600							
2.5	10600							
2	8400							
1.75	7500							
1.5	6300	0.0	0.0	0.0	100.0	100		
1	4200	0.0	0.0	0.0	100.0	90-100		
3/4	3200	151.0	151.0	3.2	96.8			
5/8	2700	455.0	606.0	13.0	87.0			
1/2	2100	559.0	1165.0	24.9	75.1	60-90		
3/8	1600	811.0	1976.0	42.3	57.7			
1/4	1100	181.0	2157.0	46.2	53.8			
#4	800	331.0	2488.0	53.3	46.7	30-56		
#8	470	755.0	3243.0	69.4	30.6			OVERLOAD
#16	470	411.0	3654.0	78.2	21.8	10-40		
#30	470							
#40	470	300.0	3954.0	84.6	15.4			
#50	470							
#100	470							
#200	470	244.0	4198.0	89.9	10.1	4-12		
Pan		72.0	4270.0					
Total Dry Weight:		4671.0						
Total Washed Weight:		4272.0						
Diff. (-#200):		399.0						

Master Band Target: N/A

Orig. Wet Weight: grams | Moisture %:

Plasticity Index Ratio (#200/#40): 0.66
Plasticity Index Test Results:

% Washed - #200: 8.5

Mix Plant Only
Lot:
Bin:

Authorized By: Josh Rich

Tested By: Josh Rich

Agency/Company: Prairie Group

Validity Check OK
/FOR DTY03504
MI504QC
(This is a Field/Laboratory Report for MISTIC Input)

josh rich
Signature

23-Apr
Date

Copies to: Materials Inspector
District Materials
Producer

ATTACHMENT A2

GEOMEMBRANE RESIN TEST RESULTS

Appendix A: Minimum Testing Frequencies and Properties for GSE Raw Materials

TABLE 1. MINIMUM TESTING FREQUENCIES

Property	Test Method[1]	Natural Resin
Density	ASTM D 1505	once per rail car compartment
Melt Flow Index	ASTM D 1238 (190/2.16)	once per rail car compartment
OIT	ASTM D 3895 (1 ATM at 200° C)	once per resin lot[2]
Carbon Black Content	ASTM D 1603, modified	N/A
Carbon Black Dispersion	ASTM D 5996	NA

NOTES:

[1]GSE utilizes test equipment and procedures that enable effective and economical confirmation that the product will conform to specifications based on the noted procedures. Some test procedures have been modified for application to geosynthetics. All procedures and values are subject to change without prior notification.

[2]OIT for LLDPE/VFPE resin is performed on a representative finished product for each lot of resin rather than on the natural (without carbon black) resin.

TABLE 2. MINIMUM PROPERTIES FOR GSE RAW MATERIALS

Property	Test Method[1]	HDPE	LLDPE/VFPE
Density [g/cm³]	ASTM D 1505	0.932	0.915
Melt Flow Index [g/10 min]	ASTM D 1238 (190/2.16)	≤ 1.0	≤ 1.0
OIT [minutes]	ASTM D 3895 (1 ATM at 200° C)	100	100[2]

NOTES:

[1]GSE utilizes test equipment and procedures that enable effective and economical confirmation that the product will conform to specifications based on the noted procedures. Some test procedures have been modified for application to geosynthetics. All procedures and values are subject to change without prior notification.

[2]OIT for LLDPE/VFPE resin is performed on a representative finished product for each lot of resin rather than on the natural (without carbon black) resin.

Chevron Phillips Chemical Company LP

CoA Date: 10/27/2009

Certificate of Analysis

Shipped To: CHEVRON PHILLIPS CHEM. CO LP: GSE
19103 GUNDLE ROAD
WESTFIELD TX 77090
USA

Recipient: UP TRACK 14732 Phouangsavanh
Fax:

CPC Delivery #: 87945749
PO #: 46822
Weight: 188300 LB
Ship Date: 10/27/2009
Package: BULK
Mode: Hopper Car
Car #: GOCX058228
Seal No: 270565

Product:
MARLEX POLYETHYLENE K306 BULK

Lot Number: 8290673

Property	Test Method	Value	Unit
Melt Index	ASTM D1238	0.1	g/10mi
HLMI Flow Rate	ASTM D1238	12.1	g/10mi
Density	D1505 or D4883	0.937	g/cm3
Production Date		09/01/2009	

The data set forth herein have been carefully compiled by Chevron Phillips Chemical Company LP.
However, there is no warranty of any kind, either expressed or implied, applicable to its use, and the user assumes all risk and liability in connection therewith.

Troy Griffin
Quality Systems Coordinator

For CoA questions contact Customer Service Representative at 800-231-1212

Chevron Phillips Chemical Company LP

Certificate of Analysis

Shipped To: CHEVRON PHILLIPS CHEM. CO LP: GSE
19103 GUNDLE ROAD
WESTFIELD TX 77090
USA

Recipient: UP TRACK 14732 Phouangsavanh
Fax:

CPC Delivery #: 87945750
PO #: 46822
Weight: 190000 LB
Ship Date: 10/27/2009
Package: BULK
Mode: Hopper Car
Car #: PSPX002022
Seal No: 270697

Product:
MARLEX POLYETHYLENE K306 BULK

Lot Number: 8290674

Property	Test Method	Value	Unit
Melt Index	ASTM D1238	0.1	g/10mi
HLMI Flow Rate	ASTM D1238	12.0	g/10mi
Density	D1505 or D4883	0.937	g/cm3
Production Date		09/01/2009	

The data set forth herein have been carefully compiled by Chevron Phillips Chemical Company LP.
However, there is no warranty of any kind, either expressed or implied, applicable to its use, and the user assumes all risk and liability in connection therewith.

Troy Griffin
Quality Systems Coordinator

For CoA questions contact Customer Service Representative at 800-231-1212

ATTACHMENT A3

REINFORCEMENT STEEL SHOP DRAWINGS

OTTO BAUM COMPANY, INC.
CONTRACTORS

866 N. Main Street / PO Box 161
Morton, IL 61550-0161
(309) 266-7114
FAX (309) 263-1050

LETTER OF TRANSMITTAL

Date: **10/21/10**

TO: **Midwest Generation LLC, Powerton Station**
13082 E Manito Rd
Pekin, IL 61554-8527

RE: **Install Metal Claning Basin Liner**
PO No. 4500067825
OBCI Proj. #10-211

ATTN: **Mark Kelly** **309.477.5240** **fax 312.788.5215**

WE ARE SENDING YOU:

- [ ] plans
- [ ] specifications
- [ ] shop drawings
- [ ] addendum
- [X] submittal
- [ ] other ____________
- [ ] via regular mail
- [ ] via overnight

Copies	Date	No,	Description
1			**Weir Extension Rebar**

THESE ARE TRANSMITTED as checked below:

- [X] for approval
- [ ] for your use
- [ ] as requested
- [ ] for review and comment
- [ ] for pricing
- [ ] approval as submitted
- [ ] approved as noted
- [ ] returned as noted
- [ ] resubmit with corrections
- [ ] other ____________

REMARKS:

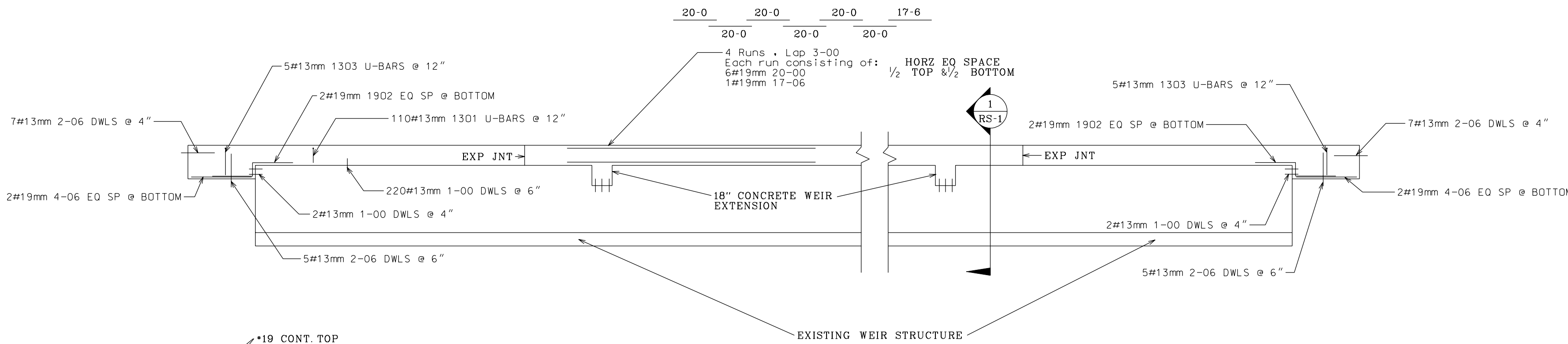
cc:

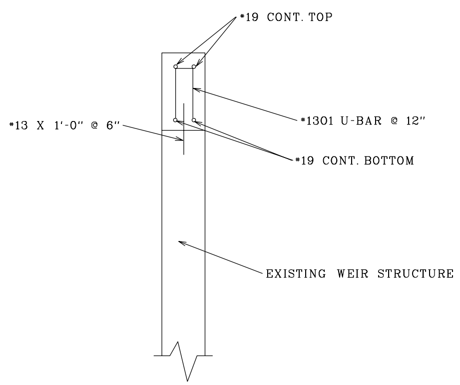
Craig Holthaus

Install Metal Claning Basin Liner
PO No. 4500067825
OBCI Proj. #10-211

Material	**Weir Extension Rebar**
Spec. Section	03300
Submittal No.	3
Prev. Submittal No.	
Manufacturer	**Mathis Kelly**
Supplier	**Mathis Kelly**

REVIEWED
By Craig Holthaus at 9:19 am, Oct 21, 2010

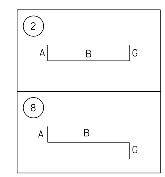




WEIR EXTENSION 1/RS-1

SIZE	EP	BAR MARK	V	BND TYP	CD	A	B	C	D	E	F/R	G	H	J	K	O
#19mm		1902		8		3-00	1-00					3-00				
#13mm		1301		2		0-112	0-04					0-112				
#13mm		1303		2		1-112	0-04					1-112				

(BENDING DIMENSIONS: columns A through O)



REBAR SIZE CONVERSION TABLE	
SOFT METRIC	INCH-POUND SYSTEM
*10	*3
*13	*4
*16	*5
*19	*6
*22	*7
*25	*8
*29	*9

* This Drawing Is In Soft Metric *

BAR LENGTH DIMENSION CONVERSION TABLE

EXAMPLE:
5-05 = 5'-5"
5-051 = 5'-5¼"
5-052 = 5'-5½"
5-053 = 5'-5¾"

REINFORCING STEEL FOR: WEIR EXTENSION

REINFORCING BAR FABRICATORS SINCE 1972

MATHIS - KELLEY
CONSTRUCTION SUPPLY COMPANY
P.O. BOX 5138 1046 W. JEFFERSON
MORTON, IL 61550
TELEPHONE: (309) 266-9733

CONTRACTOR: OTTO BAUM

PROJECT: MIDWEST GENERATION

SCALE: N/A
DRAWN BY: BAM
DATE: 10-18-10
REVISED:
DATE:
DRAWING NUMBER
RS-1

z:\asa\job\baum1\midwest.dgn Oct. 18, 2010 09:09:13

ATTACHMENT A4

CONCRETE ACCESSORIES AND ADMIXTURE MANUFACTURER'S CERTIFICATE AND LITERATURE

OTTO BAUM COMPANY, INC.
CONTRACTORS

866 N. Main Street / PO Box 161
Morton, IL 61550-0161
(309) 266-7114
FAX (309) 263-1050

LETTER OF TRANSMITTAL

Date: **10/15/10**

TO: **Midwest Generation LLC, Powerton Station**
13082 E Manito Rd
Pekin, IL 61554-8527

RE: **Install Metal Claning Basin Liner**
PO No. 4500067825
OBCI Proj. #10-211

ATTN: **Mark Kelly** **309.477.5240** **fax 312.788.5215**

WE ARE SENDING YOU:

- [ ] plans
- [ ] specifications
- [ ] shop drawings
- [ ] addendum
- [X] submittal
- [ ] other ____________
- [ ] via regular mail
- [ ] via overnight

Copies	Date	No,	Description
1			3,000 PSI Concrete Mix Design (Inlet Aprons)
1			4,000 PSI Concrete Mix Design (Weir Extensions)

THESE ARE TRANSMITTED as checked below:

- [X] for approval
- [ ] for your use
- [ ] as requested
- [ ] for review and comment
- [ ] for pricing
- [ ] approval as submitted
- [ ] approved as noted
- [ ] returned as noted
- [ ] resubmit with corrections
- [ ] other ____________

REMARKS:

cc:

Craig Holthaus

Install Metal Claning Basin Liner
PO No. 4500067825
OBCI Proj. #10-211

Material	**3,000 PSI Mix Design**
Spec. Section	03300
Submittal No.	1
Prev. Submittal No.	
Manufacturer	**Roanoke Concrete Products**
Supplier	**Roanoke Concrete Products**

REVIEWED
By Craig Holthaus at 1:27 pm, Oct 15, 2010

Roanoke Concrete Products - Mix Design

(For 3/8", 1/2", 3/4", 1", and 1 1/2" maximum size aggregate, 1" to 7" slumps)

RCW3020 - 3000 PSI White Rock

Input:

Mix Performance Requirements		
Strength Req., f'c	3000 PSI	
Min.Cementitious Content	423 lbs. per cy	
Max. W/C Ratio	0.45 Will calculate cementitious based on W/C ratio if W/C > 0	
Theoretical Initial Water Content (Calculated from ACI Table)	295 lbs. per cy	35.4 Gals./cy
User Inputed Water Content (Overides water from ACI table if >0)	190 lbs. per cy (Final SSD Water Content If > 0)	22.8 Gals./cy
Total Cementitious Content	423 lbs. per cy	
Desired Yield	27.10 cu. ft.	
Slump (whole numbers only)	4.00 in.	
Target Air Content	5.00 %	

Input:

Fine Aggregate		Coarse Aggregate		Aggregate #3	
Peoria Concrete Sand		Mining International CM11		Peoria Concrete Gravel	
FM	2.80	Nom Max. Size	1 in.	Nom Max. Size	3/8 in.
Sp. Gravity (SSD)	2.67	Sp. Gravity(SSD)	2.65	Sp. Gravity(SSD)	2.61
		Unit Wt. * (Dry Rodded)	100.0 pcf Req'd to use ACI table	SSD Wt.	0 #/cy
		Absorption *	0.75 %	Req'd unless user inputs coarse wt.	
		Workability Adjustment	0.0 %	Coarse aggregate content from ACI aggregate table reduced	
		User Inputed SSD Coarse Agg	1790 #/cy	If > 0, over-rides coarse agg. content from ACI aggregate table	

* Coarse agg. dry rodded unit wt. and absorption is required if coarse aggregate wt. is to be calculated from the ACI aggregate table.

Input:

Cementitious				
Material	Source / Description	Sp. Gravity	Replacement %	Replacement lb.
Cement	Illinois Cement Type I Portland	3.15		
Cementitious #1	Headwaters Class C Fly Ash	2.68	15.0	63
Cementitious #2		2.88		0
		Total Replacement	15.0	63
Water Reduction due to pozzolan	0.0 gals./cy	Total Cementitious = 423 lb. (360+63)		

(Water reduced only if intitial water content from ACI table is used, no effect if user imputs SSD water content)

Input:

Admixtures		
Material	Source / Description	Dosage
Water Reducer	Mira 110 Water Reducer	3.00 oz./cwt.
Superplasticizer	Daracem 19 Superplasticizer	As Required for slump oz./cwt.
Admix #3		0.00 oz./cwt.
Admix #4		0.00 oz./cwt.
Air-Entraining Agent	Daravair 1400 Air entrainment	0.71 oz./cwt.
(Zero or leave blank Air dose oz /cwt to list "As Required" on SSD mix design)		3.00 oz./cu. yd.
Water Reduction due to Admixtures (Water reduced only if intitial water content from ACI table is used)		0.00 %

RCW3020 - 3000 PSI White Rock

SSD Weights per Cubic Yard

Materials	Sp. Gravity	Weight	Abs. Vol. Ft.³	% of Total Cementitious
Illinois Cement Type I Portland	3.15	360 lbs.	1.83	
Headwaters Class C Fly Ash	2.68	63 lbs.	0.38	15.0
Cementitious #2	2.88	0 lbs.	0.00	0.0
Mining International CM11	2.65	1790 lbs.	10.82	-
Peoria Concrete Gravel	2.61	0 lbs.	0.00	-
Peoria Concrete Sand	2.67	1611 lbs.	9.67	-
Total Water	1.00	190 lbs.	3.04	-
Daravair 1400 Air entrainment	-	3.0 oz.	1.36	-
Mira 110 Water Reducer	-	12.7 oz.	-	-
Daracem 19 Superplasticizer	-	#VALUE! oz.	-	-
Admix #3	-	-	-	-
Admix #4	-	-	-	-
			27.10	

Design Strength	**3000 PSI**
Total Cementitious	**423 lb.**
Water/Cementitious Ratio	**0.449**
Target Slump	**4.00 in.**
Target Air Content	**5.00 %**
% Fine Aggregate to Total Aggregate, by volume	**47.17 %**
Theoretical Unit Weight	**148.10 pcf**
Yield	**27.10 cu. ft.**

Actual Batch Weights Per Cubic Yard

Surface Moisture Content of Coarse Agg.	1.0 %
Surface Moisture Content of Intermediate Agg.	1.0 %
Surface Moisture Content of Fine Agg.	3.5 %
Illinois Cement Type I Portland	360 lbs.
Headwaters Class C Fly Ash	63 lbs.
Cementitious #2	0
Mining International CM11	1808 lbs.
Peoria Concrete Gravel	0 lbs.
Peoria Concrete Sand	1667 lbs.
Total Water	13.9 Gals.
Daravair 1400 Air entrainment	3.0 oz.
Mira 110 Water Reducer	12.7 oz.
Daracem 19 Superplasticizer	#VALUE! oz.
Admix #3	-
Admix #4	-

Note: This is a theoretical mix design based on data generated by ACI for average material properties Actual material properties may vary, and it is therefore essential that the performance criteria of this mix design be checked by trial mixes.

Slump, in.	3/8	1/2	3/4	1	1 1/2
	Water, lbs. per cy for indicated max. sizes of agg.				
	Non Air-Entrained Concrete				
1	345	330	310	295	270
2	350	335	315	300	275
3	367	350	323	312	287
4	385	365	340	325	300
5	393	371	347	330	305
6	401	378	354	335	310
7	410	385	360	340	315
Slump, in.	Air-Entrained Concrete				
1	300	290	275	265	245
2	305	295	280	270	250
3	322	310	292	282	262
4	340	325	305	295	275
5	348	332	312	300	280
6	356	339	319	305	285
7	365	345	325	310	290

Max. Size	Ratio	Entrapped/ Entrained Air	
3/8	0	0.0	
1/2	0	0.0	
3/4	0	0.0	
1	0.67	5.0	
1 1/2	0	0.0	
	0.670	5.0	%

3/8	1/2	3/4	1	1 1/2
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	295	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

Total Water Content:	295	lbs. per cy

Default Water Content	190	lbs. per cy

Install Metal Claning Basin Liner
PO No. 4500067825
OBCI Proj. #10-211

Material	**4,000 PSI Mix Design**
Spec. Section	03300
Submittal No.	2
Prev. Submittal No.	
Manufacturer	**Roanoke Concrete Products**
Supplier	**Roanoke Concrete Products**

REVIEWED
By Craig Holthaus at 1:27 pm, Oct 15, 2010

Roanoke Concrete Products - Mix Design

(For 3/8", 1/2", 3/4", 1", and 1 1/2" maximum size aggregate, 1" to 7" slumps)

RCW4020 - 4000 psi CONC WHITE ROCK

Input:

Mix Performance Requirements		
Strength Req., f'c	4000 PSI	
Min.Cementitious Content	517 lbs. per cy	
Max. W/C Ratio	0.45 Will calculate cementitious based on W/C ratio if W/C > 0	
Theoretical Initial Water Content (Calculated from ACI Table)	295 lbs. per cy	35.4 Gals./cy
User Inputed Water Content (Overides water from ACI table if >0)	232 lbs. per cy (Final SSD Water Content if > 0)	27.9 Gals./cy
Total Cementitious Content	517 lbs. per cy	
Desired Yield	27.00 cu. ft.	
Slump (whole numbers only)	4.00 in.	
Target Air Content	5.00 %	

Input:

Fine Aggregate		Coarse Aggregate		Aggregate #3	
Peoria Concrete Sand .27asr		Mining International CM11			
FM	2.80	Nom Max. Size	1 in.	Nom Max. Size	0 in.
Sp. Gravity (SSD)	2.64	Sp. Gravity(SSD)	2.65	Sp. Gravity(SSD)	2.65
		Unit Wt. * (Dry Rodded)	100.0 pcf Req'd to use ACI table	SSD Wt.	0 #/cy
		Absorption *	0.75 %	Req'd unless user inputs coarse wt.	
* Coarse agg. dry rodded unit wt. and absorption is required if coarse aggregate wt. is to be calculated from the ACI aggregate table.		Workability Adjustment	0.0 %	Coarse aggregate content from ACI aggregate table reduced	
		User Inputed SSD Coarse Agg	1750 #/cy	If > 0, over-rides coarse agg. content from ACI aggregate table	

Input:

Cementitious				
Material	Source / Description	Sp. Gravity	Replacement %	Replacement lb.
Cement	Illinois Cement Type I Portland	3.15		
Cementitious #1	Class C Fly Ash	2.68	15.0	78
Cementitious #2				0
		Total Replacement	15.0	78
Water Reduction due to pozzolan	0.0 gals./cy	Total Cementitious = 517 lb. (439+78)		
(Water reduced only if intitial water content from ACI table is used, no effect if user imputs SSD water content)				

Input:

Admixtures		
Material	Source / Description	Dosage
Water Reducer	Mira 110 Water Reducer	3.50 oz./cwt.
Superplasticizer	Daracem 19 Superplasticizer	As Required oz./cwt.
Admix #3		0.00 oz./cwt.
Admix #4		0.00 oz./cwt.
Air-Entraining Agent	Daravair 1400 Air entrainment	0.78 oz./cwt.
(Zero or leave blank Air dose oz /cwt to list "As Required" on SSD mix design)		4.03 oz./cu. yd.
Water Reduction due to Admixtures (Water reduced only if intitial water content from ACI table is used)		0.00 %

RCW4020 - 4000 psi CONC WHITE ROCK

SSD Weights per Cubic Yard

Materials	Sp. Gravity	Weight	Abs. Vol. Ft.³	% of Total Cementitious
Illinois Cement Type I Portland	3.15	439 lbs.	2.23	
Class C Fly Ash	2.68	78 lbs.	0.47	15.0
Cementitious #2	0.00	0 lbs.	0.00	0.0
Mining International CM11	2.65	1750 lbs.	10.58	-
Aggregate #3	2.65	0 lbs.	0.00	-
Peoria Concrete Sand .27asr	2.64	1425 lbs.	8.65	-
Total Water	1.00	232 lbs.	3.72	-
Daravair 1400 Air entrainment	-	4.0 oz.	1.35	-
Mira 110 Water Reducer	-	18.1 oz.	-	-
Daracem 19 Superplasticizer	-	#VALUE! oz.	-	-
Admix #3	-	-	-	-
Admix #4	-	-	-	-
			27.00	

Design Strength	**4000 PSI**
Total Cementitious	**517 lb.**
Water/Cementitious Ratio	**0.449**
Target Slump	**4.00 in.**
Target Air Content	**5.00 %**
% Fine Aggregate to Total Aggregate, by volume	**44.97 %**
Theoretical Unit Weight	**145.33 pcf**
Yield	**27.00 cu. ft.**

Actual Batch Weights Per Cubic Yard

Surface Moisture Content of Coarse Agg.	1.0 %
Surface Moisture Content of Intermediate Agg.	1.0 %
Surface Moisture Content of Fine Agg.	3.5 %
Illinois Cement Type I Portland	439 lbs.
Class C Fly Ash	78 lbs.
Cementitious #2	0
Mining International CM11	1768 lbs.
Aggregate #3	0 lbs.
Peoria Concrete Sand .27asr	1475 lbs.
Total Water	19.8 Gals.
Daravair 1400 Air entrainment	4.0 oz.
Mira 110 Water Reducer	18.1 oz.
Daracem 19 Superplasticizer	#VALUE! oz.
Admix #3	-
Admix #4	-

Note: This is a theoretical mix design based on data generated by ACI for average material properties Actual material properties may vary, and it is therefore essential that the performance criteria of this mix design be checked by trial mixes.

Slump, in.	Water, lbs. per cy for indicated max. sizes of agg.				
	3/8	1/2	3/4	1	1 1/2
	Non Air-Entrained Concrete				
1	345	330	310	295	270
2	350	335	315	300	275
3	367	350	323	312	287
4	385	365	340	325	300
5	393	371	347	330	305
6	401	378	354	335	310
7	410	385	360	340	315
Slump, in.	Air-Entrained Concrete				
1	300	290	275	265	245
2	305	295	280	270	250
3	322	310	292	282	262
4	340	325	305	295	275
5	348	332	312	300	280
6	356	339	319	305	285
7	365	345	325	310	290

Max. Size	Ratio	Entrapped/ Entrained Air	
3/8	0	0.0	
1/2	0	0.0	
3/4	0	0.0	
1	0.67	5.0	
1 1/2	0	0.0	
	0.670	5.0	%

3/8	1/2	3/4	1	1 1/2
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	295	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

Total Water Content:	295	lbs. per cy

Default Water Content	232	lbs. per cy

Electronic Filing: Received, Clerk's Office 05/11/2021 **AS 2021-002**

ATTACHMENT A5

CONCRETE QUALITY CONTROL TESTS

TELEPHONE
309-673-2131

TESTS * INVESTIGATIONS
ANALYSIS * DESIGN * EVALUATIONS
CONSULTATION * REPORTS * INSPECTIONS
ARBITRATION * EXPERT WITNESS TESTIMONY

SOILS * PORTLAND CEMENT CONCRETE
BITUMINOUS CONCRETE * STEEL
ASPHALT * AGGREGATES * EMULSIONS
POZOLANIC MATERIALS * LIME

GEOTECHNICAL ENGINEERING MATERIALS TESTING

WHITNEY & ASSOCIATES
INCORPORATED
2406 West Nebraska Avenue
PEORIA, ILLINOIS 61604

TELEFAX
309-673-3050

GEOTECHNICAL ENGINEERING
CONSTRUCTION QUALITY CONTROL
SUBSURFACE EXPLORATIONS
ENVIROMENTAL INVESTIGATIONS

MONITORING WELL INSTALLATIONS
BUILT-UP ROOF INVESTIGATIONS
WELDER CERTIFICATIONS
INSURANCE INVESTIGATIONS

CLIENT:
Mr. Craig Holthaus
Otto Baum Company, Inc.
P. O. Box 161
Morton, Illinois 61550

W. & A. FILE NO 5486001
DATE 11/05/10
SHEET 1 OF 1

PROJECT:
Midwest Generation Powerton Station
Metal Cleaning Basin Liner Replacement
Pekin, Illinois

REPORT OF OBSERVATIONS AND TESTS OF CONCRETE

CONCRETE BATCH PLANT Roanoke Concrete CONCRETE OBSERVER Armstrong

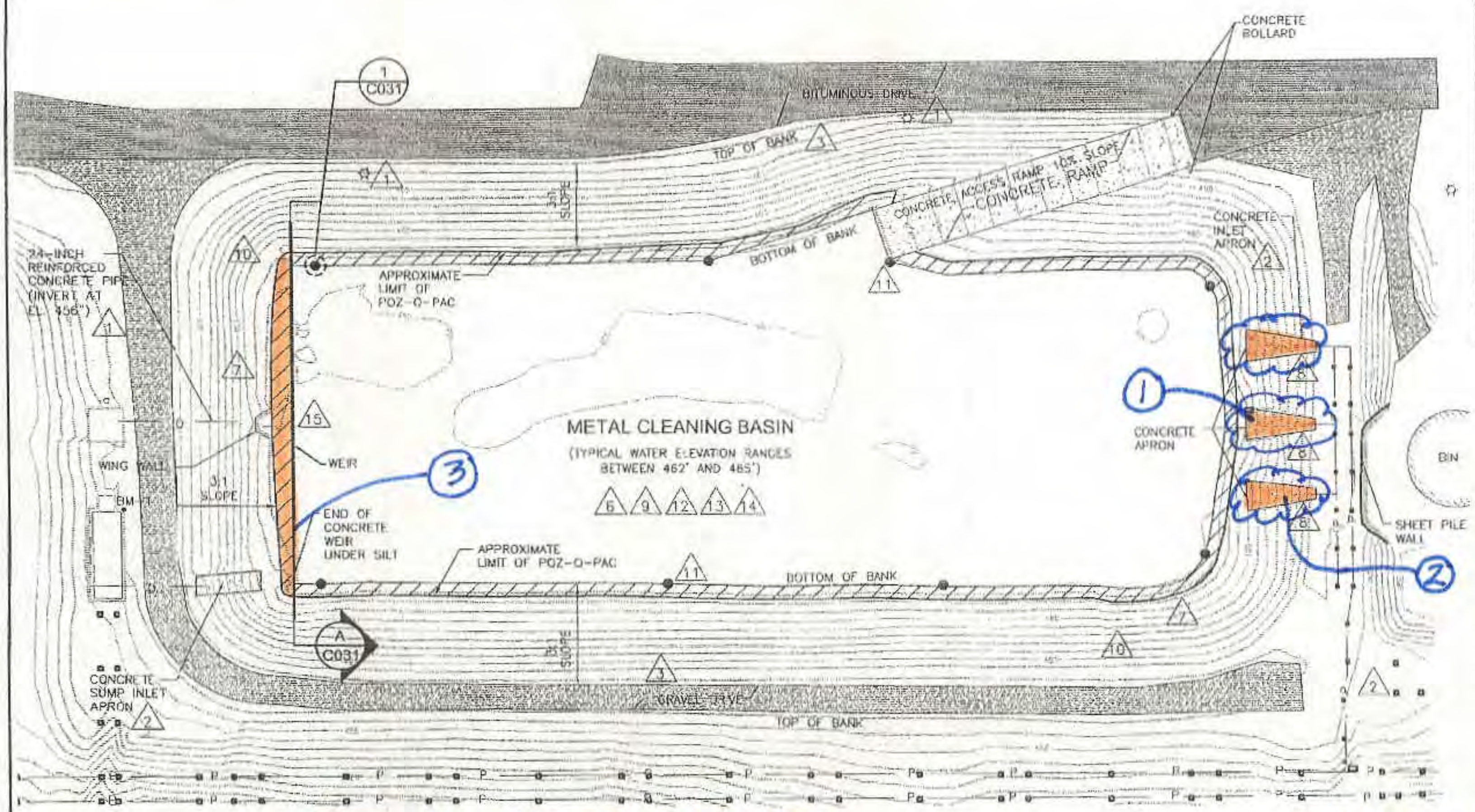
DATE	CONCRETE SUPPLIER TICKET NUMBER	TIME TRUCK DISPATCHED	TIME TRUCK UNLOADED	YARDS OF CONCRETE	SLUMP - IN	AIR CONTENT - %	CONCRETE TEMP - °F	AIR TEMP - °F	MIX DESIGN NO.	CONCRETE TYPE
11/05/10	2007042	9:03	9:53	9.00	3.75	5.6	68	33	3000#	Stone
11/05/10	2007043	9:24	10:27	9.00	3.00	--	69	34	3000#	Stone
11/05/10	2007044 *	9:36	11:16	9.00	2.50	--	67	37	3000#	Stone
11/05/10	2007045	10:38	11:38	9.00	3.00	--	68	38	3000#	Stone
11/05/10	2007047	11:25	12:14	9.00	--	5.2	67	40	3000#	Stone
11/05/10	2007048	11:50	12:42	9.00	3.50	--	62	41	3000#	Stone
11/05/10	2007049 *	12:54	1:14	4.50	4.00	--	71	42	3000#	Stone
11/05/10	2007050 *	12:59	2:09	9.00	5.00	--	70	43	4000#	Stone

DATE	MIX DESIGN NO.	LOCATIONS OF POURS
11/05/10	3000#	Ticket No. 2007044 - Pavement for spillway aprons on the south side of the metal cleaning
		basin - north end of the center apron
11/05/10	3000#	Ticket No. 2007049 - Pavement for spillway aprons on the south side of the metal cleaning
		basin - center of the west apron
11/05/10	4000#	Ticket No. 2007050 - Weir at the north end of the metal cleaning basin - west end of the
		pour

* CONCRETE CYLINDERS WERE MOLDED FROM THIS TRUCK LOAD.

REMARKS:
The locations of the concrete pours are also shown on the attached plan sheet. All tests were performed and cylinders were molded at the hopper end of the pump truck.

DISTRIBUTION :



LEGEND

- UNDERGROUND DISCHARGE PIPE
- ABOVEGROUND PIPE RACK
- LIGHT POLE
- 400 — EXISTING GROUND SURFACE CONTOUR
- MARKER POST LOCATION
- POZ-O-PAC REMOVAL AREA

CONTRACTOR NOTES:
1. CONTRACTOR SHALL FIELD VERIFY LOCATION OF UNDERGROUND PIPES WITH ASSISTANCE OF OWNER'S UTILITY LOCATOR.
2. CONTRACTOR SHALL FIELD VERIFY LOCATION OF CONCRETE STRUCTURES AND ABOVE GROUND PIPING.
3. CLEAR AND GRUB ALL BRUSH ALONG TOP OF SLOPE OF BASIN.
4. CONTRACTOR SHALL STORE ALL GEOSYNTHETICS AND SUBGRADE MATERIALS IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.
5. CONTRACTOR SHALL STORE AND STAGE EQUIPMENT AT LOCATION APPROVED BY OWNER.
6. PROTECT ALL CONCRETE AND UTILITY STRUCTURES TO REMAIN IN PLACE THROUGHOUT PROJECT DURATION.
7. REMOVE EXISTING 12-INCH POZ-O-PAC LAYER ALONG SIDE SLOPES. POZ-O-PAC LAYER AT BASE OF BASIN TO REMAIN IN PLACE, EXCEPT NORTH OF WEIR. CONTRACTOR SHALL REMOVE AN ADDITIONAL 6 INCHES OF SUBGRADE MATERIAL LOCATED BETWEEN THE WEIR AND THE WING WALL ALONG THE NORTH BOTTOM OF BANK, AS SHOWN ON SECTION B, SHEET C031.
8. CONTRACTOR SHALL REMOVE INLET APRONS AND HAUL MATERIAL TO RECYCLING FACILITY.
9. CONTRACTOR SHALL REMOVE ALL VEGETATION, ROCKS, AND OTHER DEBRIS FROM EXISTING LINER AND DISPOSE OF IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.
10. CONTRACTOR SHALL REMOVE "SOFT" SUBGRADE MATERIAL BENEATH EXISTING HYPALON LINER, AS DIRECTED BY OWNER AND/OR ENGINEER. BACKFILL AREAS WITH FILL IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS. CUT HYPALON LINER AS NEEDED TO REPAIR THE "SOFT" SUBGRADE AREAS.
11. CONTRACTOR SHALL INSTALL MARKER POSTS ALONG THE TOE OF SLOPE AS SHOWN AND IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS AND DETAIL 1 ON SHEET C031.
12. SUBGRADE MUST BE APPROVED BY OWNER AND/OR ENGINEER PRIOR TO INSTALLATION OF GEOMEMBRANE.
13. CONTRACTOR SHALL PLACE 16 OZ. NONWOVEN GEOTEXTILE OVER THE SUBGRADE IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.
14. CONTRACTOR SHALL PROVIDE MEANS TO PROTECT SUBGRADE LAYER FROM EROSION, STORM WATER, AND HEAVY EQUIPMENT TRAFFIC. DAMAGE TO SUBGRADE LAYER SHALL BE REPAIRED AT THE CONTRACTOR'S EXPENSE.
15. CONTRACTOR SHALL EXTEND CONCRETE WEIR UP BY 18" IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS AND SECTION A ON SHEET C031.

0 10 20 40
SCALE IN FEET

HORIZONTAL DATUM:
ILLINOIS STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD83.

VERTICAL DATUM:
LOCAL PLANT DATUM

BENCHMARK-1:
SE CORNER TOP CONCRETE WALL
ELEVATION = 468.09 FT.

SOURCE NOTES:

THIS DRAWING WAS DEVELOPED FROM A SURVEY BY MAURER-STUTZ, INC. DATED 10/20/09, DRAWING NO. 23209009.

LOCATION OF EXISTING LINER TAKEN FROM MIDWEST GENERATION DRAWING NO. 5060 C5008, DATED 12-19-1978.

CONCRETE FOR THE WEIR

CONCRETE FOR THE SLOPED APRONS

11-5-10

6.			
5.			
4.			
3.			
2.	ISSUED FOR CONSTRUCTION	10/22/10	HMS
1.	ISSUED FOR BID	10/05/09	HMS
0.	ISSUED FOR PERMIT	07/27/09	HMS
REVISION:		DATE:	APP'D BY:

NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 1065/1.0
DRAWN BY: 08/25/09
CHECKED BY: AJG 10/05/09
APPROVED BY: HMS 10/05/09

LINER SUBGRADE PREPARATION

METAL CLEANING BASIN LINER REPLACEMENT
MIDWEST GENERATION
POWERTON POWER STATION
PEKIN, ILLINOIS

DRAWING NO: 01965C020-02
REFERENCE:
SHEET NO. C020

TELEPHONE
309-673-2131

TESTS * INVESTIGATIONS
ANALYSIS * DESIGN * EVALUATIONS
CONSULTATION * REPORTS * INSPECTIONS
ARBITRATION * EXPERT WITNESS TESTIMONY
* * * * * * * * * *
SOILS * PORTLAND CEMENT CONCRETE
BITUMINOUS CONCRETE * STEEL
ASPHALT * AGGREGATES * EMULSIONS
POZOLANIC MATERIALS * LIME

WHITNEY & ASSOCIATES
INCORPORATED
2406 West Nebraska Avenue
PEORIA, ILLINOIS 61604

TELEFAX
309-673-3050

GEOTECHNICAL ENGINEERING
CONSTRUCTION QUALITY CONTROL
SUBSURFACE EXPLORATIONS
ENVIROMENTAL INVESTIGATIONS
* * * * * * * * * *
MONITORING WELL INSTALLATIONS
BUILT-UP ROOF INVESTIGATIONS
WELDER CERTIFICATIONS
INSURANCE INVESTIGATIONS

W. & A. FILE NO 5486002

DATES 11/12/10
12/03/10

CLIENT:
Mr. Craig Holthaus
Otto Baum Company, Inc.
P. O. Box 161
Morton, Illinois 61550

PROJECT:
Midwest Generation Powerton Station
Metal Cleaning Basin Liner Replacement
Pekin, Illinois

CONCRETE COMPRESSION TEST REPORT

(6 X 12 INCH) NOMINAL CYLINDER SIZE: AREA=28.27 SQ. IN.

COMPRESSIVE STRENGTH TEST RESULTS

CYLINDER NO.	1A	1B	1C	1D		
AGE-DAYS	7	7	28	28		
FIELD CURE-DAYS	3	3	3	3		
STANDARD CURE-DAYS	4	4	25	25		
UNIT LOAD PSI	3970	3770	4460	4630		
DATE MOLDED	11/05/10	11/05/10	11/05/10	11/05/10		
DATE RECIEVED	11/08/10	11/08/10	11/08/10	11/08/10		
DATE TESTED	11/12/10	11/12/10	12/03/10	12/03/10		
SPECIFICATIONS						
AGE-DAYS	28	28	28	28		
STRENGTH-PSI	3000	3000	3000	3000		

- (●) CYLINDERS MOLDED BY WHITNEY & ASSOCIATES REPRESENTATIVE.
- ( ) CYLINDERS MOLDED BY ARCHITECT'S OR CONTRACTOR'S REPRESENTATIVE.
- (●) CYLINDERS PICKED UP BY WHITNEY & ASSOCIATES REPRESENTATIVE.
- ( ) CYLINDERS DELIVERED TO WHITNEY & ASSOCIATES
- (●) TEST RESULTS COMPLY WITH APPLICABLE SPECIFICATIONS.
- ( ) TEST RESULTS DO NOT COMPLY WITH APPLICABLE SPECIFICATIONS.

POUR LOCATION:
Pavement for spillway aprons on the south side of the metal cleaning basin - north end of the center apron

COMMENTS:

FIELD DATA

CYLINDER NO.	1
MIX DESIGN NO.	3000#
SLUMP. IN.	2.50
AIR CONTENT %	-
AIR TEMP. -°F.	37
CONCRETE TEMP. -°F.	67
FIELD DATA SUBMITTED BY:	Whitney & Associates
MIX DATA SUBMITTED BY:	-
TIME :	11:00 a.m.
POUR SIZE :	58.50 cu. yds.

CONCRETE BATCH PLANT	Roanoke Concrete	
DELIVERY TICKET NO.	2007044	
MIX PROPORTIONS (SSD):		
CEMENT (TYPE)		lbs.
FINE AGGREGATE		lbs.
COARSE AGGREGATE		lbs.
WATER		gals.
ADDITIVES		

DISTRIBUTION:

Respectfully submitted,
WHITNEY & ASSOCIATES

TELEPHONE
309-673-2131

TESTS * INVESTIGATIONS
ANALYSIS * DESIGN * EVALUATIONS
CONSULTATION * REPORTS * INSPECTIONS
ARBITRATION * EXPERT WITNESS TESTIMONY
* * * * * * * * * *
SOILS * PORTLAND CEMENT CONCRETE
BITUMINOUS CONCRETE * STEEL
ASPHALT * AGGREGATES * EMULSIONS
POZOLANIC MATERIALS * LIME

WHITNEY & ASSOCIATES
INCORPORATED
2406 West Nebraska Avenue
PEORIA, ILLINOIS 61604

TELEFAX
309-673-3050

GEOTECHNICAL ENGINEERING
CONSTRUCTION QUALITY CONTROL
SUBSURFACE EXPLORATIONS
ENVIROMENTAL INVESTIGATIONS
* * * * * * * * * *
MONITORING WELL INSTALLATIONS
BUILT-UP ROOF INVESTIGATIONS
WELDER CERTIFICATIONS
INSURANCE INVESTIGATIONS

W. & A. FILE NO 5486003

DATES 11/12/10
12/03/10

CLIENT:
Mr. Craig Holthaus
Otto Baum Company, Inc.
P. O. Box 161
Morton, Illinois 61550

PROJECT:
Midwest Generation Powerton Station
Metal Cleaning Basin Liner Replacement
Pekin, Illinois

CONCRETE COMPRESSION TEST REPORT

(6 X 12 INCH) NOMINAL CYLINDER SIZE: AREA=28.27 SQ. IN.

COMPRESSIVE STRENGTH TEST RESULTS

CYLINDER NO.	2A	2B	2C	2D		
AGE-DAYS	7	7	28	28		
FIELD CURE-DAYS	3	3	3	3		
STANDARD CURE-DAYS	4	4	25	25		
UNIT LOAD PSI	4250	3960	4920	4810		
DATE MOLDED	11/05/10	11/05/10	11/05/10	11/05/10		
DATE RECIEVED	11/08/10	11/08/10	11/08/10	11/08/10		
DATE TESTED	11/12/10	11/12/10	12/03/10	12/03/10		
SPECIFICATIONS						
AGE-DAYS	28	28	28	28		
STRENGTH-PSI	3000	3000	3000	3000		

- ◉ CYLINDERS MOLDED BY WHITNEY & ASSOCIATES REPRESENTATIVE.
- ○ CYLINDERS MOLDED BY ARCHITECT'S OR CONTRACTOR'S REPRESENTATIVE.
- ◉ CYLINDERS PICKED UP BY WHITNEY & ASSOCIATES REPRESENTATIVE.
- ○ CYLINDERS DELIVERED TO WHITNEY & ASSOCIATES
- ◉ TEST RESULTS COMPLY WITH APPLICABLE SPECIFICATIONS.
- ○ TEST RESULTS DO NOT COMPLY WITH APPLICABLE SPECIFICATIONS.

POUR LOCATION:
Pavement for spillway aprons on the south side of the metal cleaning basin - center of the west apron

COMMENTS:

FIELD DATA

CYLINDER NO.	2
MIX DESIGN NO.	3000#
SLUMP. IN.	4.00
AIR CONTENT %	-
AIR TEMP. -°F.	42
CONCRETE TEMP. -°F.	71
FIELD DATA SUBMITTED BY:	Whitney & Associates
MIX DATA SUBMITTED BY:	-
TIME :	1:15 p.m.
POUR SIZE :	58.50 cu. yds.

CONCRETE BATCH PLANT	Roanoke Concrete	
DELIVERY TICKET NO.	2007049	
MIX PROPORTIONS (SSD):		
CEMENT (TYPE)		lbs.
FINE AGGREGATE		lbs.
COARSE AGGREGATE		lbs.
WATER		gals.
ADDITIVES		

DISTRIBUTION:

Respectfully submitted,
WHITNEY & ASSOCIATES

WHITNEY & ASSOCIATES
PEORIA, ILLINOIS

TELEPHONE
309-673-2131

TESTS * INVESTIGATIONS
ANALYSIS * DESIGN * EVALUATIONS
CONSULTATION * REPORTS * INSPECTIONS
ARBITRATION * EXPERT WITNESS TESTIMONY
* * * * * * * * * *
SOILS * PORTLAND CEMENT CONCRETE
BITUMINOUS CONCRETE * STEEL
ASPHALT * AGGREGATES * EMULSIONS
POZOLANIC MATERIALS * LIME

GEOTECHNICAL ENGINEERING MATERIALS TESTING · PEORIA

WHITNEY & ASSOCIATES

INCORPORATED

2406 West Nebraska Avenue
PEORIA, ILLINOIS 61604

TELEFAX
309-673-3050

GEOTECHNICAL ENGINEERING
CONSTRUCTION QUALITY CONTROL
SUBSURFACE EXPLORATIONS
ENVIROMENTAL INVESTIGATIONS
* * * * * * * * * *
MONITORING WELL INSTALLATIONS
BUILT-UP ROOF INVESTIGATIONS
WELDER CERTIFICATIONS
INSURANCE INVESTIGATIONS

W. & A. FILE NO 5486004

DATES 11/12/10
12/03/10

CLIENT:
Mr. Craig Holthaus
Otto Baum Company, Inc.
P. O. Box 161
Morton, Illinois 61550

PROJECT:
Midwest Generation Powerton Station
Metal Cleaning Basin Liner Replacement
Pekin, Illinois

CONCRETE COMPRESSION TEST REPORT

(6 X 12 INCH) NOMINAL CYLINDER SIZE: AREA=28.27 SQ. IN.

COMPRESSIVE STRENGTH TEST RESULTS

CYLINDER NO.	3A	3B	3C	3D		
AGE-DAYS	7	7	28	28		
FIELD CURE-DAYS	3	3	3	3		
STANDARD CURE-DAYS	4	4	25	25		
UNIT LOAD PSI	3850	4030	4720	4620		
DATE MOLDED	11/05/10	11/05/10	11/05/10	11/05/10		
DATE RECIEVED	11/08/10	11/08/10	11/08/10	11/08/10		
DATE TESTED	11/12/10	11/12/10	12/03/10	12/03/10		
SPECIFICATIONS						
AGE-DAYS	28	28	28	28		
STRENGTH-PSI	4000	4000	4000	4000		

- ● CYLINDERS MOLDED BY WHITNEY & ASSOCIATES REPRESENTATIVE.
- ○ CYLINDERS MOLDED BY ARCHITECT'S OR CONTRACTOR'S REPRESENTATIVE.
- ● CYLINDERS PICKED UP BY WHITNEY & ASSOCIATES REPRESENTATIVE.
- ○ CYLINDERS DELIVERED TO WHITNEY & ASSOCIATES
- ● TEST RESULTS COMPLY WITH APPLICABLE SPECIFICATIONS.
- ○ TEST RESULTS DO NOT COMPLY WITH APPLICABLE SPECIFICATIONS.

POUR LOCATION:
Weir at the north end of the metal
cleaning basin - west end of the pour

COMMENTS:

FIELD DATA

CYLINDER NO.	3
MIX DESIGN NO.	4000#
SLUMP. IN.	5.00
AIR CONTENT %	-
AIR TEMP. -°F.	45
CONCRETE TEMP. -°F.	70
FIELD DATA SUBMITTED BY:	Whitney & Associates
MIX DATA SUBMITTED BY:	-
TIME :	1:45 p.m.
POUR SIZE :	9.00 cu. yds.

CONCRETE BATCH PLANT	Roanoke Concrete	
DELIVERY TICKET NO.	2007050	
MIX PROPORTIONS (SSD):		
CEMENT (TYPE)		lbs.
FINE AGGREGATE		lbs.
COARSE AGGREGATE		lbs.
WATER		gals.
ADDITIVES		

DISTRIBUTION:

Respectfully submitted,
WHITNEY & ASSOCIATES

WHITNEY & ASSOCIATES
PEORIA, ILLINOIS

ATTACHMENT A6

GEOSYNTHETIC PRODUCT INFORMATION

GSE

The Pioneer Of Geosynthetics

S I N C E 1 9 7 2

Product Data Sheet

GSE Nonwoven Geotextile

GSE Nonwoven Geotextile is a family of staple fiber needlepunched geotextiles. The geotextile is manufactured using an advanced manufacturing and quality system, to produce the most uniform and consistent nonwoven needlepunched geotextile currently available in the industry. GSE combines a fiber selection and approval system with in-line quality control and a state-of-the-art laboratory to ensure that every roll shipped meets customer specifications and for various applications.

Product Specifications *These product specifications meet or exceed GRI GT12, GRI GT13 and AASHTO M288.*

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE					
			NW4	NW6	NW8	NW10	NW12	NW16
AASHTO M288 Class			3	2	1	>1	>>1	>>>1
Mass per Unit Area, oz/yd² (g/m²)	ASTM D 5261	90,000 ft²	4 (135)	6 (200)	8 (270)	10 (335)	12 (405)	16 (540)
Grab Tensile Strength, lb (N)	ASTM D 4632	90,000 ft²	120 (530)	160 (710)	220 (975)	260 (1,155)	320 (1,420)	390 (1,735)
Grab Elongation, %	ASTM D 4632	90,000 ft²	50	50	50	50	50	50
Puncture Strength, lb (N)	ASTM D 4833	90,000 ft²	60 (265)	90 (395)	120 (525)	165 (725)	190 (835)	240 (1,055)
Trapezoidal Tear Strength, lb (N)	ASTM D 4533	90,000 ft²	50 (220)	65 (290)	90 (395)	100 (445)	125 (555)	150 (665)
Apparent Opening Size, Sieve No. (mm)	ASTM D 4751	540,000 ft²	70 (0.212)	70 (0.212)	80 (0.180)	100 (0.150)	100 (0.150)	100 (0.150)
Permittivity, sec⁻¹	ASTM D 4491	540,000 ft²	1.80	1.50	1.30	1.00	0.80	0.60
Water Flow Rate, gpm/ft² (l/min/m²)	ASTM D 4491	540,000 ft²	135 (5,495)	110 (4,480)	95 (3,865)	75 (3,050)	60 (2,440)	45 (1,830)
UV Resistance (% retained after 500 hours)	ASTM D 4355	per formulation	70	70	70	70	70	70
NOMINAL ROLL DIMENSIONS								
Roll Length[1], ft (m)			850 (259)	850 (259)	600 (182)	500 (152)	400 (122)	300 (91)
Roll Width[1], ft (m)			15 (4.5)	15 (4.5)	15 (4.5)	15 (4.5)	15 (4.5)	15 (4.5)
Roll Area, ft² (m²)			12,750 (1,185)	12,750 (1,185)	9,000 (836)	7,500 (698)	6,000 (557)	4,500 (418)

NOTES:

- The property values listed are in weaker principal direction. All values listed are Minimum Average Values except apparent opening size in mm and UV resistance. Apparent opening size (mm) is a Maximum Value. UV is a typical value.
- [1]Roll lengths and widths have a tolerance of ±1%.

DS12NW R10/11/10

GSE Roll Allocation

Order 60728
Customer Clean Air and Water
Site NWG- Powerton Station

Roll#	Product Code	Description	Mfg. Date	Length
130342464	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342467	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342469	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342471	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342473	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342474	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342475	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342476	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342477	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342478	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342480	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342481	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342484	GEO-120E-EBC-E-	NW12	6/5/2009	400
130342485	GEO-120E-EBC-E-	NW12	6/5/2009	400

GSE Roll Allocation

Order 60728
Customer Clean Air and Water
Site NWG- Powerton Station

Roll#	Product Code	Description	Mfg. Date	Length
130355977	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355978	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355979	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355980	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355981	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355982	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355983	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355984	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355985	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355986	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355987	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355988	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355989	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355990	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355991	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355992	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355993	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355994	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355995	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355996	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355997	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355998	GEO-160E-EBC-E-	NW16	12/4/2009	300
130355999	GEO-160E-EBC-E-	NW16	12/4/2009	300
130356000	GEO-160E-EBC-E-	NW16	12/4/2009	300
130356001	GEO-160E-EBC-E-	NW16	12/4/2009	300
130356002	GEO-160E-EBC-E-	NW16	12/4/2009	300
130356003	GEO-160E-EBC-E-	NW16	12/4/2009	300
130356004	GEO-160E-EBC-E-	NW16	12/4/2009	300
130356005	GEO-160E-EBC-E-	NW16	12/4/2009	300
130356006	GEO-160E-EBC-E-	NW16	12/4/2009	300
130356007	GEO-160E-EBC-E-	NW16	12/4/2009	300
130356008	GEO-160E-EBC-E-	NW16	12/4/2009	300
130356009	GEO-160E-EBC-E-	NW16	12/4/2009	300
130356010	GEO-160E-EBC-E-	NW16	12/4/2009	300

Order 60728
Customer Clean Air and Water
Site NWG- Powerton Station

Roll#	Product Code	Description	Mfg. Date	Length
130356011	GEO-160E-EBC-E-	NW16	12/4/2009	300
130356012	GEO-160E-EBC-E-	NW16	12/4/2009	300

GSE Lining Technology, Inc

Roll Test Data Report

Sales Order No.	Project Number	Customer Name	Project Location	Product Name	Report Date
60728		Clean Air and Water	Pekin, IL	GEO-160E-EBC-E-00	12/16/2009 *Modified

QC APPROVED

Roll No.	ASTM D 4491 Average Sample Flow Rate (gallon/min/ft2) every 20th	Permittivity (Sec-1)	ASTM D 4751 Apparent Opening Size (mm) every roll	ASTM D 4833 Puncture Resistance (lbs) every 20th	ASTM D 4533 Trap Tear Strength CD (lbs) every 20th	Trap Tear Strength MD (lbs)	ASTM D 4632 Grab Elongation CD (%) every 20th	Grab Elongation MD (%)	Grab Strength CD (lbs)	Grab Strength MD (lbs)	ASTM D 5261 Mass per Unit Area (oz./yd2) every 20th
130355977	71	1.00	0.150	287	431	267	111	138	769	471	16.9
130355978	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355979	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355980	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355981	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355982	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355983	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355984	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355985	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355986	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355987	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355988	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355989	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355990	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355991	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355992	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355993	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355994	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355995	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355996	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355997	73	1.00	0.150	262	292	199	98	127	769	470	16.4
130355998	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130355999	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130356000	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130356001	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130356002	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130356003	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130356004	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130356005	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130356006	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130356007	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130356008	73	1.00	0.150	269	491	264	101	126	643	462	16.5

GSE Lining Technology, Inc

Roll Test Data Report

Sales Order No.	Project Number	Customer Name	Project Location	Product Name	Report Date
60728		Clean Air and Water	Pekin, IL	GEO-160E-EBC-E-00	12/16/2009 *Modified

Roll No.	ASTM D 4491 Average Sample Flow Rate (gallon/min/ft2) every 20th	Permittivity (Sec-1)	ASTM D 4751 Apparent Opening Size (mm) every roll	ASTM D 4833 Puncture Resistance (lbs) every 20th	ASTM D 4533 Trap Tear Strength CD (lbs) every 20th	Trap Tear Strength MD (lbs)	ASTM D 4632 Grab Elongation CD (%) every 20th	Grab Elongation MD (%)	Grab Strength CD (lbs)	Grab Strength MD (lbs)	ASTM D 5261 Mass per Unit Area (oz./yd2) every 20th
130356009	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130356010	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130356011	73	1.00	0.150	269	491	264	101	126	643	462	16.5
130356012	73	1.00	0.150	269	491	264	101	126	643	462	16.5

Laboratory Manager: Vicky T. Parrott

GSE-8.2.4-029 Rev -- 03/05

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Kingstree Lab - US

GSE Lining Technology, Inc

Roll Test Data Report

Sales Order No.	Project Number	Customer Name	Project Location	Product Name	Report Date
60728		Clean Air and Water Systems, LLC	Pekin, IL	HDT-060AE-WBB-B-00	12/15/2009

QC APPROVED GSE

Roll No.	Average Thickness (mils)	Minimum Thickness (mils)	TD Strength @ Yield (ppi)	MD Strength @ Yield (ppi)	TD Strength @ Break (ppi)	MD Strength @ Break (ppi)	TD Elongation @ Yield (%)	MD Elongation @ Yield (%)	TD Elongation @ Break (%)	MD Elongation @ Break (%)	TD Tear Resistance (lbs)	MD Tear Resistance (lbs)	Puncture Resistance (lbs)	Density (g/cc)	Carbon Black Content (%)	Carbon Black Dispersion Views in Cat1 - Cat2	Asperity Height Side A (mils)	Asperity Height Side B (mils)
	ASTM D 5994		ASTM D638,Type IV / D6693								ASTM D 1004		ASTM D 4833	ASTM D 1505	ASTM D 4218/1603	ASTM D 5596	GRI GM 12	
	every roll		every 4th								every 4th		every 4th	every 4th	every 4th	every 4th	every 2nd	
103176435	61	59	156	156	202	233	16	18	575	610	54	56	148	0.945	2.26	10	23	21
103176439	61	59	157	155	205	212	15	18	584	609	55	57	149	0.945	2.26	10	23	21
103176440	61	59	157	155	205	212	15	18	584	609	55	57	149	0.945	2.26	10	23	21
103176442	61	58	132	134	203	226	18	19	648	675	49	52	138	0.945	2.66	10	23	20
103176443	61	57	132	134	203	226	18	19	648	675	49	52	138	0.945	2.66	10	23	21
103176444	61	57	132	134	203	226	18	19	648	675	49	52	138	0.945	2.66	10	23	21
103176445	61	56	132	134	203	226	18	19	648	675	49	52	138	0.945	2.66	10	22	21
103176446	61	56	150	150	223	218	18	19	605	555	54	57	145	0.945	2.79	10	22	21
103176448	61	56	150	150	223	218	18	19	605	555	54	57	145	0.945	2.79	10	21	22
103176449	61	56	150	150	223	218	18	19	605	555	54	57	145	0.945	2.79	10	22	23
103176450	61	56	151	142	208	226	18	20	567	581	52	55	149	0.945	2.70	10	22	23
103176451	61	59	151	142	208	226	18	20	567	581	52	55	149	0.945	2.70	10	21	21
103176452	61	58	151	142	208	226	18	20	567	581	52	55	149	0.945	2.70	10	21	21
103176453	61	59	151	142	208	226	18	20	567	581	52	55	149	0.945	2.70	10	20	20
103176454	61	59	144	144	202	237	16	18	579	630	52	54	146	0.945	2.31	10	20	20
103176455	61	58	144	144	202	237	16	18	579	630	52	54	146	0.945	2.31	10	21	22
103176456	61	58	144	144	202	237	16	18	579	630	52	54	146	0.945	2.31	10	21	22

Laboratory Manager: Jane Allen

GSE-8.2.4-029 Rev -- 03/05

19103 Gundle Road - Houston, Texas 77073

GSE

Lining Technology, Inc

Roll Test Data Report

Sales Order No.	*Project Number*	*Customer Name*	*Project Location*	*Product Name*	*Report Date*
60728		Clean Air and Water Systems, LLC	Pekin, IL	HDT-060AE-WBB-B-00	12/16/2009

GSE QC APPROVED

Roll No.	Average Thickness (mils)	Minimum Thickness (mils)	TD Strength @ Yield (ppi)	MD Strength @ Yield (ppi)	TD Strength @ Break (ppi)	MD Strength @ Break (ppi)	TD Elongation @ Yield (%)	MD Elongation @ Yield (%)	TD Elongation @ Break (%)	MD Elongation @ Break (%)	TD Tear Resistance (lbs)	MD Tear Resistance (lbs)	Puncture Resistance (lbs)	Density (g/cc)	Carbon Black Content (%)	Carbon Black Dispersion Views in Cat1 - Cat2	Asperity Height Side A (mils)	Asperity Height Side B (mils)
	ASTM D 5994		ASTM D638,Type IV / D6693								ASTM D 1004		ASTM D 4833	ASTM D 1505	ASTM D 4218/1603	ASTM D 5596	GRI GM 12	
	every roll		every 4th								every 4th		every 4th	every 4th	every 4th	every 4th	every 2nd	
103176435	61	59	156	156	202	233	16	18	575	610	54	56	148	0.945	2.26	10	23	21
103176439	61	59	157	155	205	212	15	18	584	609	55	57	149	0.945	2.26	10	23	21
103176440	61	59	157	155	205	212	15	18	584	609	55	57	149	0.945	2.26	10	23	21
103176442	61	58	132	134	203	226	18	19	648	675	49	52	138	0.945	2.66	10	23	20
103176443	61	57	132	134	203	226	18	19	648	675	49	52	138	0.945	2.66	10	23	21
103176444	61	57	132	134	203	226	18	19	648	675	49	52	138	0.945	2.66	10	23	21
103176445	61	56	132	134	203	226	18	19	648	675	49	52	138	0.945	2.66	10	22	21
103176446	61	56	150	150	223	218	18	19	605	555	54	57	145	0.945	2.79	10	22	21
103176448	61	56	150	150	223	218	18	19	605	555	54	57	145	0.945	2.79	10	21	22
103176449	61	56	150	150	223	218	18	19	605	555	54	57	145	0.945	2.79	10	22	23
103176450	61	56	151	142	208	226	18	20	567	581	52	55	149	0.945	2.70	10	22	23
103176451	61	59	151	142	208	226	18	20	567	581	52	55	149	0.945	2.70	10	21	21
103176452	61	58	151	142	208	226	18	20	567	581	52	55	149	0.945	2.70	10	21	21
103176453	61	59	151	142	208	226	18	20	567	581	52	55	149	0.945	2.70	10	20	20
103176454	61	59	144	144	202	237	16	18	579	630	52	54	146	0.945	2.31	10	20	20
103176455	61	58	144	144	202	237	16	18	579	630	52	54	146	0.945	2.31	10	21	22
103176456	61	58	144	144	202	237	16	18	579	630	52	54	146	0.945	2.31	10	21	22
103176458	61	57	144	142	191	208	17	18	584	592	54	54	144	0.945	2.63	10	20	20
103176459	62	58	144	142	191	208	17	18	584	592	54	54	144	0.945	2.63	10	20	20
103176460	63	59	144	142	191	208	17	18	584	592	54	54	144	0.945	2.63	10	20	20
103176461	62	60	144	142	191	208	17	18	584	592	54	54	144	0.945	2.63	10	20	20
103176462	62	59	145	154	216	234	17	18	601	608	55	56	146	0.945	2.62	10	20	20
103176463	62	60	145	154	216	234	17	18	601	608	55	56	146	0.945	2.62	10	21	21

Laboratory Manager:

GSE-8.2.4-029 Rev -- 03/05

19103 Gundle Road - Houston, Texas 77073

The Pioneer Of Geosynthetics
S I N C E 1 9 7 2

Product Data Sheet

GSE White Textured Geomembrane

GSE White Textured is a co-extruded textured high density polyethylene (HDPE) geomembrane available on one or both sides. It is manufactured with the highest quality resin specifically formulated for flexible geomembranes. GSE White Textured has a U.V. stabilized upper white surface that reflects light, improves damage detection, reduces wrinkles and subgrade desiccation. This product provides increased frictional resistance, excellent chemical resistance, and endurance properties. It is used in applications that require enhanced quality assurance measures over standard geomembranes.

Product Specifications *These product specifications meet or exceed GRI GM13.*

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE VALUE				
			30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm)	ASTM D 5994	every roll	30 (0.75)	40 (1.00)	60 (1.50)	80 (2.00)	100 (2.50)
Lowest individual reading (-10%)			27 (0.69)	36 (0.91)	54 (1.40)	72 (1.80)	90 (2.30)
Density, g/cm³	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 6693, Type IV	20,000 lb					
Strength at Break, lb/in-width (N/mm)	Dumbell, 2 ipm		66 (11)	75 (13)	115 (20)	155 (27)	230 (40)
Strength at Yield, lb/in-width (N/mm)			68 (11)	90 (15)	132 (23)	177 (31)	225 (39)
Elongation at Break, %	G.L. 2.0 in (51 mm)		100	100	100	100	100
Elongation at Yield, %	G.L. 1.3 in (33 mm)		12	12	12	12	12
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	24 (106)	32 (142)	45 (200)	60 (266)	75 (333)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	65 (289)	95 (422)	130 (578)	160 (711)	190 (845)
Carbon Black Content[1], % (Range)	ASTM D 1603*/4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	Note[2]	Note[2]	Note[2]	Note[2]	Note[2]
Asperity Height, mil (mm)	ASTM D 7466	second roll	16 (0.40)	18 (0.45)	18 (0.45)	18 (0.45)	18 (0.45)
Notched Constant Tensile Load[3], hr	ASTM D 5397, Appendix	200,000 lb	1,000	1,000	1,000	1,000	1,000
Oxidative Induction Time, min	ASTM D 3895, 200° C; O_2, 1 atm	200,000 lb	>140	>140	>140	>140	>140
TYPICAL ROLL DIMENSIONS							
Roll Length[4], ft (m)	Double-Sided Textured		830 (253)	700 (213)	520 (158)	400 (122)	330 (101)
	Single-Sided Textured		840 (256)	650 (198)	420 (128)	320 (98)	250 (76)
Roll Width[4], ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft² (m²)	Double-Sided Textured		18,675 (1,735)	15,750 (1,463)	11,700 (1,087)	9,000 (836)	7,425 (690)
	Single-Sided Textured		18,900 (1,755)	14,625 (1,359)	9,450 (878)	7,200 (669)	5,625 (523)

NOTES:
- [1]GSE White may have an overall ash content greater than 3.0% due to the white layer. These values apply to the black layer only.
- [2]Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- [3]NCTL for GSE White Textured is conducted on representative smooth membrane samples.
- [4]Roll lengths and widths have a tolerance of ± 1%.
- GSE White Textured Double-Sided is available in rolls weighing approximately 4,000 lb (1,800 kg) and Single-Sided weighing approximately 3,000 lb (1,360 kg).
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.
- *Modified.

GSE Roll Allocation

Order 60728
Customer Clean Air and Water Systems, LLC
Site MWG-Powerton Station Metal Cleaning

Roll#	Resin Lot	Product Code	Description	Mfg. Date	Length
103176435	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/13/2009	520
103176439	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/13/2009	520
103176440	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176442	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176443	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176444	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176445	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176446	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176448	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176449	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176450	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176451	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176452	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176453	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176454	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176455	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176456	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/15/2009	520
103176458	8290674	HDT-060AE-WBB-B-00	HDT060A010	12/15/2009	520
103176459	8290674	HDT-060AE-WBB-B-00	HDT060A010	12/15/2009	520
103176460	8290674	HDT-060AE-WBB-B-00	HDT060A010	12/15/2009	520
103176461	8290674	HDT-060AE-WBB-B-00	HDT060A010	12/15/2009	520
103176462	8290674	HDT-060AE-WBB-B-00	HDT060A010	12/15/2009	520
103176463	8290674	HDT-060AE-WBB-B-00	HDT060A010	12/15/2009	520

GSE Roll Allocation

Order 60728
Customer Clean Air and Water Systems, LLC
Site MWG-Powerton Station Metal Cleaning

Roll#	Resin Lot	Product Code	Description	Mfg. Date	Length
103176435	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/13/2009	520
103176439	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/13/2009	520
103176440	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176442	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176443	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176444	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176445	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176446	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176448	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176449	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176450	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176451	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176452	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176453	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176454	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176455	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/14/2009	520
103176456	8290673	HDT-060AE-WBB-B-00	HDT060A010	12/15/2009	520

Report Date
1/17/2011

Quality Assurance Laboratory Test Results

Job Name: MWG - Powerton Station Metal Cleaning Basin
Sales Order: 60728

Required Testing: ASTM D 5397 - Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test

Custom Frequency: 1/Resin Lot

Custom Criteria: 1000 hours

Product Code	Resin Lot Number	Test Results
HDT-060AE-WBB-B-00	8290673	PASS

Approved By:	Debra Gortemiller
Date Approved:	December 15, 2009

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Report Date
1/17/2011

Quality Assurance Laboratory Test Results

Job Name: MWG - Powerton Station Metal Cleaning Basin
Sales Order: 60728

Required Testing: ASTM D 3895 -- Standard Test Method for Oxidative Induction Time of Polyolefins by Differential Scanning Calorimetry

Custom Frequency: 1/200,000 lbs.

Custom Criteria: 140 Minutes

Product Code	Resin Lot Number	Test Results
HDT-060AE-WBB-B-00	8290673	PASS

Approved By:	Debra Gortemiller
Date Approved:	December 15, 2009

Report Date
1/17/2011

GSE

Quality Assurance Laboratory Test Results

Job Name: MWG - Powerton Station Metal Cleaning Basin
SO Number: 60728

The table below summarizes additive performance of GSE Houston products as perceived by OIT retention after Oven and UV Aging per GRI Test Method GM13:

		Oven Aging @ 85° C (ASTM D 5721)				UV Resistance per GRI GM11			
		90 days per ASTM D 5885				1600 hours UV Aging per ASTM D 5885			
Product Type	**Formulation**	Initial HP OIT (min)	Final HP OIT (min)	Retained (%)	GRI Criteria (%)	Initial HP OIT (min)	Final HP OIT (min)	Retained (%)	GRI Criteria (%)
HDPE Geomembrane	Chevron Phillips Marlex® K306 + Carbon Black	697	661	94	80	697	565	81	50

Approved By: Debra Gortemiller
Date: December 15, 2009

The above stated data shall not be reproduced except in full, without the written approval of the laboratory.

1245 Eastland Avenue
Kingstree, SC 29556
Phone 843-382-4603
Fax 843-382-4604

Date: December 16, 2009

Project: #60728 MWG – Powerton Station

Ref: Ultraviolet (UV) Resistance and Test Frequency of GSE Geotextiles

To Whom It May Concern:

The resistance of nonwoven needle punched geotextiles to ultraviolet light depends primarily on antioxident and carbon black package mixed with resin to prepare a formulation for fiber extrusion. As long as this formulation remains the same the UV resistance of a geotextiles does not change. Therefore, GSE performs UV testing only once per resin formulation. The testing is performed according to ASTM Test Method D 4355 and results are included on GSE geotextile specification sheet. Currently, all GSE geotextiles meet or exceed a value of 70% strength retained after 500 hours of UV exposure. GSE will meet or exceed this value for the referenced project.

Although GSE geotextiles are manufactured using one of the best available antioxident packages, we recommend covering the geotextiles within 15 days of exposure to direct Sunlight. This period does not include time during which geotextiles rolls remain on site covered in black shrink-wrap. Our recommendation is based on UV performance data published in technical literature indicating geotextile strength can decrease sharply after prolonged exposure to Sunlight.

Actual data from an independent laboratory can be supplied upon request.

Vicky T. Parrott

Vicky T. Parrott
Laboratory Manager - Kingstree

ATTACHMENT A7

GEOMEMBRANE INSTALLER'S DAILY LOGS AND QC DOCUMENTATION

Appendix D

Table 1. HDPE Seam Strength Properties

Material (Mil)	Shear Strength (PPI)	Fusion Peel (PPI)	Extrusion Peel (PPI)
40	81	65	52
60	121	98	78
80	162	130	104
100	203	162	130

Table 2. LLDPE Seam Strength Properties

Material (Mil)	Shear Strength (PPI)	Fusion Peel (PPI)	Extrusion Peel (PPI)
40	60	50	48
60	90	75	72
80	120	100	96
100	150	125	120

CAAW Systems Field QC Information

Project Name:	Powerton - Metal Cleaning Pond
Project Number:	201044
Location:	Pekin, Il
QC Monitor:	Seng
Mat	60 mil HDTW

CAAW Systems

Trial Weld Testing Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Sample TW#	Date	Ambient Temp	Time (AM/PM)	Machine Number	Seamer Initials	Extrusion Temp	Fusion Temp/Speed	Peel (ppi) Inside	Peel (ppi) Outside	Shear (ppi)	Results (P/F)	Comments
1	11/9/10	59	12:50	1	KS	Barrel	Wedge	140	136	151	P	
							850	114	124	149		
						Preheat	Speed	127	133			
							300					
2	11/9/10	59	12:50	427	KK	Barrel	Wedge	129	122	145	P	
							850	123	116	148		
						Preheat	Speed	129	133			
							500					
3	11/9/10	59	12:50	428	HN	Barrel	Wedge	136	135	132	P	
							850	129	131	147		
						Preheat	Speed	135	117			
							500					
1	11/10/10	58	7:30	43	VK	Barrel	Wedge	100		180	P	
						525		114		182		
						Preheat	Speed	116				
						485						
2	11/10/10	58	9:00	13	VP	Barrel	Wedge	96		180	P	
						550		125		178		
						Preheat	Speed	98				
						500						

CAAW Systems

Trial Weld Testing Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Sample TW#	Date	Ambient Temp	Time (AM/PM)	Machine Number	Seamer Initials	Extrusion Temp	Fusion Temp/Speed	Peel (ppi) Inside	Peel (ppi) Outside	Shear (ppi)	Results (P/F)	Comments
						Barrel	Wedge	136	132	168		
							850	135	130	177		
3	11/10/10	58	11:00	1	KS	Preheat	Speed	127	124		P	
							500					
						Barrel	Wedge	124		179		
						525		118		188		
4	11/10/10	58	13:10	43	VK	Preheat	Speed	120			P	
						485						
						Barrel	Wedge	104		180		
						550		112		177		
5	11/10/10	58	13:10	13	VP	Preheat	Speed	115			P	
						500						
						Barrel	Wedge	121	128	180		
							850	133	127	177		
6	11/10/10	58	13:05	1	KS	Preheat	Speed	129	130		P	
							300					
						Barrel	Wedge	114	122	169		
							850	118	129	174		
7	11/10/10	58	13:15	427	KK	Preheat	Speed	112	118		P	
							500					

CAAW Systems

Trial Weld Testing Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Sample TW#	Date	Ambient Temp	Time (AM/PM)	Machine Number	Seamer Initials	Extrusion Temp	Fusion Temp/Speed	Peel (ppi) Inside	Peel (ppi) Outside	Shear (ppi)	Results (P/F)	Comments
1	11/11/10	62	7:15	13	VP	Barrel	Wedge	110		187	P	
						550		132		183		
						Preheat	Speed	110				
						500						
2	11/11/10	62	7:30	43	VK	Barrel	Wedge	131		178	P	
						525		106		184		
						Preheat	Speed	137				
						485						
3	11/11/10	62	9:30	427	KK	Barrel	Wedge	139	148	180	P	
							850	147	163	184		
						Preheat	Speed	153	151			
							500					
4	11/11/10	62	9:30	1	KS	Barrel	Wedge	135	143	168	P	
							850	148	136	169		
						Preheat	Speed	143	136			
							300					
5	11/11/10	62	13:15	427	KK	Barrel	Wedge	132	141	171	P	
							850	133	140	168		
						Preheat	Speed	133	129			
							500					

CAAW Systems

Trial Weld Testing Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Sample TW#	Date	Ambient Temp	Time (AM/PM)	Machine Number	Seamer Initials	Extrusion Temp	Fusion Temp/Speed	Peel (ppi) Inside	Peel (ppi) Outside	Shear (ppi)	Results (P/F)	Comments
						Barrel	Wedge	133	121	178		
							850	138	126	177		
6	11/11/10	62	13:00	1	KS	Preheat	Speed	130	124		P	
							300					
						Barrel	Wedge	102		152		
						525		120		162		
1	11/12/10	59	7:30	43	VK	Preheat	Speed	97			P	
						485						
						Barrel	Wedge	114		152		
						550		117		149		
2	11/12/10	59	7:30	239	KS	Preheat	Speed	116			P	
						500						
						Barrel	Wedge	116		158		
						550		125		145		
3	11/12/10	59	7:20	13	VP	Preheat	Speed	128			P	
						500						
						Barrel	Wedge	118	120	181		
							850	121	127	177		
4	11/12/10	59	7:30	427	KK	Preheat	Speed	119	126		P	
							500					

CAAW Systems

Trial Weld Testing Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Sample TW#	Date	Ambient Temp	Time (AM/PM)	Machine Number	Seamer Initials	Extrusion Temp	Fusion Temp/Speed	Peel (ppi) Inside	Peel (ppi) Outside	Shear (ppi)	Results (P/F)	Comments
5	11/12/10	59	13:10	43	VK	Barrel	Wedge	100		161	P	
						525		104		177		
						Preheat	Speed	110				
						485						
6	11/12/10	59	13:10	13	VP	Barrel	Wedge	118		177	P	
						550		122		180		
						Preheat	Speed	116				
						500						
7	11/12/10	59	13:15	239	KS	Barrel	Wedge	110		162	P	
						550		108		157		
						Preheat	Speed	114				
						500						
1	11/15/10	53	7:30	43	VK	Barrel	Wedge	109		169	P	
						525		118		180		
						Preheat	Speed	110		189		
						485						
2	11/15/10	53	7:30	13	VP	Barrel	Wedge	118		179	P	
						550		120		181		
						Preheat	Speed	114		188		
						500						

CAAW Systems

Trial Weld Testing Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Sample TW#	Date	Ambient Temp	Time (AM/PM)	Machine Number	Seamer Initials	Extrusion Temp	Fusion Temp/Speed	Peel (ppi) Inside	Peel (ppi) Outside	Shear (ppi)	Results (P/F)	Comments
						Barrel	Wedge	128		199		
						525		122		191		
3	11/15/10	53	13:10	43	VK	Preheat	Speed	133		194	P	
						485						
						Barrel	Wedge	119		189		
						550		116		180		
4	11/15/10	53	13:10	13	VP	Preheat	Speed	124		184	P	
						500						
						Barrel	Wedge					
						Preheat	Speed					
						Barrel	Wedge					
						Preheat	Speed					
						Barrel	Wedge					
						Preheat	Speed					

CAAW Systems

Panel Placement Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Panel Number	Date	Time (am/pm)	Roll Number	Type S or T	Final Width (Feet)	Final Length (Feet)	Final Area (Sq. Ft.)	Comments
P1	11/9/10		6549	T	22	120	2,640	
P2	11/9/10		6549	T	22	120	2,640	
P3	11/9/10		6549	T	22	120	2,640	
P4	11/9/10		6549	T	22	120	2,640	
P5	11/9/10		6460	T	22	120	2,640	
P6	11/9/10		6460	T	22	120	2,640	
P7	11/9/10		6460	T	22	120	2,640	
P8	11/9/10		6460	T	22	120	2,640	
P9	11/9/10		6462	T	22	120	2,640	
P10	11/9/10		6462	T	22	120	2,640	
P11	11/9/10		6462	T	22	120	2,640	
P12	11/9/10		6462	T	22	120	2,640	
P13	11/9/10		6461	T	22	120	2,640	
P14	11/9/10		6461	T	17	48	696	
P15	11/9/10		6461	T	22	25	276	
P16	11/9/10		6461	T	22	35	650	
P17	11/9/10		6461	T	22	46	918	
P18	11/9/10		6461	T	25	46	787	
P19	11/9/10		6461	T	22	48	748	
P20	11/9/10		6461	T	22	52	1,080	

CAAW Systems

Panel Placement Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Panel Number	Date	Time (am/pm)	Roll Number	Type S or T	Final Width (Feet)	Final Length (Feet)	Final Area (Sq. Ft.)	Comments
P21	11/9/10		6461	T	22	46	748	
P22	11/9/10		6461	T	18	22	160	
P23	11/9/10		6463	T	11	18	100	
P24	11/9/10		6463	T	22	46	781	
P25	11/9/10		6463	T	22	76	1,595	
P26	11/9/10		6463	T	22	69	1,441	
P27	11/9/10		6463	T	22	62	1,287	
P28	11/10/10		6451	T	22	154	3,234	
P29	11/10/10		6451	T	22	140	3,080	
P30	11/10/10		6458	T	22	39	858	
P31	11/10/10		6463	T	18	16	232	
P32	11/10/10		6463	T	11	10	55	
P33	11/10/10		6463	T	22	46	746	
P34	11/10/10		6463	T	22	48	1,056	
P35	11/10/10		6463	T	22	48	1,056	
P36	11/10/10		6463	T	22	48	1,056	
P37	11/10/10		6451	T	22	48	1,056	
P38	11/10/10		6451	T	22	48	1,056	
P39	11/10/10		6451	T	22	48	857	
P40	11/10/10		6451	T	24	22	528	

CAAW Systems

Panel Placement Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Panel Number	Date	Time (am/pm)	Roll Number	Type S or T	Final Width (Feet)	Final Length (Feet)	Final Area (Sq. Ft.)	Comments
P41	11/10/10		6451	T	22	44	741	
P42	11/10/10		6458	T	22	69	1,518	
P43	11/11/10		6458	T	22	67	1,330	
P44	11/11/10		6458	T	22	67	1,474	
P45	11/11/10		6458	T	22	67	1,474	
P46	11/11/10		6458	T	22	67	1,474	
P47	11/11/10		6458	T	22	67	1,474	
P48	11/11/10		6458	T	22	67	1,474	
P49	11/11/10		6458	T	22	71	1,562	
P50	11/11/10		6452	T	22	74	1,628	
P51	11/11/10		6452	T	22	74	1,628	
P52	11/11/10		6452	T	22	220	4,840	
P53	11/11/10		6452	T	22	36	715	
P54	11/11/10		6449	T	22	26	492	
P55	11/11/10		6449	T	22	33	649	
P56	11/11/10		6449	T	22	29	561	
P57	11/11/10		6449	T	22	22	407	
P58	11/11/10		6449	T	22	15	253	
P59	11/11/10		6449	T	20	8	88	
P60	11/12/10		6449	T	8	110	880	

CAAW Systems

Panel Placement Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Panel Number	Date	Time (am/pm)	Roll Number	Type S or T	Final Width (Feet)	Final Length (Feet)	Final Area (Sq. Ft.)	Comments
P61	11/12/10		6449	T	6	110	660	

CAAW Systems

Panel Seaming Summary

Project Name: Powerton - Metal Cleaning Pond QC Monitor: Seng

Project Number: 201044 Material: 60 mil HDTW

Seam Number	Date Seamed	Final Seam Length (feet)	Welder Initials	Weld Type Ext / Wedge	Machine Number	Machine Temp/ Speed/ Preheat	Time		Ambient Temp (°F)	End of Seam Destructive Test (P/F)	Comments
							Start	Stop			
P1-P2	11/9/10	120	KS	W	1	850/300	13:02		59		
P2-P3	11/9/10	120	KK	W	427	850/500	13:10		59		
P3-P4	11/9/10	120	HN	W	428	850/500	13:18		59		
P4-P5	11/9/10	120	KS	W	1	850/300	13:26		59		
P5-P6	11/9/10	120	KK	W	427	850/500	13:40		59		
P6-P7	11/9/10	120	HN	W	428	850/500	13:49		59		
P7-P8	11/9/10	120	KS	W	1	850/300	13:59		59		
P8-P9	11/9/10	120	KK	W	427	850/500	14:15		59		
P9-P10	11/9/10	120	HN	W	428	850/500	14:21		59		
P10-P11	11/9/10	120	KS	W	1	850/300	14:16		59		
P11-P12	11/9/10	120	KK	W	427	850/500	14:40		59		
P12-P13	11/9/10	120	KS	W	1	850/300	15:24		59		
P13-P14	11/9/10	46	HN	W	428	850/500	15:44		59		
P17-P13	11/9/10	22	KK	W	427	850/500	15:40		59		
P14-P15	11/9/10	19	KK	W	427	850/500	15:40		59		
P14-P16	11/9/10	23	KK	W	427	850/500	15:40		59		
P17-P14	11/9/10	11	KK	W	427	850/500	15:40		59		
P15-P16	11/9/10	22	KK	W	427	850/500	15:30		59		
P16-P17	11/9/10	35	HN	W	428	850/500	15:26		59		

CAAW Systems

Panel Seaming Summary

Project Name: Powerton - Metal Cleaning Pond QC Monitor: Seng

Project Number: 201044 Material: 60 mil HDTW

Seam Number	Date Seamed	Final Seam Length (feet)	Welder Initials	Weld Type Ext / Wedge	Machine Number	Machine Temp/ Speed/ Preheat	Time		Ambient Temp (°F)	End of Seam Destructive Test (P/F)	Comments
							Start	Stop			
P17-POLYL	11/10/10	78	VK	E	43	525/485	8:40		58		
P18-P17	11/10/10	12	VK	E	43	525/485	8:40		58		
P18-POLYL	11/10/10	74	VK	E	43	525/485	9:40		58		
P18-P19	11/10/10	16	VP	E	13	550/525	9:00		58		
P19-POLYL	11/10/10	51	VP	E	13	550/525	9:00		58		
P19-P20	11/10/10	52	KS	W	1	850?300	10:40		58		
P20-P21	11/10/10	48	KS	W	1	850?300	11:05		58		
P20-P24	11/10/10	6	KS	W	1	850?300	11:05		58		
P21-P22	11/10/10	22	KS	W	1	850?300	11:15		58		
P22-P23	11/10/10	18	KS	W	1	850?300	11:30		58		
P23-P24	11/10/10	19	KS	W	1	850?300	11:24		58		
P24-P25	11/10/10	46	KS	W	1	850?300	11:40		58		
P20-P25	11/10/10	22	KS	W	1	850?300	11:40		58		
P21-P24	11/10/10	24	KS	W	1	850?300	11:30		58		
P25-P26	11/10/10	65	KS	W	1	850?300	11:55		58		
P26-P27	11/10/10	60	KS	W	1	850?300	13:10		58		
P13-P25	11/10/10	22	KS	W	1	850?300	13:23		58		
P12-P26	11/10/10	22	KS	W	1	850?300	13:26		58		
P11-P27	11/10/10	22	KS	W	1	850?300	13:29		58		

CAAW Systems

Panel Seaming Summary

Project Name: Powerton - Metal Cleaning Pond
QC Monitor: Seng
Project Number: 201044
Material: 60 mil HDTW

Seam Number	Date Seamed	Final Seam Length (feet)	Welder Initials	Weld Type Ext / Wedge	Machine Number	Machine Temp/ Speed/ Preheat	Time		Ambient Temp (°F)	End of Seam Destructive Test (P/F)	Comments
							Start	Stop			
P1-P28	11/10/10	120	KS	W	1	850?300	15:20		58		
P28-P29	10/10/10	141	KK	W	427	850/500	15:30		58		
P29-P30	11/11/10	38	KS	W	1	850?300	9:40		58		
P30-P31	11/11/10	18	KK	W	427	850/500	9:50		58		
P31-P32	11/10/10	10	KS	W	1	850?300	13:50		58		
P30-P33	11/11/10	21	KK	W	427	850/500	9:50		58		
P31-P33	11/10/10	16	KS	W	1	850?300	13:35		58		
P32-P33	11/10/10	11	KS	W	1	850?300	13:36		58		
P34-P35	11/10/10	48	KK	W	427	850/500	13:50		58		
P35-P36	11/10/10	48	KS	W	1	850/300	14:10		58		
P36-P37	11/10/10	48	KK	W	427	850/500	14:35		58		
P37-P38	11/10/10	48	KS	W	1	850/300	14:40		58		
P38-P39	11/10/10	48	KK	W	427	850/500	14:50		58		
P39-P40	11/10/10	24	KS	W	1	850/300	15:14		58		
P40-P41	11/10/10	21	KS	W	1	850/300	15:00		58		
P41-P42	11/11/10	34	KS	W	1	850/300	9:55		58		
P39-P41	11/10/10	24	KS	W	1	850/300	15:10		58		
P42-P43	11/11/10	64	KK	W	427	850/500	10:10		62		
P42-P29	11/11/10	22	KS	W	1	850/300	10:11		62		

CAAW Systems

Panel Seaming Summary

Project Name: Powerton - Metal Cleaning Pond QC Monitor: Seng

Project Number: 201044 Material: 60 mil HDTW

Seam Number	Date Seamed	Final Seam Length (feet)	Welder Initials	Weld Type Ext / Wedge	Machine Number	Machine Temp/ Speed/ Preheat	Time		Ambient Temp (°F)	End of Seam Destructive Test (P/F)	Comments
							Start	Stop			
P43--P28	11/11/10	23	KS	W	1	850/300	10:04		62		
P43-P44	11/11/10	55	KK	W	427	850/500	10:15		62		
P44-P28	11/11/10	12	KK	W	427	850/500	10:15		62		
P44-P45	11/11/10	67	KS	W	1	850/300	10:15		62		
P45-P46	11/11/10	67	KS	W	1	850/300	10:25		62		
P46-P47	11/11/10	67	KK	W	427	850/500	10:30		62		
P47-P48	11/11/10	67	KS	W	1	850/300	10:36		62		
P48-P49	11/11/10	71	KK	W	427	850/500	10:45		62		
P49-P50	11/11/10	72	KS	W	1	850/300	10:49		62		
P50-P51	11/11/10	74	KS	W	1	850/300	11:05		62		
P51-P53	11/11/10	36	KK	W	427	850/500	13:20		62		
P53-P56	11/11/10	31	KK	W	427	850/500	13:35		62		
P56-P57	11/11/10	24	KK	W	427	850/500	13:45		62		
P57-P58	11/11/10	18	KK	W	427	850/500	13:50		62		
P58-P59	11/11/10	11	KK	W	427	850/500	13:55		62		
P54-P55	11/11/10	26	KS	W	1	850/300	11:05		62		
P55-P27	11/11/10	33	KS	W	1	850/300	11:10		62		
P28-P52	11/11/10	22	KK	W	427	850/500	11:30		62		
P44-P52	11/11/10	22	KK	W	427	850/500	11:34		62		

CAAW Systems

Panel Seaming Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Seamed	Final Seam Length (feet)	Welder Initials	Weld Type Ext / Wedge	Machine Number	Machine Temp/ Speed/ Preheat	Time		Ambient Temp (°F)	End of Seam Destructive Test (P/F)	Comments
							Start	Stop			
P45-P52	11/11/10	22	KK	W	427	850/500	11:38		62		
P46-P52	11/11/10	22	KK	W	427	850/500	11:41		62		
P47-P52	11/11/10	22	KK	W	427	850/500	11:44		62		
P48-P52	11/11/10	22	KK	W	427	850/500	11:47		62		
P49-P52	11/11/10	22	KK	W	427	850/500	11:50		62		
P50-P52	11/11/10	22	KK	W	427	850/500	11:53		62		
P51-P52	11/11/10	22	KK	W	427	850/500	11:56		62		
P54-P52	11/11/10	22	KS	W	1	850/300	13:35		62		
P55-P52	11/11/10	22	KS	W	1	850/300	13:36		62		
P52-P27	11/11/10	22	KS	W	1	850/300	13:48		62		
P1-P52	11/11/10	22	KS	W	1	850/300	13:55		62		
P2-P52	11/11/10	22	KS	W	1	850/300	13:58		62		
P3-P52	11/11/10	22	KS	W	1	850/300	14:01		62		
P4-P52	11/11/10	22	KS	W	1	850/300	14:04		62		
P5-P52	11/11/10	22	KS	W	1	850/300	14:07		62		
P6-P52	11/11/10	22	KS	W	1	850/300	14:10		62		
P7-P52	11/11/10	22	KS	W	1	850/300	14:13		62		
P8-P52	11/11/10	22	KS	W	1	850/300	14:16		62		
P9-P52	11/11/10	22	KS	W	1	850/300	14:19		62		

CAAW Systems

Panel Seaming Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Seamed	Final Seam Length (feet)	Welder Initials	Weld Type Ext / Wedge	Machine Number	Machine Temp/ Speed/ Preheat	Time Start	Time Stop	Ambient Temp (°F)	End of Seam Destructive Test (P/F)	Comments
P10-P52	11/11/10	22	KS	W	1	850/300	14:22		62		
P60-P29	11/12/10	97	KK	W	427	850/500	9:10		62		
P60-42	11/12/10	24	KK	W	427	850/500	9:10		62		
P61-P34	11/12/10	22	KK	W	427	850/500	10:20		62		
P61-P35	11/12/10	22	KK	W	427	850/500	10:20		62		
P61-P36	11/12/10	22	KK	W	427	850/500	10:20		62		
P61-P37	11/12/10	22	KK	W	427	850/500	10:20		62		
P61-P38	11/12/10	22	KK	W	427	850/500	10:20		62		
P61-P39	11/12/10	9	KK	W	427	850/500	10:20		62		

CAAW Systems

Non-Destructive Test Summary

Project Name: Powerton - Metal Cleaning Pond QC Monitor: Seng

Project Number: 201044 Material: 60 mil HDTW

Seam Number	Date Tested	Location / Seam Length Tested	Air					Vacuum	Comments
			Air Pressure				Air Test Results (P/F)	Vac. Test Results (P/F)	
			Start		End				
			PSI	Time	PSI	Time			
P1-P2	11/10/10	120	30	8:10	30	8:15	P		
P2-P3	11/10/10	120	30	8:08	30	8:13	P		
P3-P4	11/10/10	120	30	8:07	30	8:12	P		
P4-P5	11/10/10	120	30	7:59	30	8:04	P		
P5-P6	11/10/10	120	30	7:58	30	8:03	P		
P6-P7	11/10/10	120	30	7:57	30	8:02	P		
P7-P8	11/10/10	120	30	7:56	30	8:01	P		
P8-P9	11/10/10	120	30	7:55	30	8:00	P		
P9-P10	11/10/10	120	30	8:30	30	8:35	P		
P10-P11	11/10/10	120	30	8:25	30	8:30	P		
P11-P12	11/10/10	120	30	8:26	30	8:31	P		
P12-P13	11/10/10	120	30	8:29	30	8:34	P		
P13-P14	11/10/10	46	30	9:03	29	9:08	P		
P17-P13	11/10/10	22	30	9:11	30	9:16	P		
P14-P15	11/10/10	19	30	9:19	28	9:24	P		
P14-P16	11/10/10	23	30	8:57	30	9:02	P		
P17-P14	11/10/10	11	30	9:12	30	9:17	P		
P15-P16	11/10/10	22	30	9:20	30	9:25	P		
P16-P17	11/10/10	35	30	8:58	30	9:03	P		
P19-P20	11/11/10	52	30	14:02	30	14:07	P		
P20-P21	11/11/10	48	30	14:03	30	14:08	P		

CAAW Systems

Non-Destructive Test Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Tested	Location / Seam Length Tested	Air					Vacuum	Comments
			Air Pressure				Air Test Results (P/F)	Vac. Test Results (P/F)	
			Start		End				
			PSI	Time	PSI	Time			
P20-P24	11/11/10	6	30	14:05	30	14:10	P		
P21-P22	11/11/10	22	30	14:06	30	14:11	P		
P22-P23	11/11/10	18	30	14:15	30	14:20	P		
P23-P24	11/11/10	19	30	14:16	30	14:21	P		
P24-P25	11/11/10	46	30	14:17	30	14:22	P		
P20-P25	11/11/10	22	30	14:18	30	14:23	P		
P21-P24	11/11/10	24	30	14:25	30	14:30	P		
P25-P26	11/11/10	65	30	14:26	30	14:31	P		
P26-P27	11/11/10	60	30	14:27	30	14:32	P		
P13-P25	11/11/10	22	30	14:28	30	14:33	P		
P12-P26	11/11/10	22	30	14:34	30	14:39	P		
P11-P27	11/11/10	22	30	14:35	30	14:40	P		
P1-P28	11/11/10	120	30	14:36	30	14:41	P		
P28-P29	11/12/10	141	30	14:38	30	14:43	P		
P30-P31	11/12/10	18	30	10:19	29	10:24	P		
P31-P32	11/12/10	10	30	8:48	30	8:53	P		
P30-P33	11/12/10	21	30	10:18	30	10:23	P		
P31-P33	11/12/10	16	30	8:46	30	8:51	P		
P32-P33	11/12/10	11	30	8:49	30	8:54	P		
P34-P35	11/12/10	48	30	8:55	30	9:00	P		
P35-P36	11/12/10	48	30	8:56	30	9:01	P		

CAAW Systems

Non-Destructive Test Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Tested	Location / Seam Length Tested	Air					Vacuum	Comments
			Air Pressure				Air Test Results (P/F)	Vac. Test Results (P/F)	
			Start		End				
			PSI	Time	PSI	Time			
P36-P37	11/12/10	48	30	8:59	30	9:04	P		
P37-P38	11/12/10	48	30	9:00	30	9:05	P		
P38-P39	11/12/10	48	30	9:05	30	9:10	P		
P39-P40	11/12/10	24	30	9:09	29	9:14	P		
P40-P41	11/12/10	21	30	9-:08	30	9:13	P		
P41-P42	11/12/10	34	30	10:58	30	11:03	P		
P39-P41	11/12/10	24	30	9:06	30	9:11	P		
P42-P43	11/12/10	64	30	10:57	29	11:02	P		
P42-P29	11/12/10	22	30	10:47	30	10:52	P		
P43--P28	11/12/10	23	30	10:49	30	10:54	P		
P43-P44	11/12/10	55	30	11:00	30	11:05	P		
P44-P28	11/12/10	12	30	11:06	30	11:11	P		
P44-P45	11/12/10	67	30	11:25	30	11:30	P		
P45-P46	11/12/10	67	30	11:26	30	11:31	P		
P46-P47	11/12/10	67	30	11:27	30	11:32	P		
P47-P48	11/12/10	67	30	11:50	30	11:55	P		
P48-P49	11/12/10	71	30	11:51	30	11:56	P		
P49-P50	11/12/10	72	30	11:53	30	11:58	P		
P50-P51	11/12/10	74	30	13:09	29	13:14	P		
P51-P53	11/12/10	36	30	8:36	30	8:41	P		
P53-P56	11/12/10	31	30	8:51	30	8:56	P		

CAAW Systems

Non-Destructive Test Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Tested	Location / Seam Length Tested	Air					Vacuum	Comments
			Air Pressure				Air Test Results (P/F)	Vac. Test Results (P/F)	
			Start		End				
			PSI	Time	PSI	Time			
P56-P57	11/12/10	24	30	8:52	30	8:57	P		
P57-P58	11/12/10	18	30	8:53	30	8:58	P		
P58-P59	11/12/10	11	30	8:54	30	8:59	P		
P54-P55	11/12/10	26	30	7:49	30	7:54	P		
P55-P27	11/12/10	33	30	7:47	30	7:52	P		
P28-P52	11/12/10	22	30	8:21	30	8:26	P		
P44-P52	11/12/10	22	30	8:22	30	8:27	P		
P45-P52	11/12/10	22	30	8:23	30	8:28	P		
P46-P52	11/12/10	22	30	8:24	30	8:29	P		
P47-P52	11/12/10	22	30	8:33	30	8:38	P		
P48-P52	11/12/10	22	30	8:34	30	8:39	P		
P49-P52	11/12/10	22	30	8:35	30	8:40	P		
P50-P52	11/12/10	22	30	7:59	30	8:04	P		
P51-P52	11/12/10	22	30	7:58	30	8:03	P		
P54-P52	11/12/10	22	30	7:57	30	8:02	P		
P55-P52	11/12/10	22	30	7:46	30	7:51	P		
P52-P27	11/12/10	22	30	7:45	30	7:50	P		
P1-P52	11/12/10	22	30	7:15	30	7:20	P		
P2-P52	11/12/10	22	30	7:16	30	7:21	P		
P3-P52	11/12/10	22	30	7:17	30	7:22	P		
P4-P52	11/12/10	22	30	7:18	30	7:23	P		

CAAW Systems

Non-Destructive Test Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Tested	Location / Seam Length Tested	Air					Vacuum	Comments
			Air Pressure				Air Test Results (P/F)	Vac. Test Results (P/F)	
			Start		End				
			PSI	Time	PSI	Time			
P5-P52	11/12/10	22	30	7:19	30	7:24	P		
P6-P52	11/12/10	22	30	7:26	30	7:31	P		
P7-P52	11/12/10	22	30	7:27	30	7:32	P		
P8-P52	11/12/10	22	30	7:28	30	7:33	P		
P9-P52	11/12/10	22	30	7:29	30	7:34	P		
P10-P52	11/12/10	22	30	7:30	30	7:35	P		
P60-42	11/12/10	20	30	7:33	30	7:38	P		
P61-P34	11/12/10	22	30	7:34	30	7:39	P		
P61-P35	11/12/10	22	30	7:36	30	7:41	P		
P61-P36	11/12/10	22	30	7:37	30	7:42	P		
P61-P37	11/12/10	22	30	7:40	30	7:45	P		
P61-P38	11/12/10	22	30	7:41	30	7:46	P		
P61-P39	11/12/10	9	30	7:43	30	7:48	P		
P60-P29	11/12/10	7	30	13:40	29	13:45	P		
P60-P29	11/12/10	12	30	13:41	30	13:46	P		
P60-P29	11/12/10	15	30	13:42	29	13:47	P		
P60-P29	11/12/10	6	30	13:43	30	13:48	P		
P60-P29	11/12/10	11	30	13:50	30	13:55	P		
P60-P29	11/12/10	28	30	13:51	30	13:56	P		
P60-P29	11/12/10	23	30	13:52	30	13:57	P		
P60-P42	11/12/10	4	30	1353	29	13:58	P		

CAAW Systems

Seam Destructive Test Summary - Field

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Sample DT#	Seam Number	Date	Mach #/ Welder ID	Description of Sample Location	Peel (ppi)		Shear (ppi)	Results (P/F)	Comments
					Inside	Outside			
DS1	P5-P6	11/9/10	KK/427	WEOS - 85	144	129	189	P	
					126	135	191		
					130	133	187		
DS2	P10-P9	11/10/10	KK/427	EEOS - 22	125	119	197	P	
					133	122	186		
					125	129	190		
DS3	P27-P26	11/10/10	KS/1	WEOS - 13	124	136	182	P	
					118	128	169		
					129	122	188		
DS4	P44-P45	11/11/10	KS/1	WEOS - 10	128	136	178	P	
					122	118	189		
					123	131	180		
DS5	P9-P52	11/11/10	KS/1	SEOS - 5	134	128	182	P	
					125	134	182		
					136	127	188		

CAAW Systems

Repair Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Repair Number	Repair Date	Operator/ Mach #	Seam # OR Panel #	Repair Location	Description (patch, bead, ext weld, cap, DT, boot)	Size of Repair	Date Vacuum Tested	Vac. Test Results
1	11/10/10	VK/43	P14	NEOP - 2 X EEOP - 6	BOOT	4X4	11/12/10	P
2	11/10/10	VK/43	P14-P13	INT OF 13-14-17	PATCH	2X2	11/12/10	P
3	11/10/10	VK/43	P16-P17	INT OF 16-17-14	PATCH	2X2	11/12/10	P
4	11/10/10	VK/43	P15-P16	INT OF 15-16-14	PATCH	2X2	11/12/10	P
5	11/10/10	VK/43	P17-P18	SEOS - 0	PATCH	7X4	11/12/10	P
6	11/10/10	VK/43	P18-P17	NEOS - 0	PATCH	5X10	11/12/10	P
7	11/10/10	VK/43	P18-P19	SEOS - 0	PATCH	6X4	11/12/10	P
8	11/10/10	VP/13	P19-P13	EEOS - 0	PATCH	37X3	11/12/10	P
9	11/10/10	VP/13	P22-P21	INT OF 21-22-23-24	PATCH	2X2	11/12/10	P
10	11/10/10	VP/13	P20-P21	INT OF 21-20-24	PATCH	2X2	11/12/10	P
11	11/10/10	VP/13	P24-P25	INT OF 24-25-20	PATCH	2X2	11/12/10	P
12	11/10/10	VP/13	P25-P26	INT OF 25-26-13-12	PATCH	2X2	11/12/10	P
13	11/10/10	VP/13	P26-P27	INT OF 26-27-11-12	PATCH	2X2	11/12/10	P
14	11/11/10	VK/43	P9	WEOP - 41 X NEOP - 3	BOOT	4X4	11/12/10	P
15	11/11/10	VK/43	P5	WEOP - 41 X SEOP - 3	BOOT	4X4	11/12/10	P
16	11/11/10	VK/43	P33-P34	NEOS - 0	BOOT	4X7	11/12/10	P
17	11/11/10	VK/43	P34-P35	INT OF 34-35-61	PATCH	1X1	11/12/10	P
18	11/11/10	VK/43	P35-P36	INT OF 35-36-61	PATCH	1X1	11/12/10	P
19	11/12/10	KS/239	P51-P54	WEOS - 0	PATCH	2X20	11/15/10	P
20	11/12/10	KS/239	P9-P52	SEOS - 5 DS5	DT	2X4	11/15/10	P
21	11/12/10	KS/239	P26-P27	WEOS - 13 DS3	DT	2X4	11/15/10	P
22	11/12/10	KS/239	P51-P50	INT OF 51-50-52	PATCH	2X2	11/15/10	P

CAAW Systems

Repair Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Repair Number	Repair Date	Operator/ Mach #	Seam # OR Panel #	Repair Location	Description (patch, bead, ext weld, cap, DT, boot)	Size of Repair	Date Vacuum Tested	Vac. Test Results
23	11/12/10	VP/13	P33-P32	INT OF 33-32-31	PATCH	2X2	11/15/10	P
24	11/12/10	VP/13	P31-P30	INT OF 30-31-33	PATCH	2X2	11/15/10	P
25	11/12/10	VP/13	P30-P31	WEOS - 4	PATCH	2X2	11/15/10	P
26	11/12/10	VP/13	P29	WEOP - 41 X SEOP - 3	BOOT	4X4	11/15/10	P
27	11/12/10	VP/13	P29-P30	INT OF 29-30-60	PATCH	2X2	11/15/10	P
28	11/12/10	VP/13	P60-P29	WEOS - 7	PATCH	2X2	11/15/10	P
29	11/12/10	VP/13	P60-P29	WEOS - 19	PATCH	2X2	11/15/10	P
30	11/12/10	VP/13	P60-P29	WEOS - 39	PATCH	2X2	11/15/10	P
31	11/12/10	VP/13	P60-P29	WEOS - 45	PATCH	2X2	11/15/10	P
32	11/12/10	VP/13	P33-P34	SEOS - 0	PATCH	4X15	11/15/10	P
33	11/12/10	VK/43	P30-P33	INT OF R32-30-33	PATCH	2X2	11/15/10	P
34	11/12/10	VK/43	P61-P34	INT OF 60-34-R32	PATCH	2X2	11/15/10	P
35	11/12/10	VK/43	P36-P37	INT OF 36-37-61	PATCH	2X2	11/15/10	P
36	11/12/10	VK/43	P37-P60	WEOS - 5	PATCH	2X2	11/15/10	P
37	11/12/10	VK/43	P37-P38	INT OF 37-38-61	PATCH	2X2	11/15/10	P
38	11/12/10	VK/43	P38-P61	WEOS - 9	PATCH	2X2	11/15/10	P
39	11/12/10	VK/43	P38-P39	INT OF 38-39-61	PATCH	2X2	11/15/10	P
40	11/12/10	VK/43	P38-P61	WEOS - 4	PATCH	2X2	11/15/10	P
41	11/15/10	VK/43	P39-P40	INT OF 39-40-41	PATCH	2X2	11/15/10	P
42	11/15/10	VK/43	P39-P41	INT OF 39-41-61	PATCH	2X2	11/15/10	P
43	11/15/10	VP/13	P1-P2	INT OF 1-2-52	PATCH	2X2	11/15/10	P
44	11/15/10	VP/13	P2-P3	INT OF 2-3-52	PATCH	2X2	11/15/10	P

CAAW Systems

Repair Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Repair Number	Repair Date	Operator/ Mach #	Seam # OR Panel #	Repair Location	Description (patch, bead, ext weld, cap, DT, boot)	Size of Repair	Date Vacuum Tested	Vac. Test Results
45	11/15/10	VP/13	P3-P4	INT OF 3-4-52	PATCH	2X2	11/15/10	P
46	11/15/10	VP/13	P4-P5	INT OF 4-5-52	PATCH	2X2	11/15/10	P
47	11/15/10	VP/13	P5-P6	INT OF 5-6-52	PATCH	2X2	11/15/10	P
48	11/15/10	VP/13	P6-P7	INT OF 6-7-52	PATCH	2X2	11/15/10	P
49	11/15/10	VP/13	P7-P8	INT OF 7-8-52	PATCH	2X2	11/15/10	P
50	11/15/10	VP/13	P8-P9	INT OF 8-9-52	PATCH	2X2	11/15/10	P
51	11/15/10	VP/13	P9-P10	INT OF 9-10-52	PATCH	2X2	11/15/10	P
52	11/15/10	VP/13	P10-P11	INT OF 10-11-52-27	PATCH	2X2	11/15/10	P
53	11/15/10	VP/13	P5-P6	WEOS - 85 DS1	DT	2X4	11/15/10	P
54	11/15/10	VP/13	P9-P10	EEOS - 22 DS2	DT	2X4	11/15/10	P
55	11/15/10	VK/43	P35	NEOP - 11	PATCH	11X2	11/15/10	P
56	11/15/10	VK/43	P42	EEOP - 44 X SEOP - 3	BOOT	4X4	11/15/10	P
57	11/15/10	VK/43	P43	NEOP - 8 X EEOP - 6	BOOT	5X6	11/15/10	P
58	11/15/10	VK/43	P60-P29	INT OF 29-60-42	PATCH	2X2	11/15/10	P
59	11/15/10	VK/43	P60-P29	EEOS - 23	PATCH	2X2	11/15/10	P
60	11/15/10	VK/43	P60-P42	WEOS - 4	PATCH	2X2	11/15/10	P
61	11/15/10	VK/43	P60-P42	WEOS - 24	PATCH	2X2	11/15/10	P
62	11/15/10	VK/43	P42-P43	INT OF 42-43-29-28	PATCH	2X2	11/15/10	P
63	11/15/10	VK/43	P43-P44	INT OF 43-44-28	PATCH	2X2	11/15/10	P
64	11/15/10	VK/43	P44-P28	INT OF 44-28-52	PATCH	2X2	11/15/10	P
65	11/15/10	VK/43	P44-P45	INT OF 44-45-52	PATCH	2X2	11/15/10	P
66	11/15/10	VK/43	P44-P45	WEOS - 10 DS4	DT	2X4	11/15/10	P

CAAW Systems

Repair Summary

Project Name: Powerton - Metal Cleaning Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Repair Number	Repair Date	Operator/ Mach #	Seam # OR Panel #	Repair Location	Description (patch, bead, ext weld, cap, DT, boot)	Size of Repair	Date Vacuum Tested	Vac. Test Results
67	11/15/10	VK/43	P45-P46	INT OF 45-46-52	PATCH	2X2	11/15/10	P
68	11/15/10	VK/43	P46-P47	INT OF 46-47-52	PATCH	2X2	11/15/10	P
69	11/15/10	VK/43	P47-P48	INT OF 47-48-52	PATCH	2X2	11/15/10	P
70	11/15/10	VK/43	P48-P49	INT OF 48-49-52	PATCH	2X2	11/15/10	P
71	11/15/10	VK/43	P49	EEOP - 41 X SEOP - 3	BOOT	4X4	11/15/10	P
72	11/15/10	VK/43	P49-P50	INT OF 49-50-52	PATCH	2X2	11/15/10	P
73	11/15/10	VK/43	P51-P53	EEOS - 3	PATCH	1X1	11/15/10	P
74	11/15/10	VK/43	P53-P56	WEOS - 0	PATCH	1X1	11/15/10	P
75	11/15/10	VK/43	P56-P57	WEOS - 0	PATCH	1X1	11/15/10	P
76	11/15/10	VK/43	P54-P51	WEOS - 18	BOOT	4X4	11/15/10	P
77	11/15/10	VK/43	P27-P26	EEOS - 0	PATCH	2X2	11/15/10	P
78	11/15/10	VK/43	P26-P25	EEOS - 0	PATCH	1X1	11/15/10	P
79	11/15/10	VP/13	P1-P2	WEOS - 4	PATCH	1X1	11/15/10	P
80	11/15/10	VP/13	P2-P3	WEOS - 4	PATCH	2X2	11/15/10	P
81	11/15/10	VP/13	P5-P6	WEOS - 5	PATCH	1X1	11/15/10	P

CAAW Systems Field QC Information

Project Name:	Powerton - Bypass Pond
Project Number:	201044
Location:	Pekin, Il
QC Monitor:	Seng
Mat	60 mil HDTW

CAAW Systems

Trial Weld Testing Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Sample TW#	Date	Ambient Temp	Time (AM/PM)	Machine Number	Seamer Initials	Extrusion Temp	Fusion Temp/Speed	Peel (ppi)		Shear (ppi)	Results (P/F)	Comments
								Inside	Outside			
1	11/17/10	52	8:45	428	HN	Barrel	Wedge	124	131	178	P	
							850	119	129	185		
						Preheat	Speed	122	126	192		
							500					
2	11/17/10	52	8:48	1	KS	Barrel	Wedge	133	125	178	P	
							850	121	132	188		
						Preheat	Speed	129	139	185		
							300					
3	11/17/10	52	8:42	427	KK	Barrel	Wedge	121	138	192	P	
							850	123	132	186		
						Preheat	Speed	119	111	194		
							500					
4	11/17/10	52	13:15	428	HN	Barrel	Wedge	120	128	177	P	
							850	115	136	182		
						Preheat	Speed	129	121	175		
							500					
5	11/17/10	52	13:08	427	KK	Barrel	Wedge	118	128	189	P	
							850	126	130	184		
						Preheat	Speed	122	128	181		
							500					

CAAW Systems

Trial Weld Testing Summary

Project Name: Powerton - Bypass Pond QC Monitor: Seng

Project Number: 201044 Material: 60 mil HDTW

Sample TW#	Date	Ambient Temp	Time (AM/PM)	Machine Number	Seamer Initials	Extrusion Temp	Fusion Temp/Speed	Peel (ppi)		Shear (ppi)	Results (P/F)	Comments
								Inside	Outside			
6	11/17/10	52	13:11	1	KS	Barrel	Wedge	125	125	186	P	
							850	129	138	186		
						Preheat	Speed	133	124	190		
							300					
1	11/18/10	48	7:30	13	VP	Barrel	Wedge	115		168	P	
						550		98		177		
						Preheat	Speed	105		168		
						500						
2	11/18/10	48	7:35	43	VK	Barrel	Wedge	127		158	P	
						525		115		167		
						Preheat	Speed	115		166		
						485						
3	11/18/10	48	13:15	43	VK	Barrel	Wedge	118		172	P	
						525		108		178		
						Preheat	Speed	120		174		
						485						
4	11/18/10	48	13:21	13	VP	Barrel	Wedge	116		175	P	
						550		105		171		
						Preheat	Speed	102		174		
						500						

CAAW Systems

Trial Weld Testing Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Sample TW#	Date	Ambient Temp	Time (AM/PM)	Machine Number	Seamer Initials	Extrusion Temp	Fusion Temp/Speed	Peel (ppi) Inside	Peel (ppi) Outside	Shear (ppi)	Results (P/F)	Comments
5	11/18/10	48	13:10	428	HN	Barrel	Wedge	124		168	P	
							850	122		170		
						Preheat	Speed	130		170		
							500					
						Barrel	Wedge					
						Preheat	Speed					
						Barrel	Wedge					
						Preheat	Speed					
						Barrel	Wedge					
						Preheat	Speed					
						Barrel	Wedge					
						Preheat	Speed					

CAAW Systems

Panel Placement Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Panel Number	Date	Time (am/pm)	Roll Number	Type S or T	Final Width (Feet)	Final Length (Feet)	Final Area (Sq. Ft.)	Comments
P1	11/17/10		6449	T	22	51	1,122	
P2	11/17/10		6449	T	22	51	1,122	
P3	11/17/10		6449	T	22	51	1,122	
P4	11/17/10		6449	T	22	51	1,122	
P5	11/17/10		6449	T	22	51	1,122	
P6	11/17/10		6449	T	22	51	1,122	
P7	11/17/10		6449	T	22	51	1,122	
P8	11/17/10		6446	T	22	48	537	
P9	11/17/10		6446	T	15	30	177	
P10	11/17/10		6446	T	22	43	773	
P11	11/17/10		6446	T	6	12	32	
P12	11/17/10		6446	T	22	199	4,378	
P13	11/17/10		6446	T	22	221	4,862	
P14	11/17/10		6445	T	22	46	865	
P15	11/17/10		6445	T	22	32	521	
P16	11/17/10		6445	T	22	61	1,342	
P17	11/17/10		6445	T	16	17	122	
P18	11/17/10		6445	T	22	44	968	
P19	11/17/10		6445	T	18	44	394	
P20	11/17/10		6445	T	10	24	240	

CAAW Systems

Panel Placement Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Panel Number	Date	Time (am/pm)	Roll Number	Type S or T	Final Width (Feet)	Final Length (Feet)	Final Area (Sq. Ft.)	Comments
P21	11/17/10		6445	T	22	35	649	
P22	11/17/10		6445	T	22	47	1,034	
P23	11/17/10		6445	T	22	51	1,122	
P24	11/17/10		6445	T	22	31	668	
P25	11/17/10		6445	T	4	14	56	
P26	11/17/10		6445	T	22	79	1,738	
P27	11/17/10		6448	T	22	130	2,860	
P28	11/17/10		6448	T	22	48	1,056	
P29	11/17/10		6448	T	22	53	1,166	
P30	11/17/10		6448	T	22	56	1,232	
P31	11/17/10		6448	T	22	57	1,254	
P32	11/17/10		6448	T	22	60	1,320	
P33	11/17/10		6448	T	22	60	1,320	
P34	11/17/10		6448	T	22	27	594	
P35	11/17/10		6450	T	22	33	726	
P36	11/17/10		6450	T	22	57	1,254	
P37	11/17/10		6450	T	22	23	506	
P38	11/17/10		6445	T	22	23	393	
P39	11/17/10		6445	T	9	11	99	

CAAW Systems

Panel Seaming Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Seamed	Final Seam Length (feet)	Welder Initials	Weld Type Ext / Wedge	Machine Number	Machine Temp/ Speed/ Preheat	Time Start	Time Stop	Ambient Temp (°F)	End of Seam Destructive Test (P/F)	Comments
P1-P2	11/17/10	51	KS	W	1	850/300	9:30				
P2-P3	11/17/10	51	HN	W	428	850/500	9:32				
P3-P4	11/17/10	51	KK	W	427	850/500	9:35				
P4-P5	11/17/10	51	KS	W	1	850/300	9:45				
P5-P6	11/17/10	50	KK	W	427	850/500	9:45				
P6-P7	11/17/10	49	HN	W	428	850/500	9:43				
P7-P8	11/17/10	48	KK	W	427	850/500	10:10				
P8-P9	11/17/10	30	HN	W	428	850/500	10:10				
P9-P10	11/17/10	17	HN	W	428	850/500	10:35				
P10-P11	11/17/10	12	HN	W	428	850/500	10:35				
P10-P12	11/17/10	43	KS	W	1	850/300	11:06				
P9-P11	11/17/10	11	HN	W	428	850/500	10:35				
P10-P8	11/17/10	13	HN	W	428	850/500	10:35				
P12-P13	11/17/10	199	HN	W	428	850/500	10:38				
P12-P1	11/17/10	22	KS	W	1	850/300	10:45				
P12-P2	11/17/10	P	KS	W	1	850/300	10:48				
P12-P3	11/17/10	22	KS	W	1	850/300	10:51				
P12-P4	11/17/10	22	KS	W	1	850/300	10:54				
P12-P5	11/17/10	22	KS	W	1	850/300	10:57				

CAAW Systems

Panel Seaming Summary

Project Name: Powerton - Bypass Pond | QC Monitor: Seng

Project Number: 201044 | Material: 60 mil HDTW

Seam Number	Date Seamed	Final Seam Length (feet)	Welder Initials	Weld Type Ext / Wedge	Machine Number	Machine Temp/ Speed/ Preheat	Time		Ambient Temp (°F)	End of Seam Destructive Test (P/F)	Comments
							Start	Stop			
P12-P6	11/17/10	22	KS	W	1	850/300	11:00				
P12-P7	11/17/10	22	KS	W	1	850/300	11:03				
P16-P13	11/17/10	61	KS	W	1	850/300	11:19				
P16-P27	11/17/10	22	KK	W	427	850/500	14:25				
P27-P13	11/17/10	130	KK	W	427	850/500	14:29				
P13-P26	11/17/10	29	KK	W	427	850/500	14:29				
P26-P27	11/17/10	22	KS	W	1	850/300	14:05				
P28-P29	11/17/10	48	HN	W	428	850/500	14:34				
P29-P30	11/17/10	53	HN	W	428	850/500	14:26				
P30-P31	11/17/10	56	HN	W	428	850/500	15:00				
P31-P32	11/17/10	57	KK	W	427	850/500	15:00				
P32-P33	11/17/10	60	KK	W	427	850/500	15:10				
P34-P33	11/17/10	27	HN	W	428	850/500	15:16				
P33-P35	11/17/10	33	HN	W	428	850/500	15:16				
P34-P35	11/17/10	22	HN	W	428	850/500	15:13				
P36-P34	11/17/10	24	HN	W	428	850/500	15:33				
P35-P36	11/17/10	33	HN	W	428	850/500	15:33				
P25-P16	11/17/10	14	KK	W	427	850/500	16:02				
P28-P27	11/17/10	19	KK	W	427	850/500	15:30				

CAAW Systems

Panel Seaming Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Seamed	Final Seam Length (feet)	Welder Initials	Weld Type Ext / Wedge	Machine Number	Machine Temp/ Speed/ Preheat	Time		Ambient Temp (°F)	End of Seam Destructive Test (P/F)	Comments
							Start	Stop			
P29-P27	11/17/10	22	KK	W	427	850/500	15:33				
P30-P27	11/17/10	22	KK	W	427	850/500	15:36				
P31-P27	11/17/10	22	KK	W	427	850/500	15:39				
P32-P27	11/17/10	22	KK	W	427	850/500	15:42				
P33-P27	11/17/10	22	KK	W	427	850/500	15:45				
P35-P26	11/17/10	19	KK	W	427	850/500	15:48				
P36-P26	11/17/10	22	KK	W	427	850/500	15:51				
P37-P26	11/17/10	27	KK	W	427	850/500	15:56				
P16-P15	11/17/10	32	HN	W	428	850/500	11:21				
P15-P17	11/17/10	17	KS	W	1	850/300	11:35				
P15-P14	11/17/10	22	HN	W	428	850/500	11:38				
P14-P17	11/17/10	16	HN	W	428	850/500	11:38				
P26-P23	11/17/10	51	KK	W	427	850/500					
P23-P22	11/17/10	51	KK	W	427	850/500	13:35				
P22-P21	11/17/10	35	HN	W	428	850/500	13:47				
P22-P18	11/17/10	12	HN	W	428	850/500	13:47				
P21-P20	11/17/10	24	HN	W	428	850/500	13:32				
P20-P19	11/17/10	20	KS	W	1	850/300	13:39				
P18-P19	11/17/10	44	KS	W	1	850/300	13:25				

CAAW Systems

Panel Seaming Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Seamed	Final Seam Length (feet)	Welder Initials	Weld Type Ext / Wedge	Machine Number	Machine Temp/ Speed/ Preheat	Time Start	Time Stop	Ambient Temp (°F)	End of Seam Destructive Test (P/F)	Comments
P21-P19	11/17/10	23	KS	W	1	850/300	13:29				
P18-P24	11/17/10	13	KK	W	427	850/500	14:10				
P22-P24	11/17/10	22	KS	W	1	850/300	13:50				
P23-P13	11/17/10	22	KS	W	1	850/300	13:50				
P24-P13	11/17/10	22	KS	W	1	850/300	13:50				
P24-P12	11/17/10	22	KS	W	1	850/300	13:50				
P24-P1	11/17/10	9	KS	W	1	850/300	13:50				
P37-P38	11/18/10	23	HN	W	428	850/500	13:27				
P38-P39	11/18/10	11	HN	W	428	850/500	13:30				
P38-P36	11/18/10	22	HN	W	428	850/500	1333				
P39-P36	11/18/10	9	HN	W	428	850/500	13:36				

CAAW Systems

Non-Destructive Test Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Tested	Location / Seam Length Tested	Air				Air Test Results (P/F)	Vacuum	Comments
			Air Pressure					Vac. Test Results (P/F)	
			Start		End				
			PSI	Time	PSI	Time			
P1-P2	11/17/10	51	30	10:00	30	10:05	P		
P2-P3	11/17/10	51	30	10:01	30	10:06	P		
P3-P4	11/17/10	51	30	10:02	30	10:07	P		
P4-P5	11/17/10	51	30	10:07	30	10:12	P		
P5-P6	11/17/10	50	30	10:10	30	10:15	P		
P6-P7	11/17/10	49	30	10:11	30	10:16	P		
P7-P8	11/17/10	48	30	11:00	30	11:05	P		
P8-P9	11/17/10	30	30	11:02	30	11:07	P		
P9-P10	11/17/10	17	30	11:01	30	11:06	P		
P10-P11	11/17/10	12	30	11:03	30	11:08	P		
P10-P12	11/17/10	43	30	11:43	30	11:48	P		
P9-P11	11/17/10	11	30	11:04	30	11:09	P		
P10-P8	11/17/10	13	30	11:01	30	11:06	P		
P12-P13	11/17/10	199	30	11:30	30	11:35	P		
P12-P1	11/17/10	22	30	11:31	30	11:36	P		
P12-P2	11/17/10	P	30	11:32	29	11:37	P		
P12-P3	11/17/10	22	30	11:33	30	11:38	P		
P12-P4	11/17/10	22	30	11:34	30	11:39	P		
P12-P5	11/17/10	22	30	11:40	29	11:45	P		
P12-P6	11/17/10	22	30	11:41	30	11:46	P		
P12-P7	11/17/10	22	30	11:42	30	11:47	P		

CAAW Systems

Non-Destructive Test Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Tested	Location / Seam Length Tested	Air					Vacuum	Comments
			Air Pressure				Air Test Results (P/F)	Vac. Test Results (P/F)	
			Start		End				
			PSI	Time	PSI	Time			
P16-P13	11/18/10	61	30	9:29	30	9:34	P		
P16-P27	11/18/10	22	30	9:29	29	9:34	P		
P27-P13	11/18/10	130	30	9:27	30	9:32	P		
P13-P26	11/18/10	29	30	9:28	30	9:33	P		
P26-P27	11/18/10	22	30	9:28	30	9:33	P		
P28-P29	11/18/10	48	30	9:42	28	9:47	P		
P29-P30	11/18/10	53	30	9:46	30	9:51	P		
P30-P31	11/18/10	56	30	9:50	30	9:55	P		
P31-P32	11/18/10	57	30	9:51	30	9:56	P		
P32-P33	11/18/10	60	30	10:09	30	10:14	P		
P34-P33	11/18/10	27	30	10:11	29	10:16	P		
P33-P35	11/18/10	33	30	10:10	30	10:15	P		
P34-P35	11/18/10	22	30	10:12	30	10:17	P		
P36-P34	11/18/10	24	30	10:18	29	10:23	P		
P35-P36	11/18/10	33	30	10:17	30	10:22	P		
P25-P16	11/18/10	14	30	13:12	30	13:17	P		
P28-P27	11/18/10	19	30	9:40	29	9:45	P		
P29-P27	11/18/10	22	30	9:42	29	9:47	P		
P30-P27	11/18/10	22	30	9:47	30	9:52	P		
P31-P27	11/18/10	22	30	9:51	28	9:56	P		
P32-P27	11/18/10	22	30	9:54	30	9:59	P		

CAAW Systems

Non-Destructive Test Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Tested	Location / Seam Length Tested	Air					Vacuum	Comments
			Air Pressure				Air Test Results (P/F)	Vac. Test Results (P/F)	
			Start		End				
			PSI	Time	PSI	Time			
P33-P27	11/18/10	22	30	10:09	30	10:14	P		
P35-P26	11/18/10	19	30	10:22	30	10:27	P		
P36-P26	11/18/10	22	30	10:23	30	10:28	P		
P37-P26	11/18/10	27	30	10:24	30	10:29	P		
P16-P15	11/18/10	32	30	9:33	29	9:38	P		
P15-P17	11/18/10	17	30	9:34	30	9:39	P		
P15-P14	11/18/10	22	30	9:35	30	9:40	P		
P14-P17	11/18/10	16	30	9:36	30	9:41	P		
P26-P23	11/18/10	51	30	9:28	30	9:33	P		
P23-P22	11/18/10	51	30	9:08	29	9:13	P		
P22-P21	11/17/10	35	30	14:26	30	14:31	P		
P22-P18	11/17/10	12	30	14:27	30	14:32	P		
P21-P20	11/17/10	24	30	14:28	29	14:33	P		
P20-P19	11/17/10	20	30	14:29	30	14:34	P		
P18-P19	11/17/10	44	30	14:35	30	14:39	P		
P21-P19	11/17/10	23	30	14:22	30	14:27	P		
P18-P24	11/17/10	13	30	14:36	30	14:31	P		
P22-P24	11/18/10	22	30	9:07	30	9:12	P		
P23-P13	11/18/10	22	30	9:27	30	9:32	P		
P24-P13	11/18/10	22	30	9:13	29	9:18	P		
P24-P12	11/18/10	22	30	9:15	30	9:20	P		

CAAW Systems

Non-Destructive Test Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Seam Number	Date Tested	Location / Seam Length Tested	Air					Vacuum	Comments
			Air Pressure				Air Test Results (P/F)	Vac. Test Results (P/F)	
			Start		End				
			PSI	Time	PSI	Time			
P24-P1	11/18/10	9	30	9:16	30	9:21	P		
P37-P38	11/18/10	23	30	13:38	30	13:43	P		
P38-P39	11/18/10	11	30	13:40	30	13:45	P		
P38-P36	11/18/10	22	30	13:39	29	13:44	P		
P39-P36	11/18/10	9	30	13:44	30	13:49	P		

CAAW Systems

Seam Destructive Test Summary - Field

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Sample DT#	Seam Number	Date	Mach #/ Welder ID	Description of Sample Location	Peel (ppi)		Shear (ppi)	Results (P/F)	Comments
					Inside	Outside			
DS1	P12-P7	11/17/10	KS/1	WEOS - 11	124	135	185	P	
					129	133	188		
					127	138	182		
DS2	P35-P26	11/17/10	KK/427	WEOS 11	164	139	188	P	
					135	142	189		
					138	144	193		

CAAW Systems

Repair Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Repair Number	Repair Date	Operator/ Mach #	Seam # OR Panel #	Repair Location	Description (patch, bead, ext weld, cap, DT, boot)	Size of Repair	Date Vacuum Tested	Vac. Test Results
1	11/18/10	VK/43	P1-P2	INT OF 1-2-12	PATCH	2X2	11/19/10	P
2	11/18/10	VK/43	P2-P3	INT OF 2-3-12	PATCH	2X2	11/19/10	P
3	11/18/10	VK/43	P3-P4	INT OF 3-4-12	PATCH	2X2	11/19/10	P
4	11/18/10	VK/43	P4-P5	INT OF 4-5-12	PATCH	2X2	11/19/10	P
5	11/18/10	VK/43	P5-P6	INT OF 5-6-12	PATCH	2X2	11/19/10	P
6	11/18/10	VK/43	P6-P7	INT OF 6-7-12	PATCH	2X2	11/19/10	P
7	11/18/10	VK/43	P7-P12	SEOS - 11 DS1	DT	2X3	11/19/10	P
8	11/18/10	VK/43	P10-P12	INT OF 7-10-12	PATCH	2X3	11/19/10	P
9	11/18/10	VK/43	P8-P9	INT OF 8-9-10	PATCH	2X2	11/19/10	P
10	11/18/10	VK/43	P9-P11	INT OF 9-10-11	PATCH	2X2	11/19/10	P
11	11/18/10	VK/43	P10	NEOP - 3 X EEOP - 4	BOOT	4X4	11/19/10	P
12	11/18/10	VK/43	P5	NEOP - 5 X EEOP - 10	BOOT	4X4	11/19/10	P
13	11/18/10	VK/43	P16-P15	INT OF 15-16-14	PATCH	2X2	11/19/10	P
14	11/18/10	VK/43	P15-P17	INT OF 14-15-17	PATCH	2X2	11/19/10	P
15	11/18/10	VK/43	P28-P14	EEOS - 0	PATCH	3X9	11/19/10	P
16	11/18/10	VK/43	P16	SEOP - 37 X EEOP - 3	BOOT	4X4	11/19/10	P
17	11/18/10	VK/43	P25-P16	INT OF 16-25-28-27	PATCH	2X2	11/19/10	P
18	11/18/10	VK/43	P16-P13	INT OF 13-16-27	PATCH	2X2	11/19/10	P
19	11/18/10	VK/43	P28-P29	INT OF 27-28-29	PATCH	2X2	11/19/10	P
20	11/18/10	VK/43	P29	WEOP - 11 X SEOP - 1	BOOT	4X4	11/19/10	P
21	11/18/10	VK/43	P28-P29	WEOS - 19	PATCH	2X2	11/19/10	P
22	11/18/10	VK/43	P28-P29	EEOS - 3	PATCH	2X2	11/19/10	P

CAAW Systems

Repair Summary

Project Name: Powerton - Bypass Pond | QC Monitor: Seng

Project Number: 201044 | Material: 60 mil HDTW

Repair Number	Repair Date	Operator/ Mach #	Seam # OR Panel #	Repair Location	Description (patch, bead, ext weld, cap, DT, boot)	Size of Repair	Date Vacuum Tested	Vac. Test Results
23	11/18/10	VP/13	P29-P30	INT OF 29-30-27	PATCH	2X2	11/19/10	P
24	11/18/10	VP/13	P30	SEOP - 6 X WEOP - 2	BOOT	4X4	11/19/10	P
25	11/18/10	VP/13	P30-P31	INT OF 27-30-31	PATCH	2X2	11/19/10	P
26	11/18/10	VP/13	P31-P32	INT OF 27-31-32	PATCH	2X2	11/19/10	P
27	11/18/10	VP/13	P31	NEOP - 4 X WEOP - 11	BOOT	4X4	11/19/10	P
28	11/18/10	VP/13	P32-P33	INT OF 27-32-33	PATCH	2X2	11/19/10	P
29	11/18/10	VP/13	P33-P34	INT OF 33-34-35	PATCH	2X2	11/19/10	P
30	11/18/10	VP/13	P33-P35	INT OF 27-26-33-35	PATCH	4X2	11/19/10	P
31	11/18/10	VP/13	P35-P36	INT OF 26-35-36	PATCH	2X2	11/19/10	P
32	11/18/10	VP/13	P35-P36	INT OF 34-35-36	PATCH	2X2	11/19/10	P
33	11/18/10	VP/13	P36	WEOP - 4 X SEOP - 11	BOOT	4X4	11/19/10	P
34	11/18/10	VP/13	P36-P37	INT OF 26-36-37	PATCH	2X2	11/19/10	P
35	11/18/10	VP/13	P26-P37	SEOS - 27	BOOT	5X5	11/19/10	P
36	11/18/10	VP/13	P26-P35	SEOS - 11 DS2	DT	2X3	11/19/10	P
37	11/18/10	VP/13	P37-P38	INT OF 37-38-36	PATCH	2X2	11/19/10	P
38	11/18/10	VP/13	P38-P39	INT OF 38-39-36	PATCH	2X2	11/19/10	P
39	11/18/10	VP/13	P13-P26	INT OF 13-26-27	PATCH	2X2	11/19/10	P
40	11/18/10	VP/13	P23-P26	INT OF 26-23-13	PATCH	2X2	11/19/10	P
41	11/18/10	VP/13	P23-P22	INT OF 22-23-13-24	PATCH	2X2	11/19/10	P
42	11/18/10	VP/13	P13-P12	INT OF 12-13-24	PATCH	2X2	11/19/10	P
43	11/18/10	VP/13	P1-P12	INT OF 1-12-24	PATCH	2X2	11/19/10	P
44	11/18/10	VP/13	P18-P22	INT OF 18-22-24	PATCH	2X2	11/19/10	P

CAAW Systems

Repair Summary

Project Name: Powerton - Bypass Pond

QC Monitor: Seng

Project Number: 201044

Material: 60 mil HDTW

Repair Number	Repair Date	Operator/ Mach #	Seam # OR Panel #	Repair Location	Description (patch, bead, ext weld, cap, DT, boot)	Size of Repair	Date Vacuum Tested	Vac. Test Results
45	11/18/10	VP/13	P18-P19	INT OF 18-19-21-22	PATCH	2X2	11/19/10	P
46	11/18/10	VP/13	P19-P21	SWEOS - 11	PATCH	2X2	11/19/10	P
47	11/18/10	VP/13	P19-P20	INT OF 19-20-21	PATCH	2X2	11/19/10	P
48	11/18/10	VP/13	P18	EEOP - 1 X SEOP X 9	BOOT	4X4	11/19/10	P

ATTACHMENT A8

GEOMEMBRANE INSTALLER’S SUBGRADE ACCEPTANCE

CERTIFICATE OF ACCEPTANCE OF SUBGRADE SURFACE PREPARATION FOR GEOMEMBRANE INSTALLATION

PROJECT NAME: Powerton Generating Station

LOCATION: Pekin, IL

JOB NUMBER: 201044 CLIENT: Otto Baum Company, Inc.

AREA ACCEPTED: Entire area of the Metals Cleaning Pond

COMMENTS: ______________________________

INSTALLER: The undersigned authorized representative of CAAW Systems certifies that he or she has visually inspected the subgrade surface of the area described above and has found the surface to be acceptable for installation of the geosynthetic materials.

CAAW Systems shall be responsible for the integrity of finished geosynthetic material until completion of the installation or demobilization from site.

This certification is based on observations of the subgrade surface conditions only. CAAW Systems has made no sub-terrain inspections or tests and makes no representations or warranties as to the conditions that may exist below the surface of the subgrade.

CERTIFICATE APPROVED BY:

Installers Acceptance		Inspectors Acceptance	
Company:	Clean Air And Water Systems, LLC	Company:	Otto Baum
By:	Thong Ingels	By:	Dave Stewart
Title:	Superintendent	Title:	Foreman
Date:	11/16/10	Date:	11/16/10

CERTIFICATE OF ACCEPTANCE OF SUBGRADE SURFACE PREPARATION FOR GEOMEMBRANE INSTALLATION

PROJECT NAME: Powerton Generating Station

LOCATION: Pekin, IL

JOB NUMBER: 201044 CLIENT: Otto Baum Company, Inc.

AREA ACCEPTED: Entire area of the Bypass Pond

COMMENTS:

INSTALLER: The undersigned authorized representative of CAAW Systems certifies that he or she has visually inspected the subgrade surface of the area described above and has found the surface to be acceptable for installation of the geosynthetic materials.

CAAW Systems shall be responsible for the integrity of finished geosynthetic material until completion of the installation or demobilization from site.

This certification is based on observations of the subgrade surface conditions only. CAAW Systems has made no sub-terrain inspections or tests and makes no representations or warranties as to the conditions that may exist below the surface of the subgrade.

CERTIFICATE APPROVED BY:

	Installers Acceptance		Inspectors Acceptance
Company:	Clean Air And Water Systems, LLC	Company:	Otto Baum
By:	Thong Ingels	By:	Dave Stewart
Title:	Superintendent	Title:	Foreman
Date:	11/19/10	Date:	11/19/10

ATTACHMENT A9

GEOMEMBRANE INSTALLATION CERTIFICATE

January 11, 2011

Midwest Generation, LLC
Powerton Generating Station
13082 East Manito Road
Pekin, IL 61554-8587

RE: Geosynthetic material installation certification

To Whom It May Concern

The HDPE geomembrane and geotextiles installed in the Metals Cleaning Basin and Bypass Pond were installed in accordance with the project specifications and manufactures recommendations.

Sincerely,

Matt Albert

Matt Albert
Project Estimator
CAAW Systems, LLC.

Corporate Office
123 Elm Street
P.O. Box 337
Dousman, WI. 53118-0337
(262) 965-4366 Fax (262) 965-4369

www.caawsystem.com

Regional Office
2727 W. 2nd St., Ste 235
Hastings, NE 68901
(402) 463-0857 Fax (402) 463-0858

ATTACHMENT A10

GEOMEMBRANE INSTALLATION WARRANTIES

INSTALLATION WARRANTY- GEOMEMBRANE LINERS

PROJECT NAME: Powerton Generating Station

Subject to the terms and conditions set forth below, Clean Air And Water Systems, LLC warrants to Purchaser, _Midwest Generation, LLC_, that the _60 mil HDPE White Textured Geomembrane_ installed in the _Metals Cleaning Basin and Bypass Pond_, was installed by Clean Air And Water Systems, LLC, in accordance with the specifications in a good and workmanlike manner and that the installation of the liner is free from defects in workmanship for a period of two (2) years from the date upon which the material was installed.

This warranty covers only defects in workmanship occurring during the installation of the liner. This warranty does not cover ay damage to, or defects in the liner found to have been a result of misuse, abuse or conditions existing after it was installed, including, but not limited to, rough handling; malicious mischief; vandalism; sabotage; fire; acts of God; acts of the public enemy; acts of war, public rebellion, severe weather conditions of all types; damage due to ice; excessive stress from any source; floating debris; damage due to machinery; foreign objects or animals. Nor does this warranty cover any defects which are found to have been a result of improper or defective design or engineering unless the design or engineering was performed by Clean Air And Water Systems, LLC. In the event circumstances are found to exist which purchaser believes may give rise to a claim under this warranty, the following procedure shall be followed:

a) Purchaser shall give Clean Air And Water Systems, LLC written notice of the facts and circumstances of said claim within ten (10) days of becoming aware of said facts and circumstances. Said notice shall be by registered or certified mail, return receipt requested, postage prepaid, addressed to Member, Clean Air And Water Systems, LLC, 123 Elm Street, PO Box 337, Dousman, Wisconsin 53118. The words "WARRANTY CLAIM" shall be clearly marked on the face of envelope in the lower right hand corner. Said notice shall contain, at a minimum, the name and address of the owner, the name and address of the installation, the name and address of the installer, the date upon which the material was purchased and the facts known to Purchaser upon which the claim is based. Failure to strictly comply with all the requirements of this paragraph shall void this warranty.
b) Within twenty days after receipt of the notice described in paragraph a., above, Clean Air And Water Systems, LLC shall notify Purchaser either that it will send a representative to inspect the allegedly defective liner or that it does not wish to do so. Purchaser shall pay the expenses incurred by Clean Air And Water Systems, LLC in making the inspection, including current per diem rates for personnel involved in making the inspection, in the event Clean Air And Water Systems, LLC determines that the claim is not covered by this warranty.
c) Purchaser SHALL NOT REPAIR, REPLACE, REMOVE, ALTER OR DISTURB ANY LINER, NOR SHALL Purchaser ALLOW ANYONE ELSE TO REPAIR, REPLACE, REMOVE, ALTER, OR DISTURB ANY LINER PRIOR TO SUCH INSPECTION OR RECEIPT OF CLEAN AIR AND WATER SYSTEMS, LLC.'S NOTICE THAT IT ELECTS NOT TO INSPECT. A FAILURE TO STRICTLY COMPLY WITH THIS PARAGRAPH SHALL VOID THIS WARRANTY OR MAY LEAD TO A DETERMINATION THAT THE ALLEGED DEFECTS ARE NOT WITHIN THE SCOPE OF THIS WARRANTY.
d) If Clean Air And Water Systems, LLC determines that the alleged defects are covered by this warranty, Clean Air And Water Systems, LLC shall, in its sole discretion, either repair the defective liner or provide Purchaser with replacement liner. THE REMEDIES PROVIDED HEREIN ARE THE EXCLUSIVE REMEDIES AVAILABLE UNDER THIS WARRANTY. Any determination as to whether a particular defect is covered by this warranty will be made by Clean Air And Water Systems, LLC in its sole and complete discretion.

e) Purchaser agrees that it shall provide Clean Air And Water Systems, LLC with clean, dry and unobstructed access to the liner in order for Clean Air And Water Systems, LLC to perform the inspections and warranty work which may be required pursuant to this warranty.

THE REMEDIES PROVIDED TO Purchaser HEREIN ARE THE EXCLUSIVE REMEDIES AVAILABLE UNDER THIS WARRANTY AND ARE INTENDED FOR THE SOLE BENEFIT OF Purchaser. NEITHER THIS WARRANTY NOR ANY RIGHTS HEREUNDER SHALL BE ASSIGNABLE. CLEAN AIR AND WATER SYSTEMS, LLC SHALL HAVE NO LIABILITY UNDER THIS WARRANTY TO THIRD PARTIES OR STRANGERS TO THIS AGREEMENT. THE WARRANTY SET FORTH ABOVE IS THE ONLY WARRANTY APPLICABLE TO THE LINER AND ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL CLEAN AIR AND WATER SYSTEMS, LLC BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL OR CONSEQUENTIAL DAMAGES FOR, RESULTING FROM, OR IN CONNECTION WITH, ANY LOSS RESULTING FROM THE USE OF THE LINER. IN THE EVENT THE EXCLUSIVE REMEDY PROVIDED HEREIN FAILS IN ITS ESSENTIAL PURPOSE, AND IN THAT EVENT ONLY, Purchaser SHALL BE ENTITLED TO RETURN OF THE PURCHASE PRICE FOR SO MUCH OF THE MATERIAL AS CLEAN AIR AND WATER SYSTEMS, LLC DETERMINES IN ITS SOLE DISCRETION, TO HAVE VIOLATED THE WARRANTY PROVIDED HEREIN. EXCEPT FOR THE WARRANTY SET FORTH ABOVE, NO REPRESENTATION OR WARRANTY MADE BY ANY SALES OR OTHER REPRESENTATIVE CLEAN AIR AND WATER SYSTEMS, LLC, OR ANY OTHER PERSON, CONCERNING THE LINER SHALL BE BINDING UPON CLEAN AIR AND WATER SYSTEMS, LLC.

Any waiver of the terms and conditions of this warranty shall be in writing signed by CLEAN AIR AND WATER SYSTEMS, LLC the failure to insist upon strict compliance with any of the terms and conditions contained herein shall not act as a waiver of strict compliance with all of the remaining terms and conditions or this warranty and shall not operate as a waiver as to any of the terms and conditions of this warranty as to future claims under this warranty.

CLEAN AIR AND WATER SYSTEMS, LLC

BY: Brian McKeown

Brian K. McKeown/ Member

I have read and agree to be bound by the terms and conditions of the foregoing warranty.

By: ______________________________

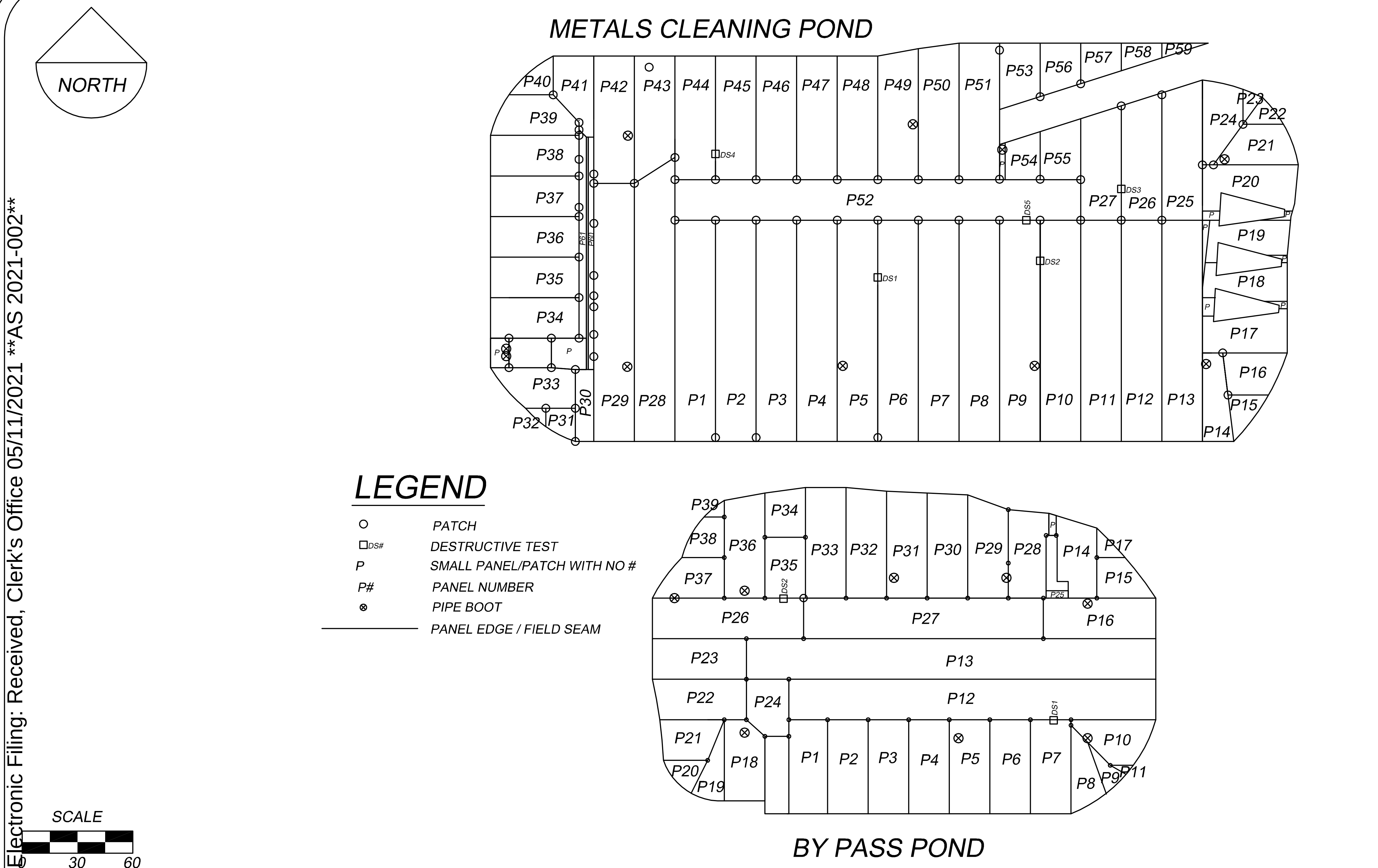
Title: ______________________________

Company: ______________________________

Date: ______________________________

ATTACHMENT A11

GEOMEMBRANE AS-BUILT PANEL LAYOUT



DRAWN BY M.A.			
SCALE 1"=60'			
JOB # 201044			
DATE 12-17-10	#	REVISIONS	DATE

WWW.CAAWSYSTEMS.COM
CLEAN AIR AND WATER SYSTEMS, LLC
123 ELM STREET PO BOX 337
DOUSMAN, WI 53118
262-965-4366
FAX: 262-965-4369

PROJECT NAME: POWERTON GENERATING STATION

DRAWING NAME: AS BUILT PANEL LAYOUT FOR BYPASS AND METAL CLEANING PONDS

LOCATION: PEKIN, IL

DRAWING NUMBER: AB-1

FILENAME: POWERTON

ATTACHMENT A12

LEAK LOCATION SURVEY REPORT

LEAK LOCATION SERVICES, INC.
16124 UNIVERSITY OAK ● SAN ANTONIO, TEXAS 78249 ● (210) 408-1241 / FAX (210) 408-1242

December 7, 2010

Mr. Craig Holthaus
Otto Baum Company, Inc.
866 N. Main Street
Morton, IL 61550

Email: craigholthaus@ottobaum.com

Subject: Report for "Geomembrane Leak Location Survey of Bypass Basin and Metal Basin at the Midwest Generation Powerton Plant in Pekin, Illinois"; LLSI Project 1337A

Dear Mr. Holthaus:

On December 2 and 3, of 2010, John Ortiz, of Leak Location Services, Inc. (LLSI) conducted a geomembrane leak location survey of the Bypass Basin at the Midwest Generation Powerton Plant in Pekin, Illinois. The Metal Basin could not be surveyed because the cover material was frozen. Only the floor area of the Bypass Basin was surveyed on this mobilization. The surveyed area was approximately 0.5 acres and is lined, from the top down, with a 6-inch warning layer of gravel, 12-inch cushion layer of sand, 12-oz non-woven geotextile, a single 60-mil geomembrane and a16-oz non-woven geotextile. This report documents the results of the survey. Appendix A contains the details of the survey and Appendix B contains photographs of the leak.

One leak was found during the survey. A 1 foot by 1 foot rip, was located approximately 45 feet from the south toe line and approximately 10 feet from the east toe line. The leak was exposed and documented for repair. Figure 1 shows the surveyed area and approximate location of the leak. The leak location survey was performed in accordance with the ASTM Standard 7007. The Metal Basin will be surveyed at a later date.

If there are any questions regarding the leak location survey or this report, please contact us at (210) 408-1241. We appreciate this opportunity to have been of service on this important project.

Approved by:

Glenn T. Darilek
Principal Engineer

Very truly yours,

John Ortiz
Project Manager

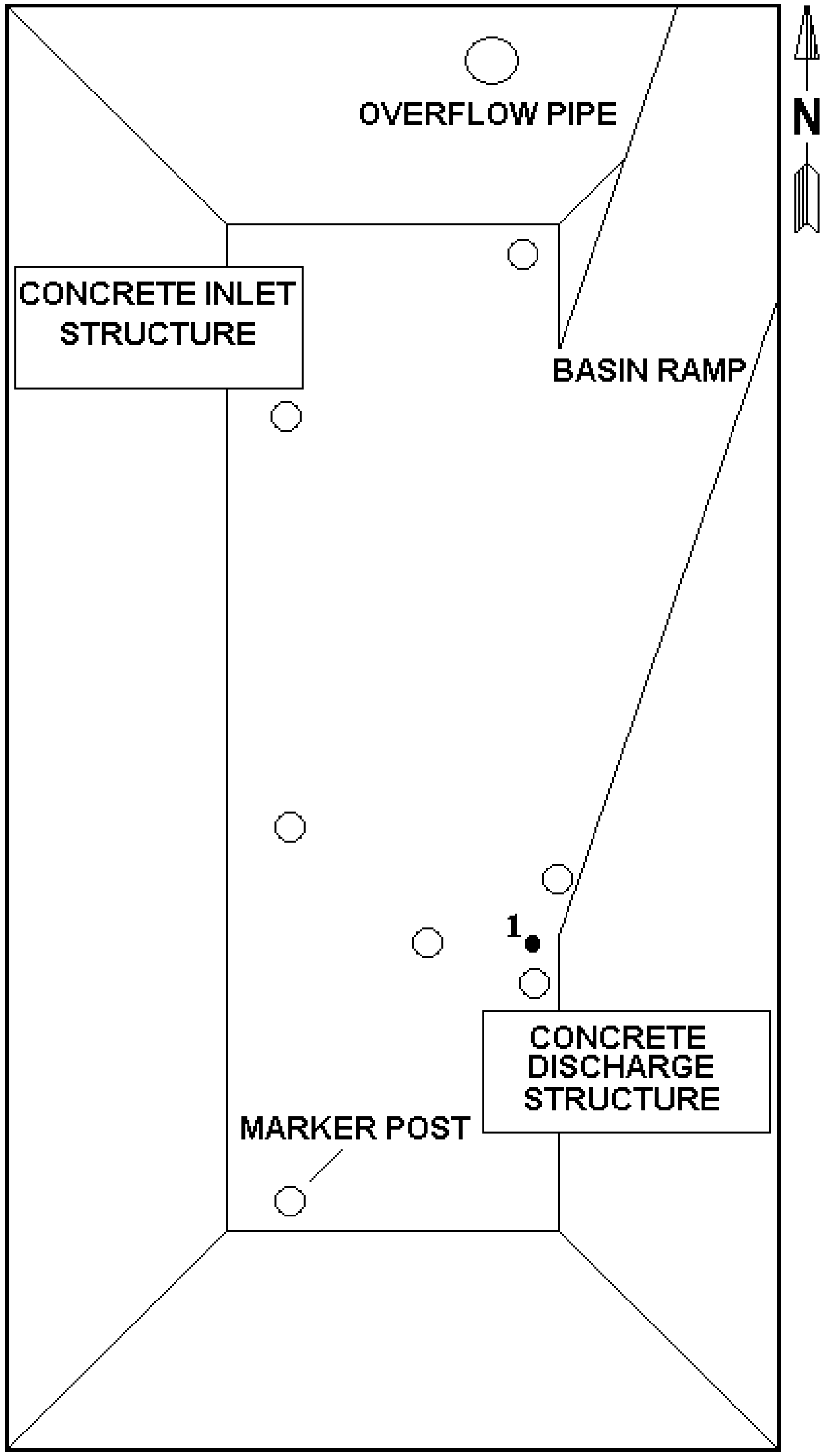


FIGURE 1. APPROXIMATE LOCATIONS OF LEAKS FOUND IN BYPASS BASIN

APPENDIX A

SURVEY DETAILS

APPENDIX A

SURVEY DETAILS

I. DESCRIPTION OF THE SURVEY SITE

The Bypass Basin contained two concrete inlet structures and eight marker post. A strip of the earth materials at the top of the ramp was removed to provide electrical isolation for the survey. Only the floor area and ramp were surveyed.

Facility Name - Midwest Generation Powerton Power Station
Location - Pekin, Illinois
Survey Area - Approximately 0.5 acres
Depth - Approximately 20 feet
Slopes - 3:1

II. SURVEY PARAMETERS

Date(s) - December 2 and 3, 2010
Climate - Cold with some snow flurries
Geomembrane - 60-mil HDPE geomembrane
Layering - From the top down, a 6-inch warning layer of gravel, 12-inch cushion layer of sand, 12-oz non-woven geotextile, a single 60-mil geomembrane and a 16-oz non-woven geotextile.
Specific Conditions of Survey - Near freezing conditions
Leak Detection Sensitivity Setting - 6 mm leak detection at an average distance of 7.5 feet
Operator - John Ortiz

III. LEAK LOCATION METHOD

A. Principles of the Electrical Leak Location Method

The electrical leak location method is to impress a high DC voltage across the geomembrane and measure the resulting potential gradients on or in the conducting material on the geomembrane. Leaks are indicated by a characteristic pattern in the potential measurements caused by electrical current flowing through the leaks.

B. Surveys with Earth Materials on the Geomembrane

A high voltage isolated DC power supply is used to impress a voltage across the geomembrane using one electrode placed in the earth material on top of geomembrane and a second electrode placed in the electrically conducting material located under the geomembrane. The leak survey is conducted by making potential gradient measurements on the moist earth material using a dipole probe using non-polarizing electrodes. These measurements were made along parallel survey lines. A portable digital data logger is used to collect the data. The data is then downloaded into a portable computer for display, plotting, and analysis. When a leak signal is detected, manual measurements are made to accurately locate the leak position between the survey lines. The locations of the leaks are marked for excavation.

C. Equipment

The leak location power supply provides an excitation signal of approximately 340 volts DC. The data acquisition system has an input resistance greater than 50 megohms and measures signals as low as 1 millivolt with an accuracy of about 1 millivolt.

D. Results of Artificial Leak Tests and Calibration Tests

Type of Test Leak - Artificial per D7007
Diameter - 6.4 mm
Depth - 18 inches under earth materials, on top of 12-oz non-woven geotextile

Date	**Time**	**Operator**	**Recorder**	**Distance from Leak**	**Signal/Noise**
12/2/10	10:35	J. Ortiz	7	-7.5 feet 10 feet	3.27 23.3
12/2/10	14:30	J. Ortiz	7	-10 feet 10 feet	15.62 9.16

APPENDIX B

PHOTOGRAPHS OF THE LEAK


5
6
7
8
9
10

LEAK LOCATION SERVICES, INC.

16124 UNIVERSITY OAK ● SAN ANTONIO, TEXAS 78249 ● (210) 408-1241 / FAX (210) 408-1242

March 21, 2011

Mr. Craig Holthaus
Otto Baum Company, Inc.
866 N. Main Street
Morton, IL 61550

Email: craigholthaus@ottobaum.com

Subject: Report for "Geomembrane Leak Location Survey of the Metal Cleaning Basin at the Midwest Generation Powerton Plant in Pekin, Illinois"; LLSI Project 1337A

Dear Mr. Holthaus:

On March 17, of 2011, John Ortiz, of Leak Location Services, Inc. (LLSI) conducted a geomembrane leak location survey on the floor area of the Metal Cleaning Basin at the Midwest Generation Powerton Plant in Pekin, Illinois. The Metal Basin has a single 60-mil geomembrane over a 16-oz non-woven geotextile. The geomembrane was covered with a 12-oz non-woven geotextile, 12-inch cushion layer and 6-inch warning layer. The Pond had an approximate survey area of 42,000 square feet. This report documents the results of the survey. The appendix contains the details of the survey.

One leak was found during the survey. A 3-inch diameter puncture was located approximately 265 feet from the south toe line and approximately 25 feet from the east toe line. The leak was exposed and documented for repair. However, due to standing water, the leak could not be electrically isolated. Additional measurements could not be taken to determine if any additional leaks existed in the near vicinity. Figure 1 shows the surveyed area and approximate location of the leak. The leak location survey was performed in accordance with the ASTM Standard D7007.

If there are any questions regarding the leak location survey or this report, please contact us at (210) 408-1241. We appreciate this opportunity to have been of service on this important project.

Approved by:

Glenn T. Darilek
Principal Engineer

Very truly yours,

John Ortiz
Project Manager

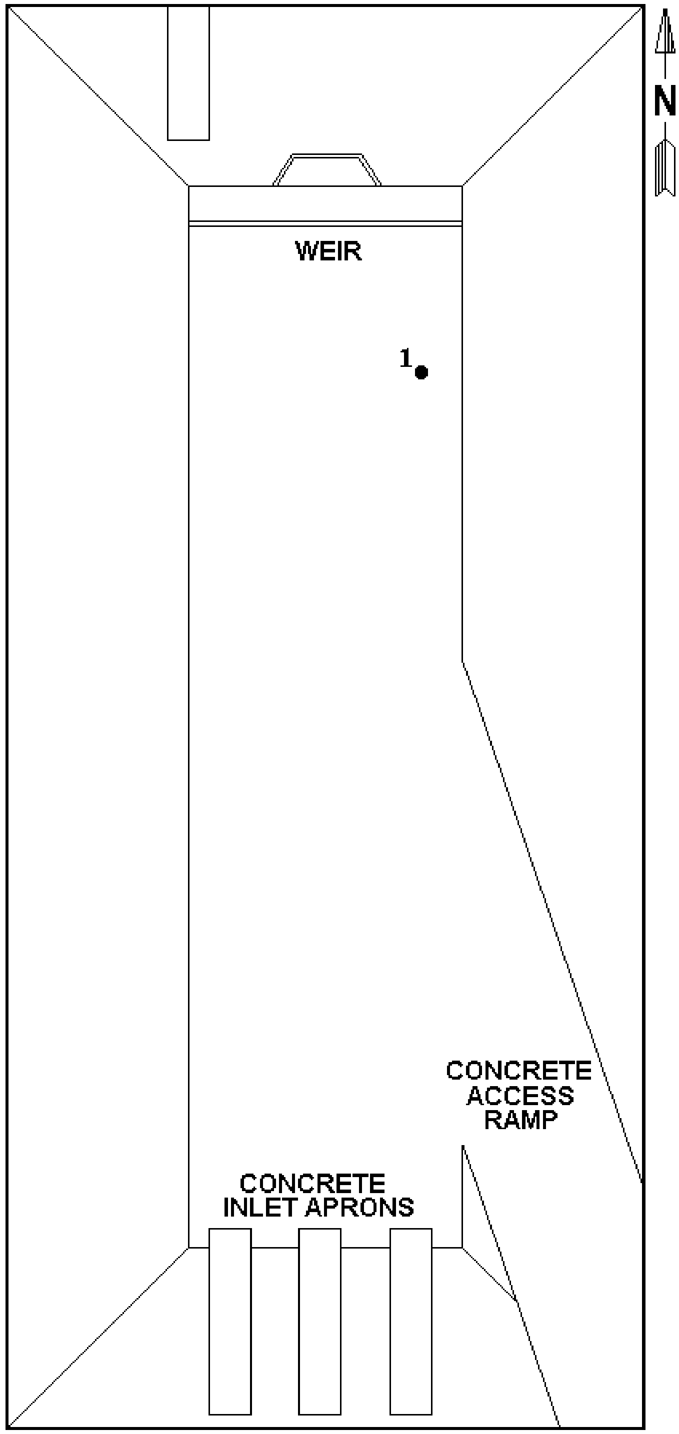


FIGURE 1. APPROXIMATE LOCATIONS OF LEAKS FOUND IN METAL CLEANING BASIN

APPENDIX

SURVEY DETAILS

APPENDIX

SURVEY DETAILS

I. DESCRIPTION OF THE SURVEY SITE

The Metal Cleaning Basin contains a concrete access ramp, four concrete inlet aprons and a weir. The concrete access ramp and three of the concrete inlet aprons could not be isolated because of standing water. Only the floor area was surveyed.

Facility Name - Midwest Generation Powerton Power Station
Location - Pekin, Illinois
Survey Area - Approximately 42,000 square feet
Depth - Approximately 20 feet
Slopes - 3:1

II. SURVEY PARAMETERS

Date(s) - March 17, 2011
Climate - Cool
Geomembrane - 60-mil HDPE geomembrane
Layering - From the top down, a 6-inch warning layer of gravel, 12-inch cushion layer of sand, 12-oz non-woven geotextile, a single 60-mil geomembrane and a 16-oz non-woven geotextile
Specific Conditions of Survey - Standing water, approximately 3-inches above the geomambrane at leak 1
Leak Detection Sensitivity Setting - 6 mm leak detection at an average distance of 10 feet
Operator - John Ortiz

III. LEAK LOCATION METHOD

A. Principles of the Electrical Leak Location Method

The electrical leak location method is to impress a high DC voltage across the geomembrane and measure the resulting potential gradients on or in the conducting material on the geomembrane. Leaks are indicated by a characteristic pattern in the potential measurements caused by electrical current flowing through the leaks.

B. Surveys with Earth Materials on the Geomembrane

A high voltage isolated DC power supply is used to impress a voltage across the geomembrane using one electrode placed in the earth material on top of geomembrane and a second electrode placed in the electrically conducting material located under the geomembrane. The leak survey is conducted by making potential gradient measurements on the moist earth material using a dipole probe using non-polarizing electrodes. These measurements were made along parallel survey lines. A portable digital data logger is used to collect the data. The data is then downloaded into a portable computer for display, plotting, and analysis. When a leak signal is detected, manual measurements are made to accurately locate the leak position between the survey lines. The locations of the leaks are marked for excavation.

C. Equipment

The leak location power supply provides an excitation signal of approximately 340 volts DC. The data acquisition system has an input resistance greater than 50 megohms and measures signals as low as 1 millivolt with an accuracy of about 1 millivolt.

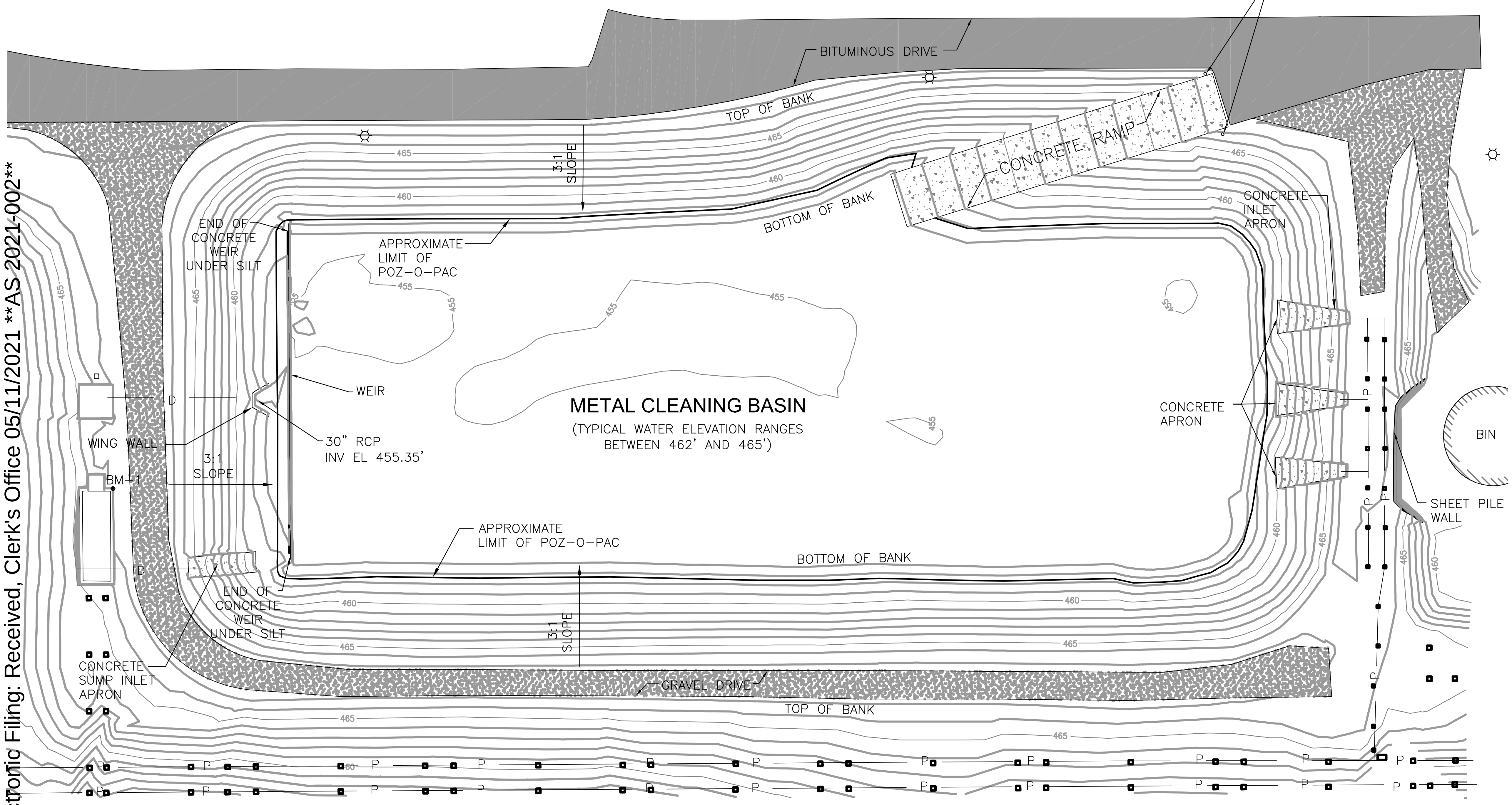
D. Results of Artificial Leak Tests and Calibration Tests

Type of Test Leak - Artificial per D7007
Diameter - 6.4 mm
Depth - 18 inches under earth materials, on top of 12-oz non-woven geotextile

Date	**Time**	**Operator**	**Recorder**	**Distance from Leak**	**Noise (N)**	**Signal + Noise (S + N)**	**(S + N) / N**
3/17/11	11:20	J. Ortiz	6	-10 feet 10 feet	48	1140 1112	24 23
3/17/11	14:00	J. Ortiz	6	-5 feet 5 feet	48	1632 2216	34 46

ATTACHMENT B

DOCUMENTATION SURVEY



LEGEND

— D —	UNDERGROUND DISCHARGE PIPE
■—■ P —■	ABOVEGROUND PIPE RACK
☼	LIGHT POLE
460	GROUND SURFACE CONTOUR

HORIZONTAL DATUM:
ILLINOIS STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD83.

VERTICAL DATUM:
LOCAL PLANT DATUM

BENCHMARK-1:
SE CORNER TOP CONCRETE WALL
ELEVATION = 468.09 FT.

SOURCE NOTES:

THIS DRAWING WAS DEVELOPED FROM A SURVEY BY MAURER-STUTZ, INC. DATED 10/20/09, DRAWING NO. 23209009.

LOCATION OF EXISTING LINER TAKEN FROM MIDWEST GENERATION DRAWING NO. 5080 C5008, DATED 12-19-1978.

N

0 10 20 40
SCALE IN FEET

	REVISION:	DATE:	APP'D BY:
6.			
5.			
4.	RECORD DOCUMENTATION	06/16/11	HMS
3.	ISSUED FOR CONSTRUCTION	10/22/10	HMS
2.	ADDENDUM 1	10/22/09	HMS
1.	ISSUED FOR BID	10/05/09	HMS
0.	ISSUED FOR PERMIT	07/27/09	HMS

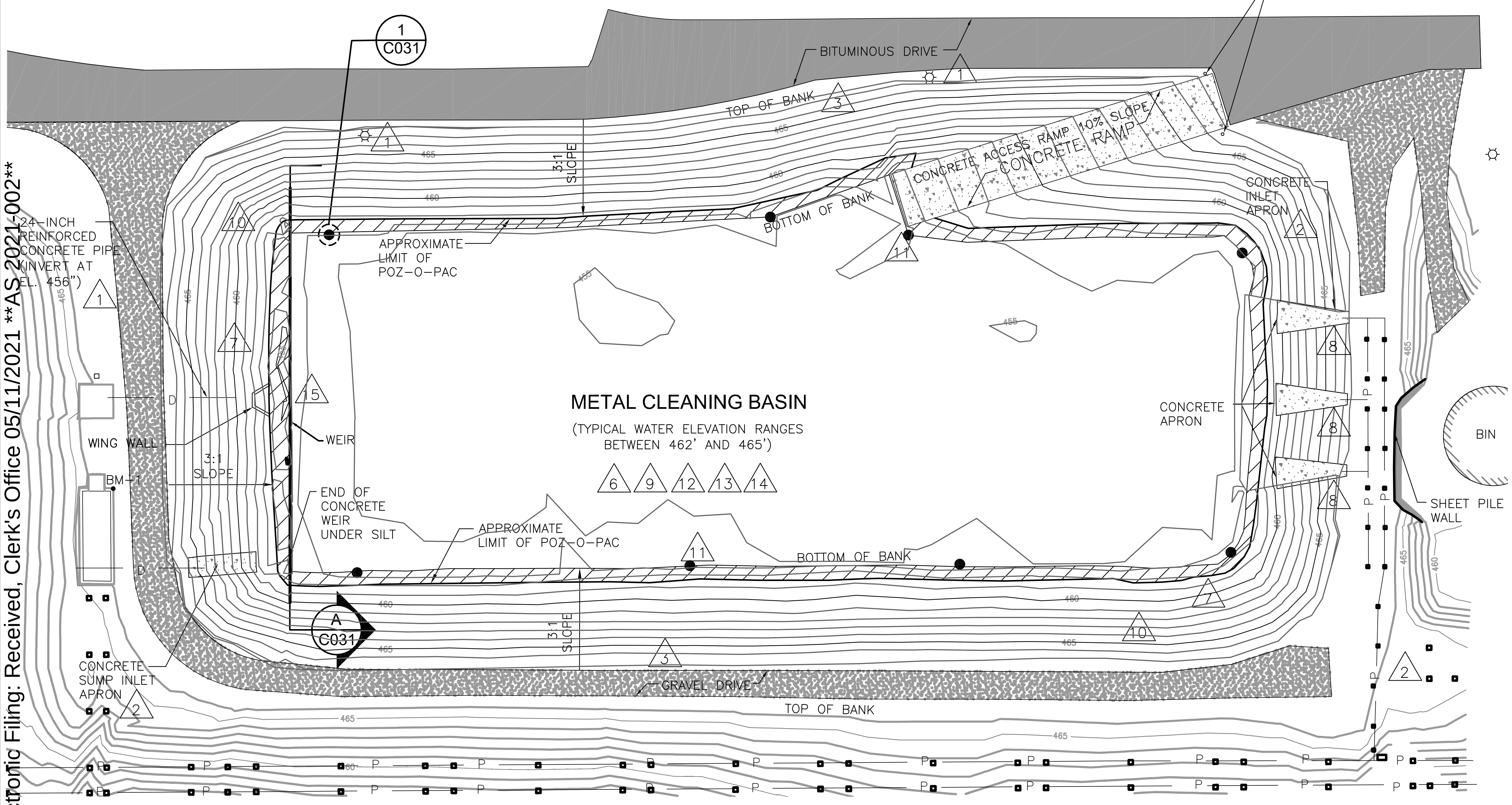
NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 1965/4.0
DRAWN BY: RLH/KNW 07/17/09
CHECKED BY: RJG 07/17/09
APPROVED BY: HMS 07/27/09

PRE-CONSTRUCTION CONDITIONS

METAL CLEANING BASIN LINER REPLACEMENT
MIDWEST GENERATION
POWERTON POWER STATION
PEKIN, ILLINOIS

DRAWING NO: D1965C010-04
REFERENCE: .
SHEET NO. C010



LEGEND

— D —	UNDERGROUND DISCHARGE PIPE
—▪—▪ P ▪—	ABOVEGROUND PIPE RACK
☼	LIGHT POLE
460	PREPARED SUBGRADE SURFACE CONTOUR
●	MARKER POST LOCATION
▨	POZ-O-PAC REMOVAL AREA

CONTRACTOR NOTES: △

1. CONTRACTOR SHALL FIELD VERIFY LOCATION OF UNDERGROUND PIPES WITH ASSISTANCE OF OWNER'S UTILITY LOCATOR.
2. CONTRACTOR SHALL FIELD VERIFY LOCATION OF CONCRETE STRUCTURES AND ABOVE GROUND PIPING.
3. CLEAR AND GRUB ALL BRUSH ALONG TOP OF SLOPE OF BASIN.
4. CONTRACTOR SHALL STORE ALL GEOSYNTHETICS AND SUBGRADE MATERIALS IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.
5. CONTRACTOR SHALL STORE AND STAGE EQUIPMENT AT LOCATION APPROVED BY OWNER.
6. PROTECT ALL CONCRETE AND UTILITY STRUCTURES TO REMAIN IN PLACE THROUGHOUT PROJECT DURATION.
7. REMOVE EXISTING 12-INCH POZ-O-PAC LAYER ALONG SIDE SLOPES. POZ-O-PAC LAYER AT BASE OF BASIN TO REMAIN IN PLACE, EXCEPT NORTH OF WEIR. CONTRACTOR SHALL REMOVE AN ADDITIONAL 6 INCHES OF SUBGRADE MATERIAL LOCATED BETWEEN THE WEIR AND THE WING WALL ALONG THE NORTH BOTTOM OF BANK, AS SHOWN ON SECTION B, SHEET C031.
8. CONTRACTOR SHALL REMOVE INLET APRONS AND HAUL MATERIAL TO RECYCLING FACILITY.
9. CONTRACTOR SHALL REMOVE ALL VEGETATION, ROCKS, AND OTHER DEBRIS FROM EXISTING LINER AND DISPOSE OF IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.
10. CONTRACTOR SHALL REMOVE "SOFT" SUBGRADE MATERIAL BENEATH EXISTING HYPALON LINER, AS DIRECTED BY OWNER AND/OR ENGINEER. BACKFILL AREAS WITH FILL IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS. CUT HYPALON LINER AS NEEDED TO REPAIR THE "SOFT" SUBGRADE AREAS.
11. CONTRACTOR SHALL INSTALL MARKER POSTS ALONG THE TOE OF SLOPE AS SHOWN AND IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS AND DETAIL 1 ON SHEET C031.
12. SUBGRADE MUST BE APPROVED BY OWNER AND/OR ENGINEER PRIOR TO INSTALLATION OF GEOMEMBRANE.
13. CONTRACTOR SHALL PLACE 16 OZ. NONWOVEN GEOTEXTILE OVER THE SUBGRADE IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.
14. CONTRACTOR SHALL PROVIDE MEANS TO PROTECT SUBGRADE LAYER FROM EROSION, STORM WATER, AND HEAVY EQUIPMENT TRAFFIC. DAMAGE TO SUBGRADE LAYER SHALL BE REPAIRED AT THE CONTRACTOR'S EXPENSE.
15. CONTRACTOR SHALL EXTEND CONCRETE WEIR UP BY 18" IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS AND SECTION A ON SHEET C031.

N

0 10 20 40
SCALE IN FEET

HORIZONTAL DATUM:
ILLINOIS STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD83.

VERTICAL DATUM:
LOCAL PLANT DATUM

BENCHMARK-1:
SE CORNER TOP CONCRETE WALL
ELEVATION = 468.09 FT.

SOURCE NOTES:

THIS DRAWING WAS DEVELOPED FROM A SURVEY BY MAURER-STUTZ, INC. DATED 10/20/09, DRAWING NO. 23209009.

LOCATION OF EXISTING LINER TAKEN FROM MIDWEST GENERATION DRAWING NO. 5080 C5008, DATED 12-19-1978.

BASIN SUBGRADE AND SITE IMPROVEMENTS FROM A SURVEY PROVIDED BY MILLENNIA PROFESSIONAL SERVICES, MARCH 2011.

REVISION:		DATE:	APP'D BY:
6.			
5.			
4.			
3.	RECORD DOCUMENTATION	06/08/11	HMS
2.	ISSUED FOR CONSTRUCTION	10/22/10	HMS
1.	ISSUED FOR BID	10/05/09	HMS
0.	ISSUED FOR PERMIT	07/27/09	HMS

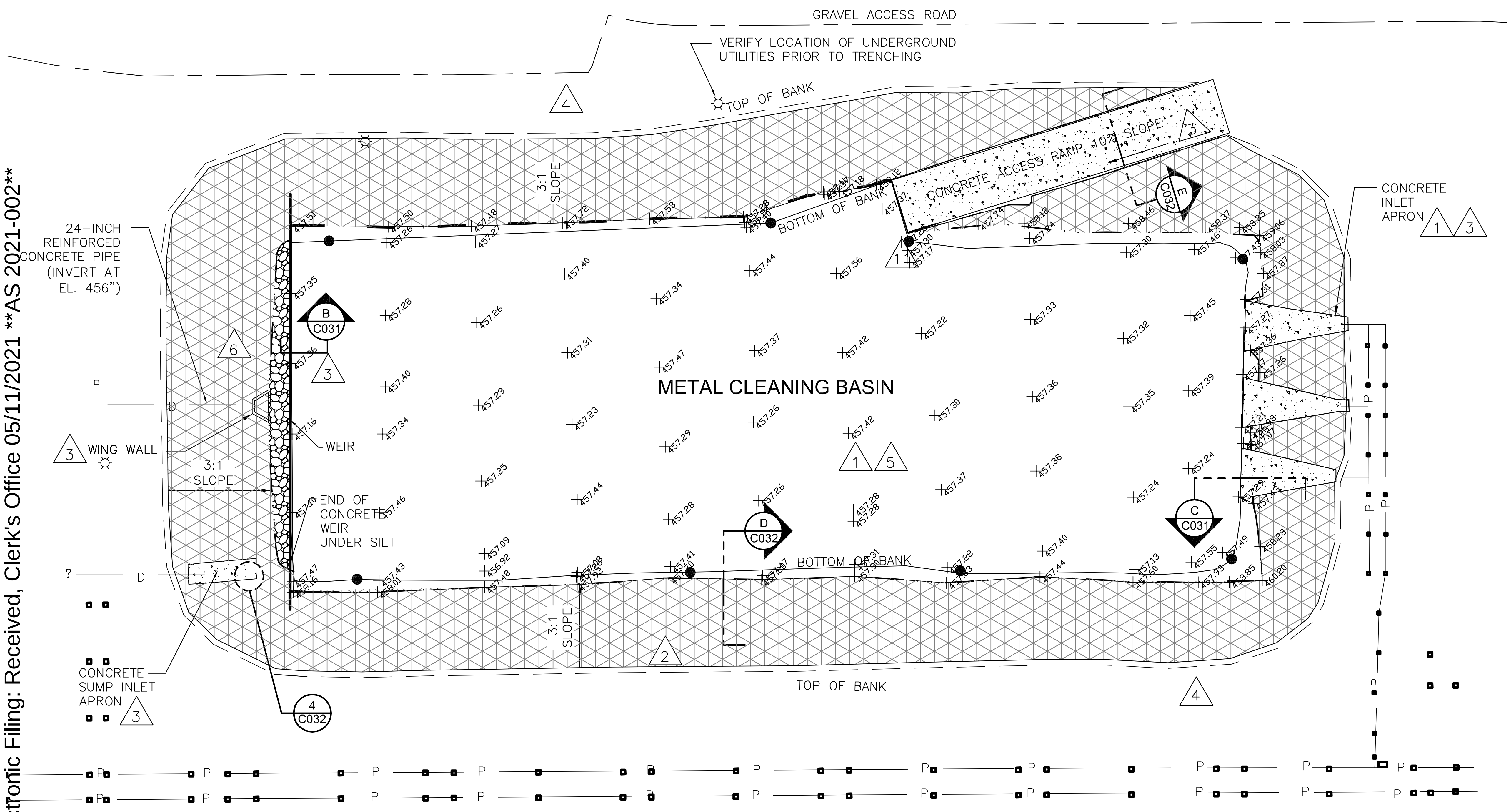
NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 1965/4.0
DRAWN BY: KNW 08/25/09
CHECKED BY: RJG 10/05/09
APPROVED BY: HMS 10/05/09

LINER SUBGRADE PREPARATION

METAL CLEANING BASIN LINER REPLACEMENT
MIDWEST GENERATION
POWERTON POWER STATION
PEKIN, ILLINOIS

DRAWING NO: D1965C020-03
REFERENCE: -
SHEET NO. C020



LEGEND

— D —	UNDERGROUND DISCHARGE PIPE
—■ P ■—	ABOVEGROUND PIPE RACK
— — —	ANCHOR TRENCH
— · · —	12 OZ. NON-WOVEN GEOTEXTILE
☼	LIGHT POLE
●	MARKER POST LOCATION
× 457.32	TOP OF WARNING LAYER (ELEVATION, FT.)
(hatch)	HDPE GEOMEMBRANE
(stipple)	CONCRETE
(stones)	RIPRAP

CONTRACTOR NOTES:

1. PRIOR TO GEOMEMBRANE INSTALLATION CONTRACTOR SHALL CONSTRUCT INLET APRONS WITH HDPE WELD STRIPS AROUND PERIMETER AND 12-INCH DEEP FOOTING AT TOP AND BOTTOM OF APRON TO MATCH PREEXISTING APRON CONSTRUCTION. APRON TO EXTEND AT MINIMUM 3 FEET BEYOND TOE OF BANK. SEE DETAIL.
2. CONTRACTOR SHALL INSTALL 60 MIL HDPE, WHITE, TEXTURED GEOMEMBRANE IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION PRIOR TO PLACEMENT OF THE WARNING LAYER. CONTRACTOR SHALL PROVIDE AND FOLLOW AN APPROVED GEOMEMBRANE LAYOUT PLAN.
3. CONTRACTOR SHALL ATTACH GEOMEMBRANE TO STRUCTURES IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION AND DETAILS ON SHEET C031 AND C032.
4. GEOMEMBRANE SHALL BE ANCHORED INTO 2.5 FEET DEEP TRENCHES ALONG TOP OF BANK, AS SHOWN ON SHEET C031. CONTRACTOR SHALL ADVISE OWNER AND/OR ENGINEER IF PROPOSED LOCATION FOR ANCHOR TRENCH IS NOT FEASIBLE.
5. CONTRACTOR SHALL PLACE 12-OZ. NON-WOVEN GEOTEXTILE, CUSHION MATERIAL AND WARNING LAYER MATERIAL OVER THE GEOMEMBRANE AT BASE AND 4 FEET ON SIDE SLOPES FOLLOWING ENGINEER APPROVAL AND PASSING QUALITY CONTROL RESULTS IN ACCORDANCE WITH TECHNICAL SPECIFICATIONS (SEE SHEET C031).
6. CONTRACTOR SHALL PLACE RIPRAP 18 INCHES THICK, BETWEEN WEIR AND WING WALL ALONG THE BOTTOM OF BANK.
7. CONTRACTOR SHALL PROVIDE SURVEY DOCUMENTATION OF THE ITEMS LISTED IN THE TECHNICAL SPECIFICATIONS.
8. CONTRACTOR SHALL PERFORM A LEAK LOCATION SURVEY IN ACCORDANCE WITH TECHNICAL SPECIFICATIONS.
9. RESTORE AREAS DISTURBED BY EQUIPMENT AND MATERIAL LAYDOWN.

0 10 20 40
SCALE IN FEET

HORIZONTAL DATUM:
ILLINOIS STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD83.

VERTICAL DATUM:
LOCAL PLANT DATUM

BENCHMARK-1:
SE CORNER TOP CONCRETE WALL
ELEVATION = 468.09 FT.

SOURCE NOTES:

THIS DRAWING WAS DEVELOPED FROM A SURVEY BY MAURER-STUTZ, INC. DATED 10/20/09, DRAWING NO. 23209009.

LOCATION OF EXISTING LINER TAKEN FROM MIDWEST GENERATION DRAWING NO. 5080 C5008, DATED 12-19-1978. BASIN SUBGRADE AND SITE IMPROVEMENTS FROM A SURVEY PROVIDED BY MILLENNIA PROFESSIONAL SERVICES, MARCH 2011.

REVISION:		DATE:	APP'D BY:
6.			
5.			
4.			
3.	RECORD DOCUMENTATION	06/08/11	HMS
2.	ISSUED FOR CONSTRUCTION	10/22/10	HMS
1.	ISSUED FOR BID	10/05/09	HMS
0.	ISSUED FOR PERMIT	07/27/09	HMS

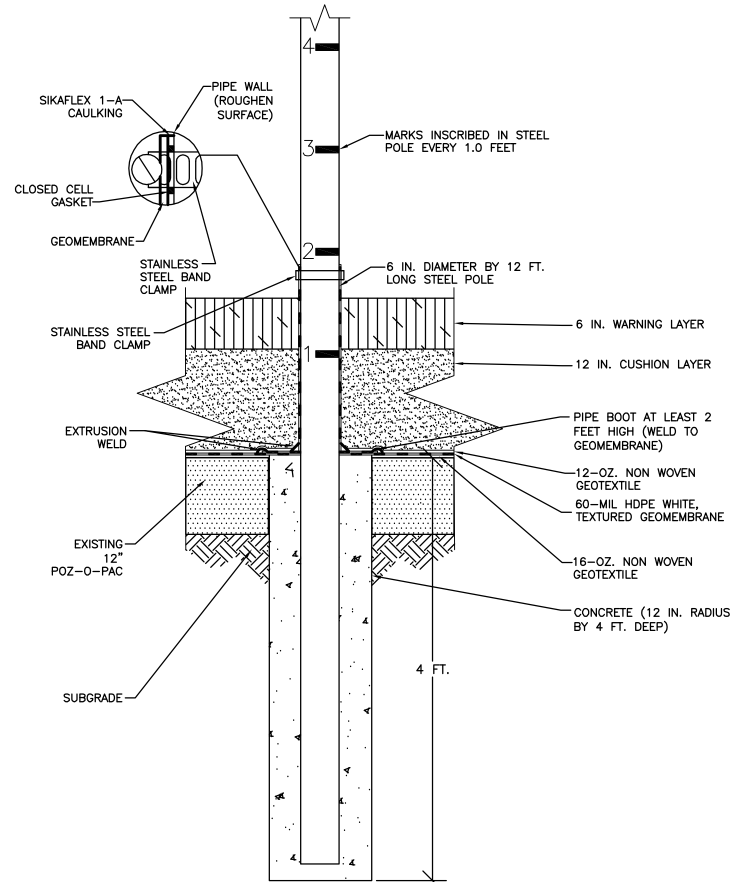
NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 1965/4.0
DRAWN BY: KNW 08/25/09
CHECKED BY: RJG 10/05/09
APPROVED BY: HMS 10/05/09

WARNING LAYER

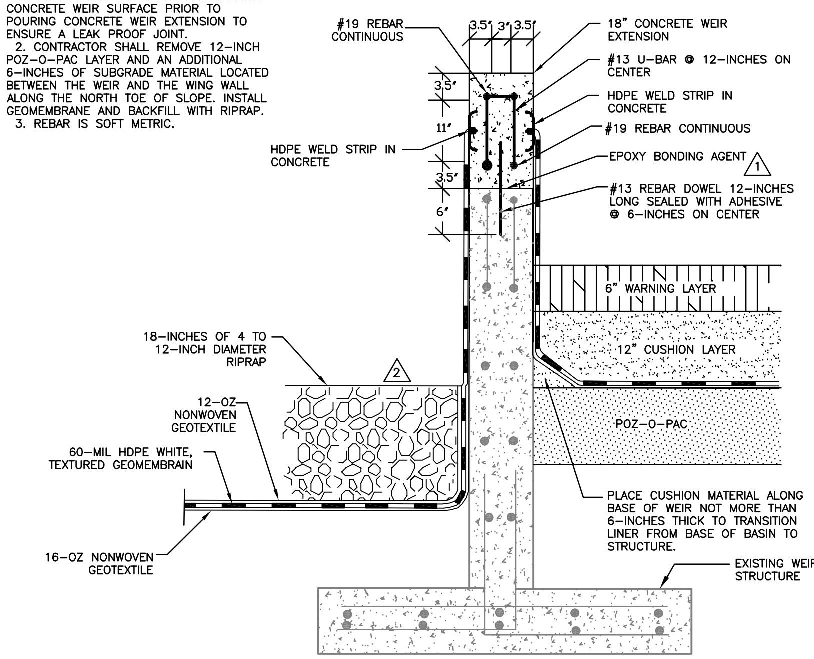
METAL CLEANING BASIN LINER REPLACEMENT
MIDWEST GENERATION
POWERTON POWER STATION
PEKIN, ILLINOIS

DRAWING NO: D1965C030-03
REFERENCE: .
SHEET NO. C030

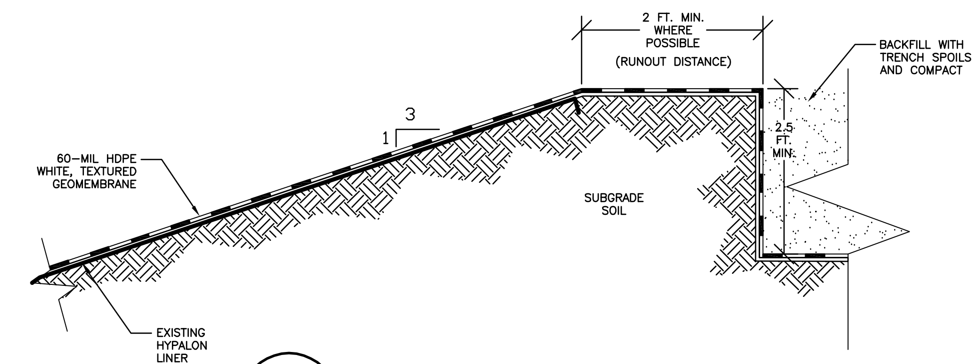


1 / C020 MARKER POST DETAIL
NOT TO SCALE

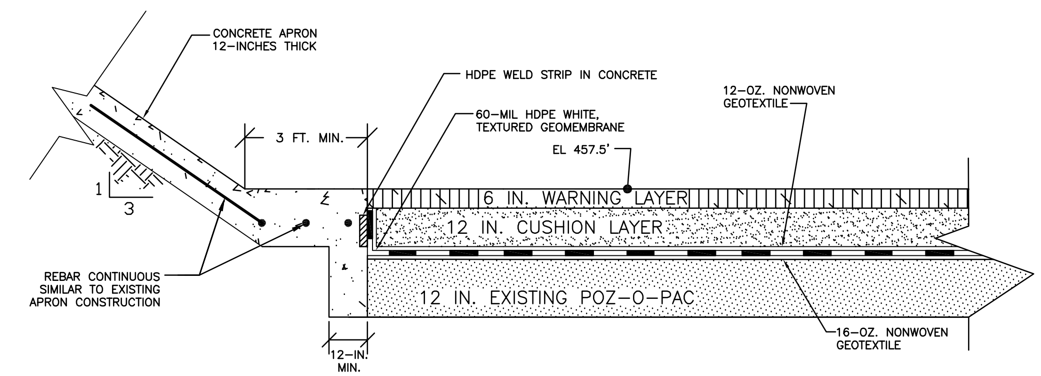
CONTRACTOR NOTES: 1
1. CONTRACTOR SHALL PREPARE EXISTING CONCRETE WEIR SURFACE PRIOR TO POURING CONCRETE WEIR EXTENSION TO ENSURE A LEAK PROOF JOINT.
2. CONTRACTOR SHALL REMOVE 12-INCH POZ-O-PAC LAYER AND AN ADDITIONAL 6-INCHES OF SUBGRADE MATERIAL LOCATED BETWEEN THE WEIR AND THE WING WALL ALONG THE NORTH TOE OF SLOPE. INSTALL GEOMEMBRANE AND BACKFILL WITH RIPRAP.
3. REBAR IS SOFT METRIC.



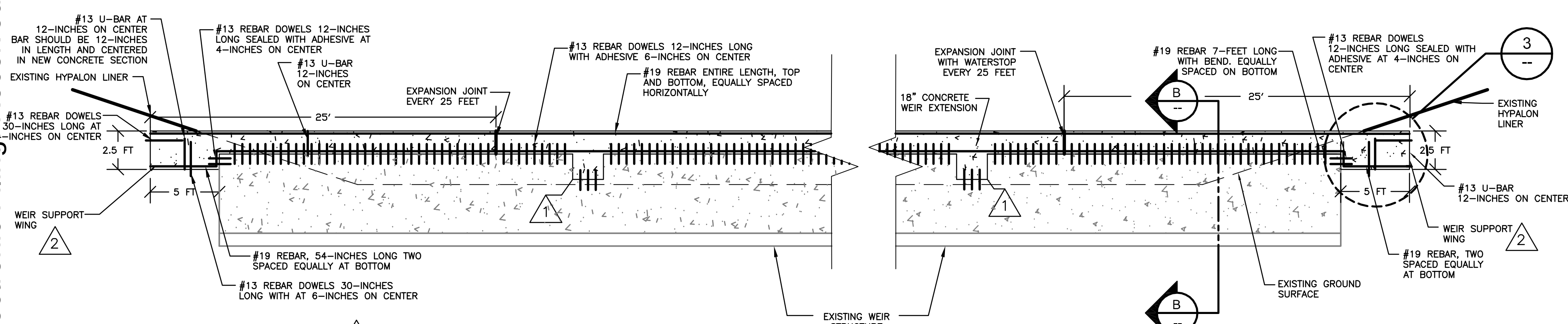
B / -- CONCRETE WEIR EXTENSION DETAIL
NOT TO SCALE



2 / C030 ANCHOR TRENCH SECTION
NOT TO SCALE

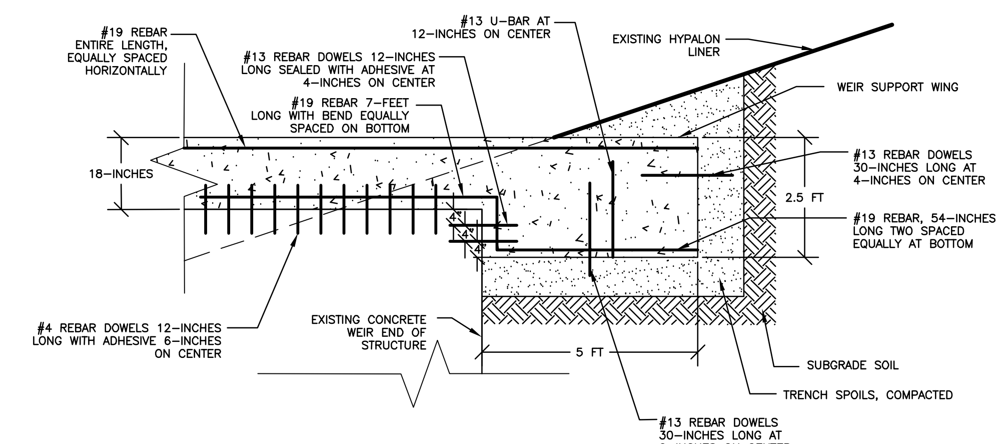


C / C030 CONCRETE INLET APRON SECTION
NOT TO SCALE



CONTRACTOR NOTE: 2
1. CONTRACTOR SHALL REMOVE METAL SLIDING GATES AND REPLACE WITH CONCRETE REBAR DOWELS AND ADHESIVE IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION.
2. CONTRACTOR SHALL INSTALL WEIR SUPPORT WINGS AND BACKFILL WITH TRENCH SPOILS IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.
3. REBAR IS SOFT METRIC.

A / C020 CONCRETE WEIR EXTENSION SECTION
NOT TO SCALE



3 / - WEIR SUPPORT WING DETAIL
NOT TO SCALE

	REVISION:	DATE:	APP'D BY:
6.			
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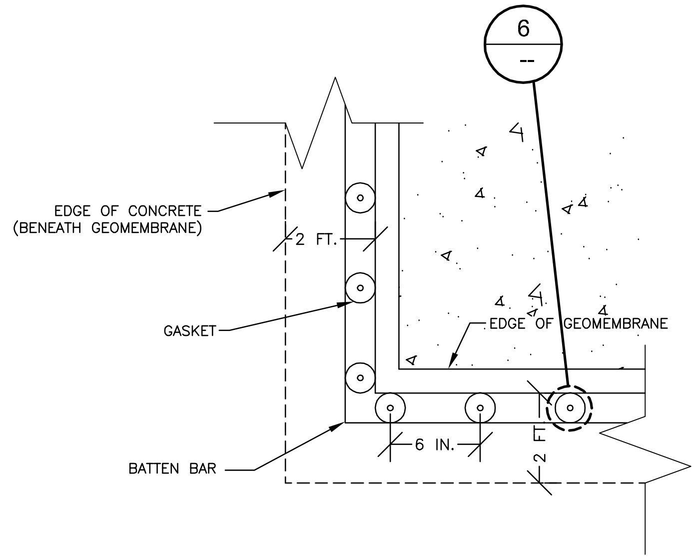
4.			
3.	RECORD DOCUMENTATION	06/08/11	HMS
2.	ISSUED FOR CONSTRUCTION	10/22/10	HMS
1.	ISSUED FOR BID	10/05/09	HMS
0.	ISSUED FOR PERMIT	07/27/09	HMS

NATURAL RESOURCE TECHNOLOGY

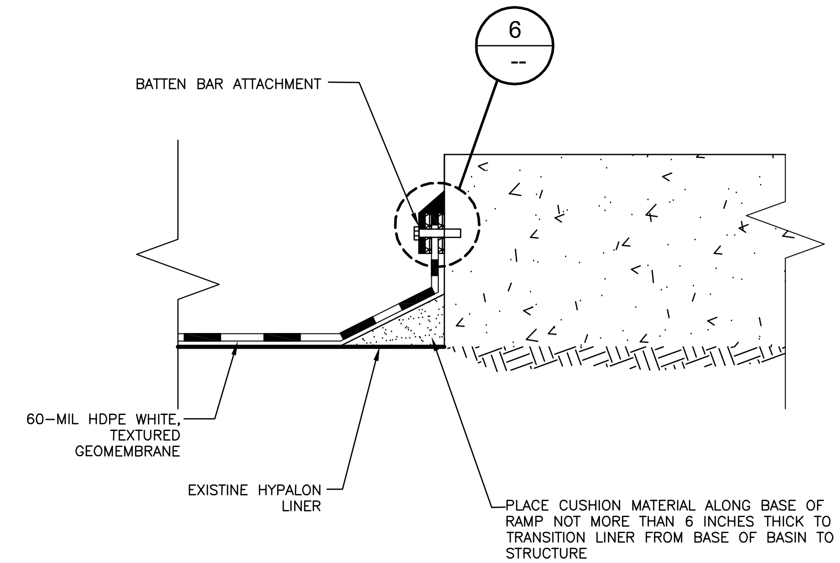
PROJECT NO. 1965/4.0
DRAWN BY: KNW 08/12/09
CHECKED BY: RJG 10/05/09
APPROVED BY: HMS 10/05/09

DETAILS AND SECTIONS
METAL CLEANING BASIN LINER REPLACEMENT
MIDWEST GENERATION
POWERTON POWER STATION
PEKIN, ILLINOIS

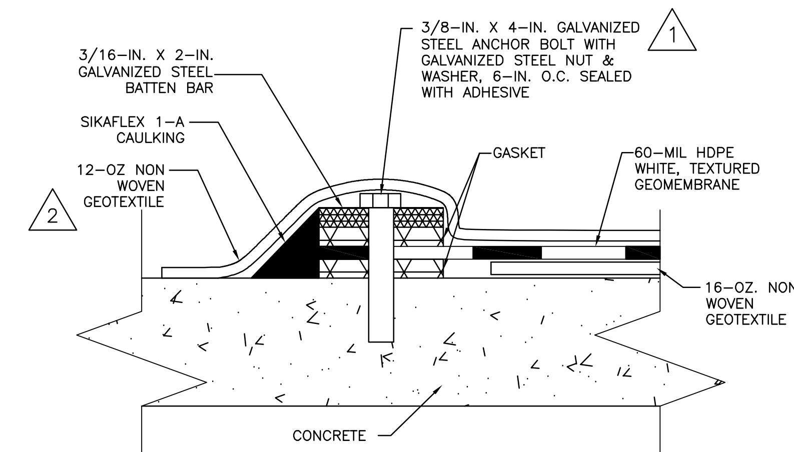
DRAWING NO: D1965C031-03
REFERENCE:.
SHEET NO. C031



4 / C030 SUMP INLET APRON DETAIL
NOT TO SCALE

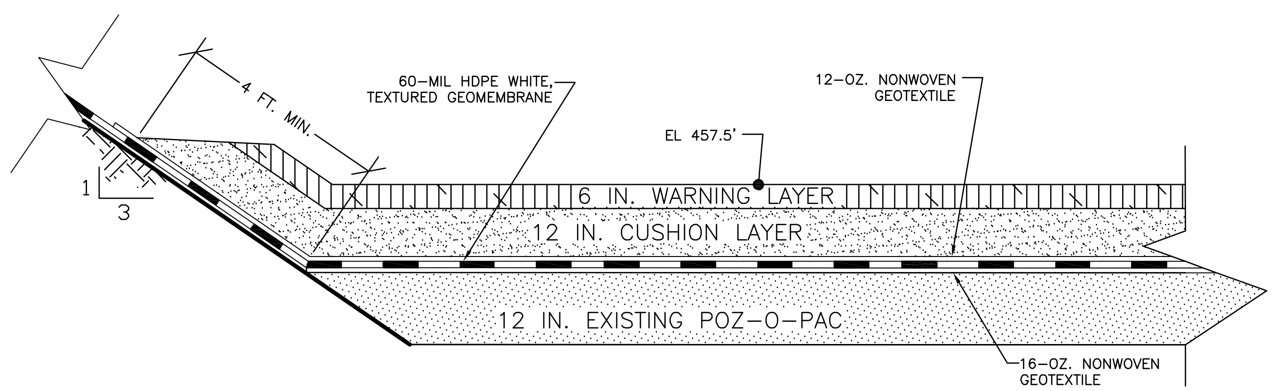


5 / ._. CONCRETE RAMP CONNECTION DETAIL
NOT TO SCALE



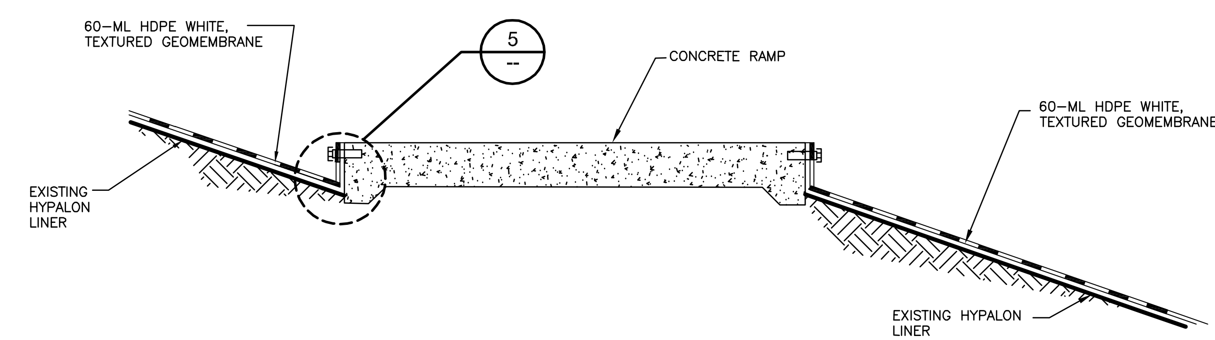
NOTE:
1. ANCHOR BOLTS 6 IN. ON CENTER.
2. 12-OZ. NONWOVEN GEOTEXTILE TO BE USED TO PROTECT GEOMEMBRANE BELOW CUSHION LAYER OR RIPRAP LAYER.

6 / -- BATTEN BAR ATTACHMENT
NOT TO SCALE



NOTE:
1. GEOMEMBRANE SEAMS SHALL BE PLACED 2 TO 5 FT. FROM TOE OF SLOPE AT A MINIMUM.

D / C030 SLOPE TRANSITION SECTION
NOT TO SCALE



E / C030 CONCRETE RAMP SECTION
NOT TO SCALE

	REVISION:	DATE:	APP'D BY:
6.			
5.			
4.			
3.	RECORD DOCUMENTATION	06/08/11	HMS
2.	ISSUED FOR CONSTRUCTION	10/22/10	HMS
1.	ISSUED FOR BID	10/05/09	HMS
0.	ISSUED FOR PERMIT	07/27/09	HMS

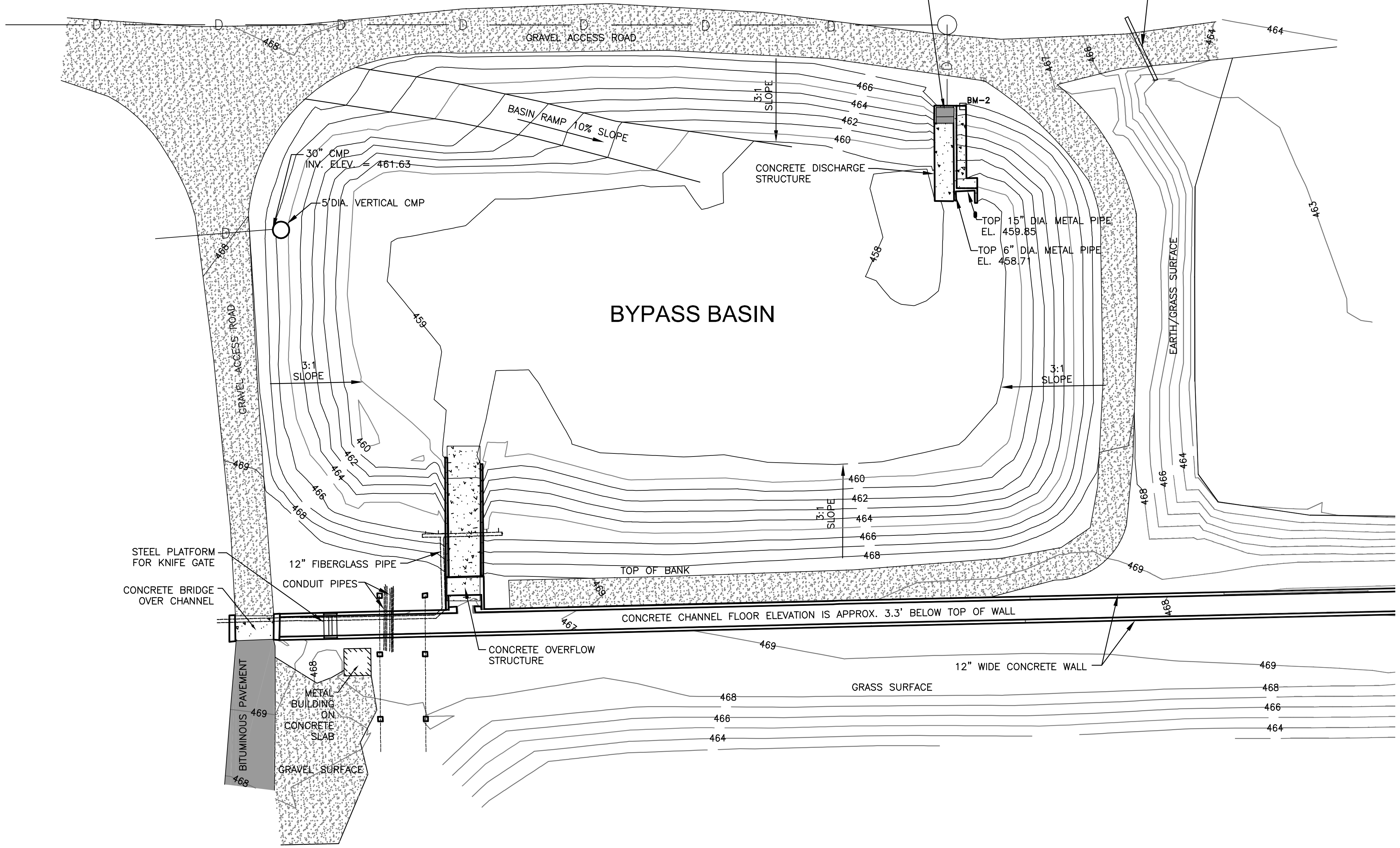
NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 1965/4.0
DRAWN BY: KNW 08/25/09
CHECKED BY: RJG 10/05/09
APPROVED BY: HMS 10/05/09

DETAILS AND SECTIONS

METAL CLEANING BASIN LINER REPLACEMENT
MIDWEST GENERATION
POWERTON POWER STATION
PEKIN, ILLINOIS

DRAWING NO: D1965C032-03
REFERENCE: 1965/4/
SHEET NO. C032



LEGEND

—— D ——	UNDERGROUND DISCHARGE PIPE
---■---■---	ABOVEGROUND INTAKE PIPE
460	GROUND SURFACE CONTOUR
BM-2	BENCHMARK 2

HORIZONTAL DATUM:
ILLINOIS STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD83.

VERTICAL DATUM:
LOCAL PLANT DATUM

BENCHMARK 2:
NORTHEAST CORNER OF CONCRETE DISCHARGE STRUCTURE. CHISELED "+" IN CONCRETE ELEVATION 468.75 FT.

SOURCE NOTES:
THIS DRAWING WAS DEVELOPED FROM A SURVEY MAURER STUTZ, INC. DATED SEPTEMBER 7, 2010, DRAWING NO. 23210023.
LOCATION OF BASIN AND ACCESS RAMP TAKEN FROM MIDWEST GENERATION DRAWING NO. 5295 C5001-2, DATED 6-26-1980.

N

0 10 20 40
SCALE IN FEET

	REVISION:	DATE:	APP'D BY:
6.			
5.			
4.			
3.			
2.	RECORD DOCUMENTATION	06/08/11	HMS
1.	ISSUED FOR BID	10/06/10	HMS
0.	ISSUED FOR PERMIT	06/30/10	HMS

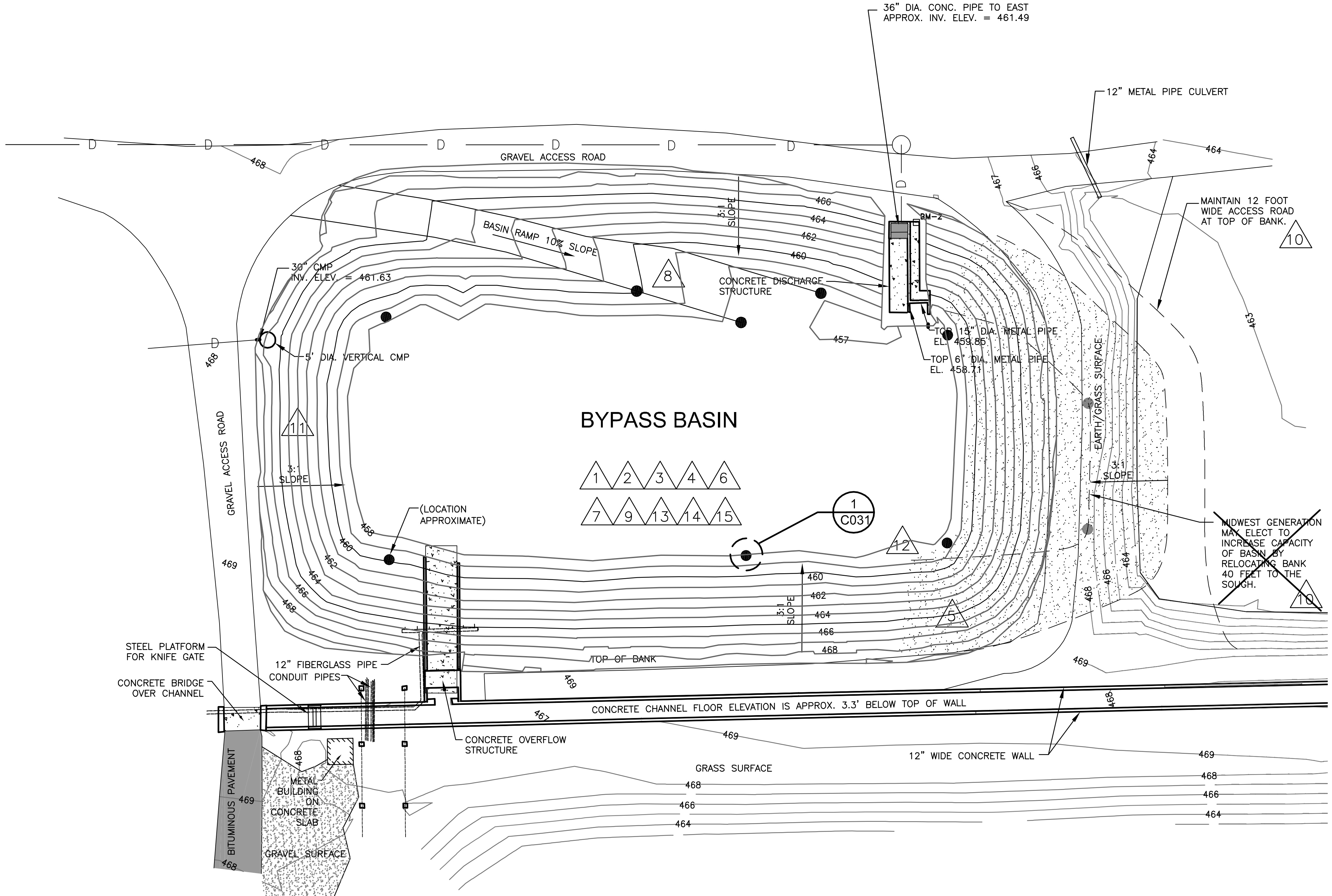
NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 1965.5/5.4
DRAWN BY: KNW 06/30/10
CHECKED BY: RJG 06/30/10
APPROVED BY: HMS 06/130/10

PRE-CONSTRUCTION CONDITIONS

BYPASS BASIN LINER REPLACEMENT
MIDWEST GENERATION
POWERTON POWER STATION
PEKIN, ILLINOIS

DRAWING NO: D1965C010-02
REFERENCE: -
SHEET NO. C010



LEGEND

— D —	UNDERGROUND DISCHARGE PIPE
	ABOVEGROUND INTAKE PIPE
460	PREPARED SUBGRADE SURFACE CONTOUR
	12 OZ. NON-WOVEN GEOTEXTILE
●	MARKER POST LOCATION
● (grey)	ADDITIONAL MARKER POST LOCATION IF BANK IS RELOCATED.
	~~BANK/AREA FOR POSSIBLE RELOCATION~~
BM-2	BENCHMARK 2

CONTRACTOR NOTES: △

1. CONTRACTOR SHALL FIELD VERIFY LOCATION OF UNDERGROUND PIPES WITH ASSISTANCE OF OWNER'S UTILITY LOCATOR.
2. CONTRACTOR SHALL FIELD VERIFY LOCATION OF CONCRETE STRUCTURES AND ABOVE GROUND PIPING.
3. CONTRACTOR SHALL STORE ALL GEOSYNTHETICS AND SUBGRADE MATERIALS IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.
4. CONTRACTOR SHALL STORE AND STAGE EQUIPMENT AT LOCATION APPROVED BY OWNER.
5. CLEAR AND GRUB ALL BRUSH ALONG TOP OF SLOPE OF BASIN.
6. PROTECT ALL CONCRETE AND UTILITY STRUCTURES THROUGHOUT PROJECT DURATION.
7. CONTRACTOR SHALL REMOVE ALL VEGETATION, ROCKS, AND OTHER DEBRIS FROM EXISTING LINER AND DISPOSE OF IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.
8. CONTRACTOR SHALL CLEAN OFF THE RAMP SURFACE TO THE EXTENT PRACTICAL TO REMOVE ROCKS THAT MAY POSE A HAZARD TO GEOMEMBRANE, AS APPROVED BY GEOMEMBRANE INSTALLER, ENGINEER AND/OR OWNER.
9. CONTRACTOR SHALL REMOVE 12-INCH LAYER OF POZ-O-PAC AND 6-INCHES OF POZ-O-PAC SUBGRADE FROM THE BASE OF BASIN.
10. ~~CONTRACTOR SHALL RELOCATE SOUTHERN BANK 40 FEET TO THE SOUTH, AS DIRECTED BY OWNER. SEGREGATE GRAVEL ACCESS ROAD MATERIAL TO BE REUSED AS BASE COURSE MATERIAL. MATERIAL REMOVED FROM THE EXISTING BANK MAY BE USED TO RECONSTRUCT NEW SOUTHERN BANK IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.~~
11. CONTRACTOR SHALL REMOVE "SOFT" SUBGRADE MATERIAL BENEATH EXISTING HYPALON LINER, AS DIRECTED BY OWNER AND/OR ENGINEER. BACK FILL AREAS WITH FILL IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS. CUT HYPALON AS NEEDED TO REPAIR THE "SOFT" SUBGRADE AREAS.
12. CONTRACTOR SHALL INSTALL MARKER POSTS ALONG THE TOE OF SLOPE AS SHOWN AND IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS AND DETAIL 1 ON SHEET C031.
13. CONTRACTOR SHALL PLACE 16 OZ. NONWOVEN GEOTEXTILE AT BASE OF BASIN AND WHERE HYPALON LINER DOES NOT EXIST OR WAS REMOVED OF THE PREPARED SUBGRADE IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.
14. SUBGRADE SHALL BE APPROVED BY OWNER AND/OR ENGINEER PRIOR TO INSTALLATION OF GEOMEMBRANE.
15. CONTRACTOR SHALL PROVIDE MEANS TO PROTECT SUBGRADE FROM EROSION, STORM WATER, AND HEAVY EQUIPMENT TRAFFIC. DAMAGE TO SUBGRADE SHALL BE REPAIRED AT THE CONTRACTOR'S EXPENSE.

HORIZONTAL DATUM:
ILLINOIS STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD83.

VERTICAL DATUM:
LOCAL PLANT DATUM

BENCHMARK 2:
NORTHEAST CORNER OF CONCRETE DISCHARGE STRUCTURE. CHISELED "+" IN CONCRETE ELEVATION 468.75 FT.

SOURCE NOTES:
THIS DRAWING WAS DEVELOPED FROM A SURVEY MAURER STUTZ, INC. DATED SEPTEMBER 7, 2010, DRAWING NO. 23210023.
LOCATION OF BASIN AND ACCESS RAMP TAKEN FROM MIDWEST GENERATION DRAWING NO. 5295 C5001-2, DATED 6-26-1980.
BASIN SUBGRADE AND SITE IMPROVEMENTS FROM A SURVEY PROVIDED BY MILLENNIA PROFESSIONAL SERVICES, MARCH 2011.

N

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SCALE IN FEET

	REVISION	DATE	APP'D BY
6.			
5.			
4.			
3.			
2.	RECORD DOCUMENTATION	06/08/11	HMS
1.	ISSUED FOR BID	10/06/10	HMS
0.	ISSUED FOR PERMIT	06/30/10	HMS

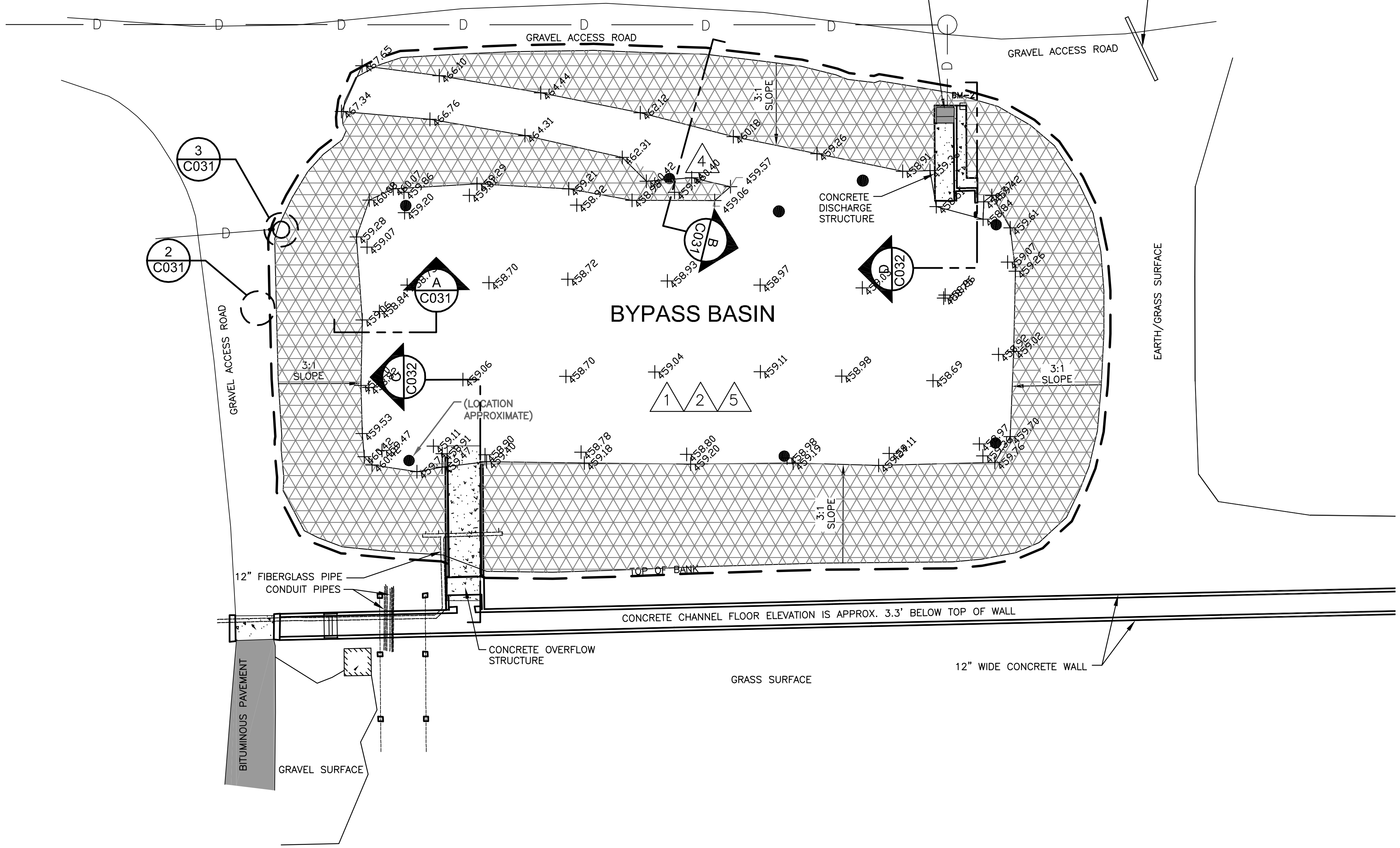
NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 1965/5.4
DRAWN BY: KNW 06/30/10
CHECKED BY: RJG 06/30/10
APPROVED BY: HMS 06/30/10

LINER SUBGRADE PREPARATION

BYPASS BASIN LINER REPLACEMENT
MIDWEST GENERATION
POWERTON POWER STATION
PEKIN, ILLINOIS

DRAWING NO: D1965C020-02
REFERENCE: -
SHEET NO. C020



LEGEND

—— D ——	UNDERGROUND DISCHARGE PIPE
---▫---	ABOVEGROUND INTAKE PIPE
—— ——	ANCHOR TRENCH
× 459.11	TOP OF WARNING LAYER (ELEVATION, FT.)
●	MARKER POST LOCATION
□ BM-2	BENCHMARK 2
(hatch)	HDPE GEOMEMBRANE

HORIZONTAL DATUM:
ILLINOIS STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD83.

VERTICAL DATUM:
LOCAL PLANT DATUM

BENCHMARK 2:
NORTHEAST CORNER OF CONCRETE DISCHARGE STRUCTURE. CHISELED "+" IN CONCRETE ELEVATION 468.75 FT.

CONTRACTOR NOTES: △
1. CONTRACTOR SHALL INSTALL 60 MIL HDPE, WHITE, TEXTURED GEOMEMBRANE IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION PRIOR TO PLACEMENT OF THE WARNING LAYER. CONTRACTOR SHALL PROVIDE AND FOLLOW AN APPROVED GEOMEMBRANE LAYOUT PLAN.
2. GEOMEMBRANE SHALL BE ANCHORED INTO 2.5 FEET DEEP TRENCHES ALONG TOP OF BASIN BANK, AS SHOWN ON SHEET C031. CONTRACTOR SHALL ADVISE OWNER AND/OR ENGINEER IF PROPOSED LOCATION FOR ANCHOR TRENCH IS NOT POSSIBLE.
3. CONTRACTOR SHALL PLACE 12-OZ. NON-WOVEN GEOTEXTILE, CUSHION MATERIAL AND WARNING LAYER MATERIAL OVER THE GEOMEMBRANE AT BASE AND 4 FEET ON SIDE SLOPES FOLLOWING ENGINEER APPROVAL AND PASSING QUALITY CONTROL RESULTS IN ACCORDANCE WITH TECHNICAL SPECIFICATIONS (SEE SHEET C031).
4. CONTRACTOR SHALL PLACE 2 LAYERS OF 12-OZ. NONWOVEN GEOTEXTILE, CUSHION AND WARNING LAYER MATERIALS OVER THE GEOMEMBRANE ON THE RAMP, AS SHOWN ON SHEET C031.
5. RESTORE AREAS DISTURBED BY EQUIPMENT AND MATERIAL LAYDOWN.
6. CONTRACTOR SHALL PROVIDE SURVEY DOCUMENTATION OF THE ITEMS LISTED IN THE TECHNICAL SPECIFICATIONS.
7. CONTRACTOR SHALL PERFORM A LEAK LOCATION SURVEY IN ACCORDANCE WITH TECHNICAL SPECIFICATIONS.

SOURCE NOTES:
THIS DRAWING WAS DEVELOPED FROM A SURVEY MAURER STUTZ, INC. DATED SEPTEMBER 7, 2010, DRAWING NO. 23210023.
LOCATION OF BASIN AND ACCESS RAMP TAKEN FROM MIDWEST GENERATION DRAWING NO. 5295 C5001-2, DATED 6-26-1980.
BASIN SUBGRADE AND SITE IMPROVEMENTS FROM A SURVEY PROVIDED BY MILLENNIA PROFESSIONAL SERVICE, MARCH 2011.

N

0 10 20 40
SCALE IN FEET

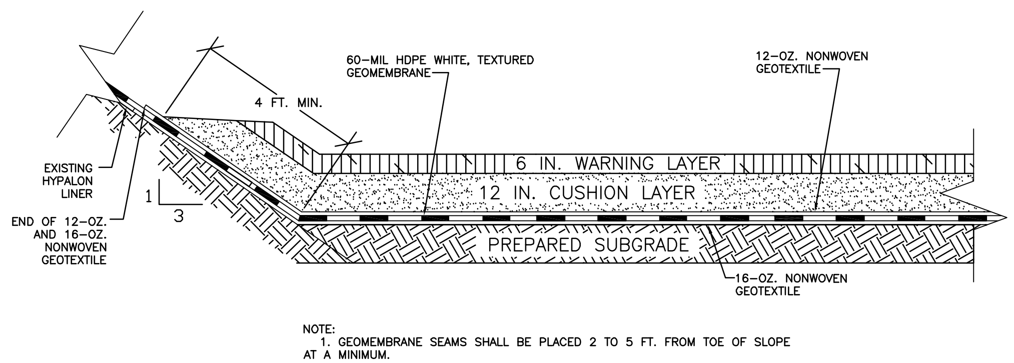
REVISION:		DATE:	APP'D BY:
6.			
5.			
4.			
3.			
2.	RECORD DOCUMENTATION	06/08/11	HMS
1.	ISSUED FOR BID	10/06/10	HMS
0.	ISSUED FOR PERMIT	06/30/10	HMS

NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 1965.5/5.4
DRAWN BY: KNW 06/30/10
CHECKED BY: RJG 06/30/10
APPROVED BY: HMS 06/30/10

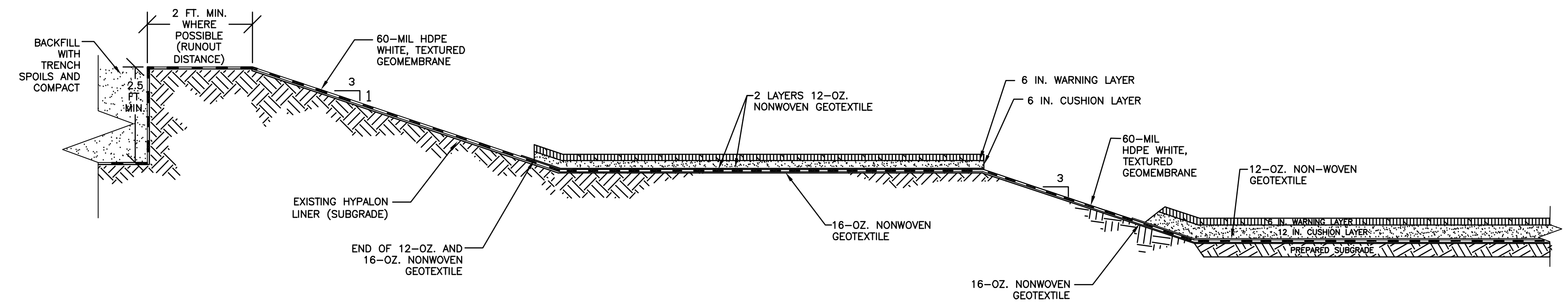
WARNING LAYER PLAN
BYPASS BASIN LINER REPLACEMENT
MIDWEST GENERATION
POWERTON POWER STATION
PEKIN, ILLINOIS

DRAWING NO: D1965C030-02
REFERENCE: -
SHEET NO. C030



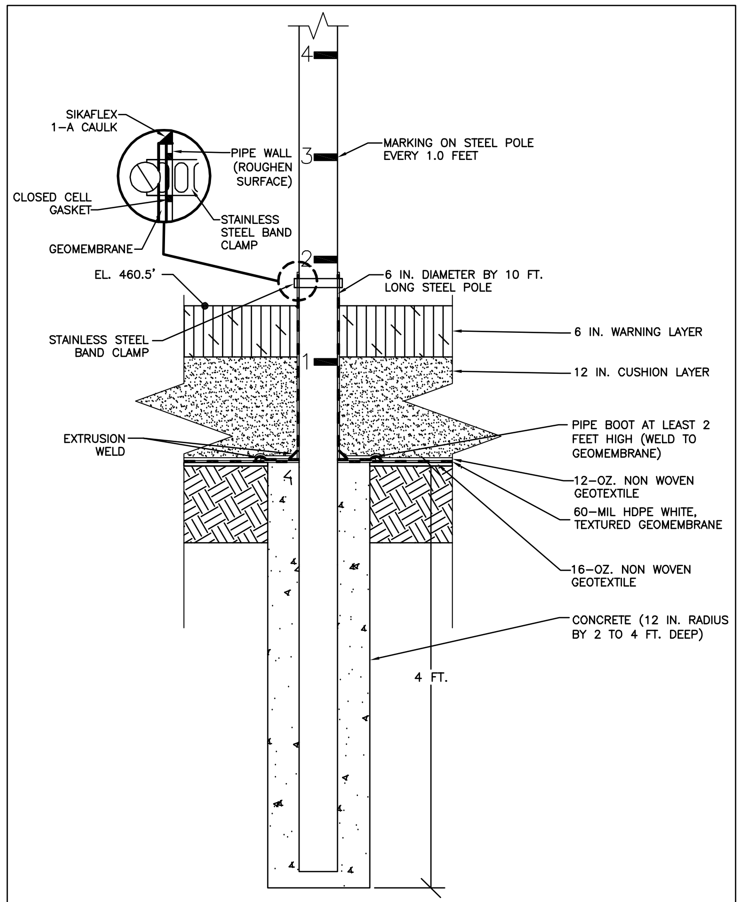
NOTE:
1. GEOMEMBRANE SEAMS SHALL BE PLACED 2 TO 5 FT. FROM TOE OF SLOPE AT A MINIMUM.

A / C030 SLOPE TRANSITION SECTION
NOT TO SCALE

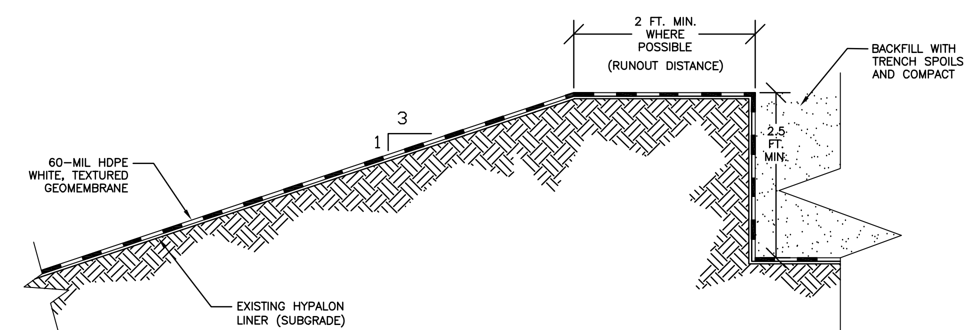


NOTE:
16-OZ. NONWOVEN GEOTEXTILE TO BE PLACED AT BASE OF BASIN AND WHERE HYPALON LINER DOES NOT EXIST OR WAS REMOVED OF PREPARED SUBGRADE

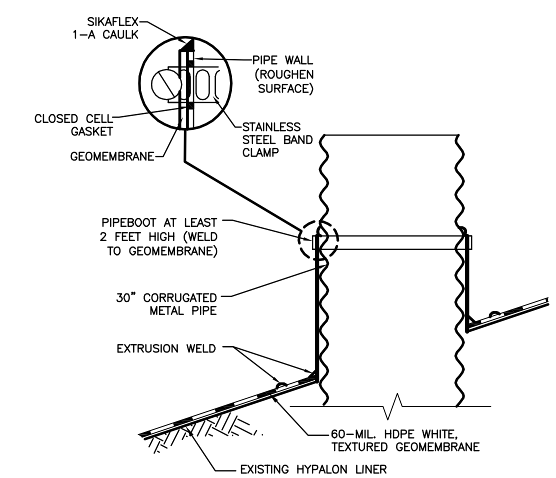
B / C030 RAMP SECTION
NOT TO SCALE



1 / C020 MARKER POST DETAIL
NOT TO SCALE



2 / C030 ANCHOR TRENCH DETAIL
NOT TO SCALE



3 / C030 OVERFLOW PIPE DETAIL
NOT TO SCALE

NOT FOR CONSTRUCTION

6.			
5.			
4.			
3.			
2.	RECORD DOCUMENTATION	06/16/11	HMS
1.	ISSUED FOR BID	10/06/10	HMS
0.	ISSUED FOR PERMIT	06/30/10	HMS
	REVISION:	DATE:	APP'D BY:

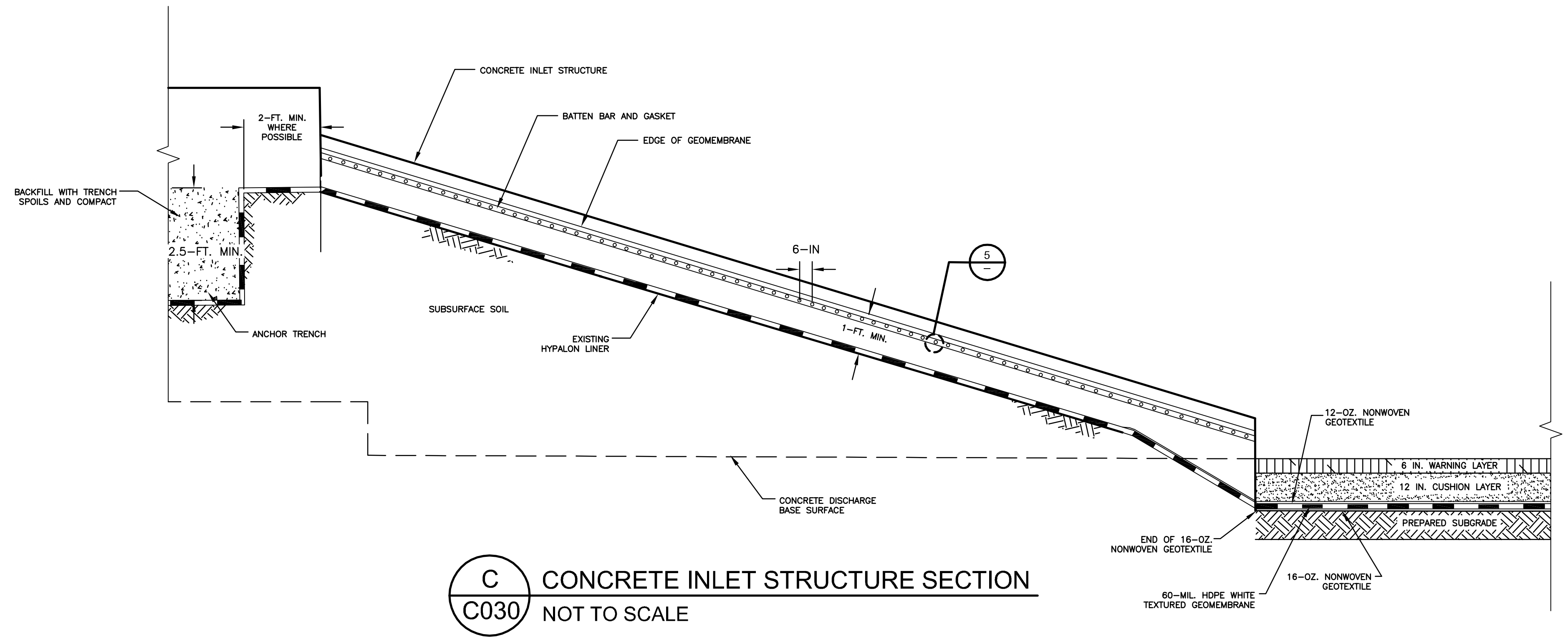
NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 1965/5.4
DRAWN BY: KNW 06/30/10
CHECKED BY: RJG 06/30/10
APPROVED BY: HMS 06/30/10

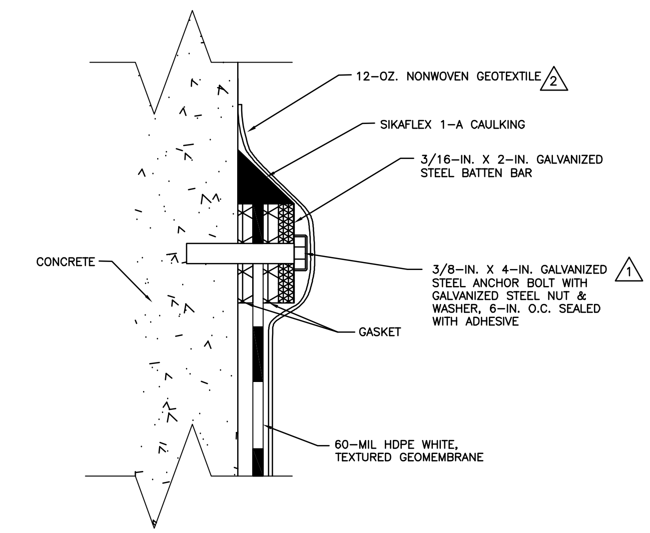
DETAILS AND SECTIONS

BYPASS BASIN LINER REPLACEMENT
MIDWEST GENERATION
POWERTON POWER STATION
PEKIN, ILLINOIS

DRAWING NO: D1965C031-02
REFERENCE:
SHEET NO. C031

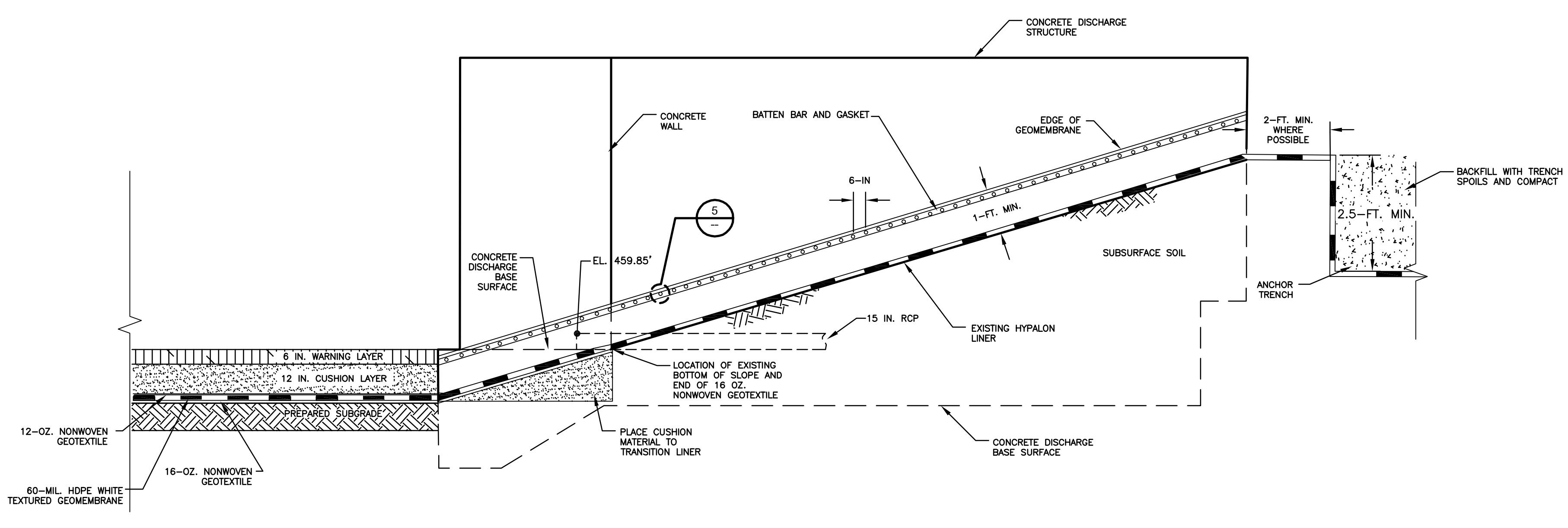


C / C030 — CONCRETE INLET STRUCTURE SECTION
NOT TO SCALE



NOTE:
1. ANCHOR BOLTS 6 IN. ON CENTER.
2. 12-OZ. NONWOVEN GEOTEXTILE TO BE USED TO PROTECT GEOMEMBRANE BELOW CUSHION/WARNING LAYERS.

5 / -- — BATTEN BAR ATTACHMENT
NOT TO SCALE



D / - — CONCRETE DISCHARGE STRUCTURE SECTION
NOT TO SCALE

6.			
5.			
4.			
3.			
2.	RECORD DOCUMENTATION	06/16/11	HMS
1.	ISSUED FOR BID	10/06/10	HMS
0.	ISSUED FOR PERMIT	06/30/10	HMS
	REVISION:	DATE:	APP'D BY:

NATURAL RESOURCE TECHNOLOGY

NOT FOR CONSTRUCTION

DETAILS AND SECTIONS

BYPASS BASIN LINER REPLACEMENT
MIDWEST GENERATION
POWERTON POWER STATION
PEKIN, ILLINOIS

PROJECT NO.	1965/5.4
DRAWN BY:	KNW 06/30/10
CHECKED BY:	RJG 06/30/10
APPROVED BY:	HMS 06/30/10

DRAWING NO: D1965C032-02
REFERENCE:
SHEET NO. C032

ATTACHMENT C

NRT CQA DAILY FIELD REPORTS

FIELD NOTE SUMMARY

Project Number / Task: 1965.0/4.0

Project Names: Metal Cleaning Basin Liner Replacement

Date:	November 1, 2010
Work Scope:	Subgrade Inspection – Metal Cleaning Basin
NRT Staff:	John Swanson
Contractors:	Otto Baum – Dave Stewart
Weather:	Partly Sunny 50s degree F
Equipment:	Digital camera
Field Comments:	11/1 • I arrive on site around 0830, checked in at gate house. • Completed contractor safety training with Mark Kelly of Midwest Gen • Otto Baum preparing weir wall, removing steel gates, exposed ends, northern side slope requires further grading/shaping. • Hypalon liner removed from all side slopes. • Additional material added to side slopes and base of basin, soft spots repaired, and rough grading and shaping complete. • Concrete inlet aprons on south end of basin demolished. • West side of concrete ramp to be exposed. • Question from Otto Baum regarding specific construction of joints and water stops in weir extension. Need clarification by 11/2 am. • Asked Dave Stewart to remove large pieces of hypalon under newly placed material on side slopes and further compact eastern side slope. • Concrete form layout and rebar over the next couple of days. Concrete pour likely Wednesday or Thursday according to Dave S. • Left site at 1400
Scope Changes:	• None
Site Conditions:	In good condition, compaction of eastern side slope and grading of northern side slope required.

Signature: John P. Swanson

Date: 11/1/10

View of basin subgrade from the northwest corner of the basin facing southeast. Note concrete aprons and hypalon removed.

View of excavated weir wall during steel gate removal.

FIELD NOTE SUMMARY

Project Number / Task: 1965.0/4.0
Project Names: Metal Cleaning Basin Liner Replacement

Date:	November 4-5, 2010
Work Scope:	Subgrade and Rebar Inspection – Metal Cleaning Basin
NRT Staff:	John Swanson
Contractors:	Otto Baum – Dave Stewart; CAAW – Brian McKeown
Weather:	Partly Sunny 40s-50s degree F
Equipment:	Digital camera
Field Comments:	11/4 • I arrive on site around 1155, checked in at gate house. • CAAW inspected and approved subgrade with some general smoothing. Inspected and approved test anchor trench. • CAAW inspected and approved in place concrete structures. Plan to attach batten strips over the top of end of existing concrete ramp due to elevation of subgrade. • Inspected rebar in weir wall extension. Rebar installed and sealed with adhesive per rebar submittal except two pieces of bar in ends of existing walls. Requested that those to be installed on each end. • Bottom toes on apron could only be excavated ~12 inches due to poz-o-pac. Top toe increased to 3 feet except western apron which was 18 inches due to poz-o-pac. • Weld strips installed in concrete forms for aprons. Additional shipped overnight for weir wall. • Left site at 1700 11/5 • I arrive on site around 0800, checked in at gate house. • Rebar added to ends of weir wall. Epoxy bonding agent added to top. Waterstops in place and weld strips installed. • Whitney Materials Testing onsite for air test, slump, and cylinders. • Pour began at 0915 and continued ~1415, covered concrete with plastic sheeting • Left site at 1430
Scope Changes:	• None
Site Conditions:	In good condition.

Signature: [signature] Date: 11/5/10

John P. Swanson

View of the concrete apron forms. Note HDPE weld strip.

View of the construction of the concrete apron.

FIELD NOTE SUMMARY

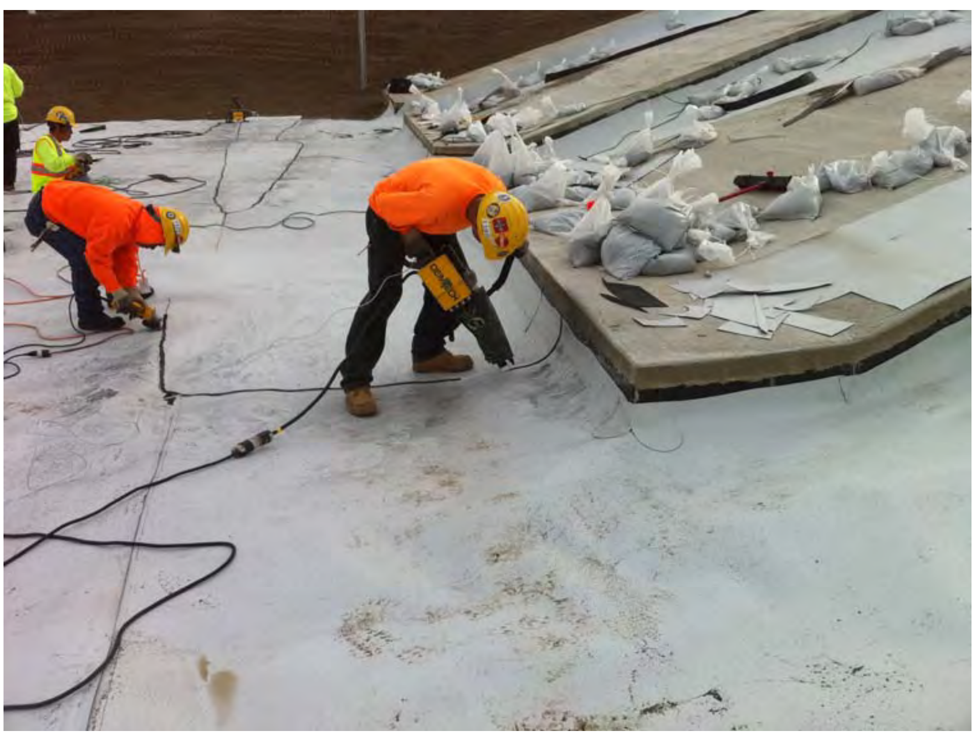
Project Number / Task: 1965.0/4.0
Project Names: Metal Cleaning Basin Liner Replacement

Date:	November 9-10, 2010
Work Scope:	Liner Installation – Metal Cleaning Basin
NRT Staff:	John Swanson
Contractors:	Otto Baum – Dave Stewart; CAAW
Weather:	Partly Sunny 60s-70s degree F
Equipment:	Digital camera
Field Comments:	<u>11/9</u> • I arrive on site around 0730, checked in at gate house. • CAAW onsite filling sand bags. Began installing 16oz geotextile on western sidewall, thermally bonding the seams, and following with HDPE liner and double track seaming. • Otto Baum to cover wing wall with soil, clean out around ramp, cut protruding wings off the sides of aprons. • Otto Baum excavating anchor trench on east side of basin. • 16 oz geotextile and HPDE liner installed on southern half of western sidewall and placed on southern sidewall around aprons. • Pressure testing of seams tomorrow, destructive testing of seam samples completed. • Left site at 1630 <u>11/10</u> • I arrive on site around 0745, checked in at gate house. • CAAW pressure testing seams, detailing/welding around aprons, and destructive testing of extrusion welding and seaming samples completed. • Otto Baum completed anchor trench, covered weir wing walls, and cleaned out around ramp. • CAAW finished 16oz geotextile and liner installation on the northern portion of the west sidewall and around aprons to the southeast corner. • Left site at 1430
Scope Changes:	• None
Site Conditions:	In good condition.

Signature: [signature] Date: 11/11/10

John P. Swanson

View of 16 oz geotextile being placed on the western slope and thermally bonded at the seams.



View of extrusion seaming around aprons.

FIELD NOTE SUMMARY

Project Number / Task: 1965.0/4.0

Project Names: Metal Cleaning Basin Liner Replacement

Date:	November 11-12, 2010
Work Scope:	Liner Installation – Metal Cleaning Basin
NRT Staff:	John Swanson
Contractors:	Otto Baum – Dave Stewart; CAAW
Weather:	Partly Sunny 60s-70s degree F
Equipment:	Digital camera
Field Comments:	11/11 • I arrive on site around 0730, checked in at gate house. • CAAW finished installing 16oz geotextile and HDPE liner on northern and eastern sidewalls. • CAAW seamed remaining panels, welded liner to weir wall, booted marker posts, pressure tested remaining seams, destructive tested sample seams. • Otto Baum backfilled and compacted the western and southern portions of the anchor trench in two lifts. • Left site at 1530 11/12 • I arrive on site around 0745, checked in at gate house. • CAAW finished welding liner to weir wall, repaired damaged areas and seam defects, vacuum tested extrusion seams, attached liner to existing concrete structures with batten strips and caulk, and placed 12oz geotextile over liner and ~4 feet up side walls.. • Otto Baum continued backfilling anchor trench. • Left site at 1230
Scope Changes:	• None
Site Conditions:	In good condition.

Signature: ______________________ Date: 11/13/10

John P. Swanson

View of liner being attached to weir wall HDPE weld strip.

View of extrusion seaming vacuum testing.

FIELD NOTE SUMMARY

Project Number / Task: 1965.0/4.0
Project Names: Metal Cleaning Basin Liner Replacement

Date:	November 17-19, 2010
Work Scope:	Cushion and Warning Layer Placement – Metal Cleaning Basin
NRT Staff:	John Swanson
Contractors:	Otto Baum – Dave Stewart; CAAW
Weather:	Partly Sunny 40s-50s degree F
Equipment:	Digital camera
Field Comments:	<u>11/17</u> • I arrive on site around 0745, checked in at gate house. • Cushion layer placement – dumped on concrete ramp and spread with skid loader keeping 1 ft between equipment and liner. • Cushion layer placed over approximately half of basin. • Left site at 1500 <u>11/18</u> • I arrive on site around 0745, checked in at gate house. • Cushion layer placement continued. Laser guided grading box and laser level used for final elevation. • Left site at 1500 <u>11/19</u> • I arrive on site around 0745, checked in at gate house. • Cushion layer placement completed and graded with laser guided grading box on skid loader. • Started placing white rock CA-6 as warning layer. • Left site at 1230
Scope Changes:	• None
Site Conditions:	In good condition.

Signature: [signature] Date: 11/20/10

John P. Swanson

View of liner placement of cushion layer sand.

View of finished cushion layer and beginning of warning layer.

FIELD NOTE SUMMARY

Project Number / Task: 1965.0/4.0

Project Names: Metal Cleaning Basin Liner Replacement

Date:	November 24, 2010
Work Scope:	Warning Layer Inspection – Metal Cleaning Basin
NRT Staff:	John Swanson
Contractors:	Offsite
Weather:	Rainy mid 30s degree F
Equipment:	Digital camera
Field Comments:	11/24 • I arrive on site around 1115, checked in at gate house. • Otto Baum left around 10:30 due to poor weather. • Warning layer placed and compacted. Some clean up and finishing required around ramp, aprons, and marker posts. Called Dave with Otto Baum, scheduled to be completed before leak detection survey. • Rip rap placed north of weir wall. • Left site at 1230
Scope Changes:	• None
Site Conditions:	In good condition. Some cleanup and finishing/smoothing of warning layer required around ramp, aprons, and marker posts.

Signature: John P. Swanson

Date: 11/25/10

View of warning layer in the southern end of basin where additional cleanup and finishing is required.

View of finished rip rap north of weir wall.

FIELD NOTE SUMMARY

Project Number / Task: 1965.0/4.0
Project Names: Metal Cleaning Basin Liner Replacement

Date:	March 17, 2011
Work Scope:	Leak Location Survey – Metal Cleaning Basin
NRT Staff:	Heather Simon
Contractors:	Otto Baum – Dave Stewart, Leak Location Services – John Ortiz
Weather:	
Equipment:	Digital camera
Field Comments:	12/2 • I arrive on site around 0900, checked in at gate house. • I arrive at basins and meet with Dave Stewart and John Ortiz. • Otto Baum is exposing the liner at the toe of the ramp to isolate the weld strip. • Begin leak location survey at 1130. • False readings from the geotextile locked on aprons. Otto Baum removed the geotextile at the base of the aprons since it's not needed. • Survey completed at 1500. One 3-inch leak located under the warning layer ~100 ft from the weir wall. • Otto Baum will coordinate with Clean Air and Water to repair the leak.
Scope Changes:	• None
Site Conditions:	In good condition.

Signature: [signature] Date: 3/18/11
Heather M. Simon

View Looking Northwest Along Ramp.

FIELD NOTE SUMMARY

Project Number / Task: 1965.5/5.3
Project Names: Bypass Basin Liner Replacement

Date:	November 11-12, 2010
Work Scope:	Subgrade Preparation – Bypass Basin
NRT Staff:	John Swanson
Contractors:	Otto Baum – Dave Stewart
Weather:	Partly Sunny 60s-70s degree F
Equipment:	Digital camera
Field Comments:	11/11 • I arrive on site around 0730, checked in at gate house. • Otto Baum removing 16 inches of pozopac from the base of the basin and removing existing hypalon liner. • Completed approximately 75% of gross removal of pozopac • Left site at 1530 11/12 • I arrive on site around 0745, checked in at gate house. • Otto Baum continuing removal of pozopac and hypalon liner. • Began final grading. • Left site at 1230
Scope Changes:	• None
Site Conditions:	In good condition.

Signature: Date: 11/12/10

John P. Swanson

View of pozopac removal and subgrade preparation.

View of pozopac load out and subgrade preparation.

FIELD NOTE SUMMARY

Project Number / Task: 1965.5/5.3
Project Names: Bypass Basin Liner Replacement

Date:	November 17-19, 2010
Work Scope:	Liner Installation – Bypass Basin
NRT Staff:	John Swanson
Contractors:	Otto Baum – Dave Stewart; CAAW
Weather:	Partly Sunny 40s-50s degree F
Equipment:	Digital camera
Field Comments:	11/17 • I arrive on site around 0745, checked in at gate house. • CAAW installed 16oz geotextile and HDPE liner in entire basin. • CAAW seamed remaining panels, began pressure testing seams, destructive tested sample seams. • Left site at 1500 11/18 • I arrive on site around 0745, checked in at gate house. • CAAW booted marker posts, installed batten strips and caulk on existing concrete structures, finished pressure testing, patched seams, vacuum tested patches. • Left site at 1500 11/19 • I arrive on site around 0745, checked in at gate house. • Liner surveyed including seams, anchor trench, repairs, patches, and marker posts • CAAW installed and thermally bonded 12 oz geotextile. A double layer was installed on the ramp. • Otto Baum backfilled anchor trench. • Left site at 1230
Scope Changes:	• None
Site Conditions:	In good condition.

Signature: [signature] Date: 11/19/10

John P. Swanson

View of 16 oz geotextile in place and HDPE liner being placed.

View of finished liner with finished 12 oz goetextile .

FIELD NOTE SUMMARY

Project Number / Task: 1965.5/5.3
Project Names: Bypass Basin Liner Replacement

Date:	November 24, 2010
Work Scope:	Warning Layer Inspection – Bypass Basin
NRT Staff:	John Swanson
Contractors:	Offsite
Weather:	Rainy mid 30s degree F
Equipment:	Digital camera
Field Comments:	11/24 • I arrive on site around 1115, checked in at gate house. • Otto Baum left around 10:30 due to poor weather. • Ramp built with 6 in of cushion layer and 6 in of rolled warning layer. • Cushion layer partially placed in the southern portion of the basin. Remaining cushion and warning layers will be placed when weather allows. • Left site at 1230
Scope Changes:	• None
Site Conditions:	In good condition.

Signature: John P. Swanson

Date: 11/24/10

View of partially placed cushion layer in southern portion of the basin.

View of finished ramp into bypass basin.

FIELD NOTE SUMMARY

Project Number / Task: 1965.5/5.3
Project Names: Bypass Basin Liner Replacement

Date:	December 1, 2010
Work Scope:	Subgrade and Warning Layer Inspection – Bypass Basin
NRT Staff:	John Swanson
Contractors:	Otto Baum
Weather:	Overcast 25 degrees F
Equipment:	Digital camera
Field Comments:	<u>11/24</u> • I arrive on site around 0715, checked in at gate house. • Otto Baum onsite pumping water and placing warning layer on the southern portion of the basin. • Cushion layer is solid and holding up well to equipment with the exception of the a few areas in the northern portion of the basin. Otto Baum to continue pumping water out of basin. • Soft material will be removed and replaced with dry material before warning layer is placed over. • Left site at 1000
Scope Changes:	• None
Site Conditions:	In good condition. Pumping and material placement required in northern portion of basin.

Signature: John P. Swanson

Date: 12/1/10

View of soft spots and ponding in the northern portion of the basin.

View of placement of warning layer in the southern portion of the basin.

FIELD NOTE SUMMARY

Project Number / Task: 1965.0/5.3
Project Names: Bypass Basin Liner Replacement

Date:	December 2, 2010
Work Scope:	Leak Location Survey – Bypass Basin
NRT Staff:	Eric Tlachac
Contractors:	Otto Baum – Dave Stewart, Leak Location Services – John Ortiz
Weather:	Cloudy with flurries, 30s degree F
Equipment:	Digital camera
Field Comments:	12/2 • I arrive on site around 0900, checked in at gate house. • I arrive at basins and meet with Dave Stewart and John Ortiz. • Otto Baum is working on the metal cleaning basin warning layer, and the leak location survey is being prepared on the bypass basin. • The leak location survey cannot be performed on the metal cleaning basin because it is frozen. Wait until spring to perform. • Begin leak location survey calibration on bypass basin at 1030. Calibration is successful. • Begin leak location survey at 1100. • Survey completed at 1310. One leak located at the bottom of the ramp near the outer marker post. • Clean Air and Water scheduled to repair the leak on Monday (12/6) • Leak location survey calibration failed on the Metal Cleaning Basin. • Will flood the metal cleaning basin in attempt to melt ice and will attempt calibration again tomorrow. • Left site a 1615.
Scope Changes:	• None
Site Conditions:	In good condition. Metal cleaning basin has about 1 inch of ice on bottom preventing the leak location survey.

Signature: [signature] Eric J. Tlachac   Date: 12/2/10

Bypass Field Notes 20101202

View of the bypass basin during the leak location survey.

View of the uncovered leak in the bypass basin from the detection survey.

EXHIBIT 15

NATURAL RESOURCE TECHNOLOGY
ENVIRONMENTAL CONSULTANTS

234 W. FLORIDA STREET, FIFTH FLOOR
MILWAUKEE, WISCONSIN 53204
(P) 414.837.3607
(F) 414.837.3608

Mr. Mark Kelly
Midwest Generation, LLC
Powerton Station
13082 East Manito Road
Pekin, IL 61554

July 18, 2014
(2113.2)

RE: Construction Documentation Transmittal
Ash Surge Basin Liner Replacement
Midwest Generation Powerton Generation Station

Dear Mr. Kelly:

Natural Resource Technology, Inc. (NRT) has prepared this correspondence to transmit construction record documents for the liner replacement completed in 2013 for the Ash Surge Basin at the Powerton Station.

Documentation of the major construction components, including field reports, laboratory test results, and documentation drawings are attached to this letter.

Please contact NRT if you have any questions or comments regarding this transmittal.

Sincerely,

NATURAL RESOURCE TECHNOLOGY, INC.

Eric J. Tlachac, PE
Senior Engineer

Joseph R. Ridgway, PE
Environmental Engineer

ATTACHMENTS:

Attachment A:	Daily Field Reports
Attachment B:	Borrow Source Samples
Attachment C:	Geosynthetic Certifications
	C1: Geomembrane Certification
	C2: Geotextile Certification
Attachment D:	Geosynthetics Installer Submittals
	D1: Field Tensiometer Calibration
	D2: Installer Crew Resumes
	D3: Subgrade Acceptance
	D4: Geosynthetic Material Installation Certificate
	D5: Geomembrane Installation Warranties
Attachment E:	Geosynthetics Installation
	E1: Trial Weld Summary
	E2: Panel Placement Summary
	E3: Panel Seaming Summary
	E4: Repair Summary
	E5: Non-Destructive Test Summary
Attachment F:	Liner Integrity Survey Reports
	F1: Bare Liner Integrity Survey Report
	F2: Soil Covered Liner Integrity Survey Report
Attachment G:	Construction Documentation Drawing Set

ATTACHMENT A

DAILY FIELD REPORTS

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	July 3, 2013
Work Scope:	Dredging and subgrade preparation
NRT Staff:	Joseph R. Ridgway
Contractors:	Terra Contracting
Weather:	High 60s, sunny
Equipment:	Digital camera

Field Comments:

- Arrive onsite around 08:20, check in at guard shack
- Inspect Secondary Ash Settling Basin in operation, visually survey exposed liner along perimeter and attachments – in good condition
- Status update from Ricky Burnett (Terra)
- Discussion with Bill Gaynor (MWG) and Ricky
- Slope to weir wall – intended to not alter treatment processes
    - Bill questions need for slope; will discuss with Maria Race for permitting perspective
    - Bill proposes not placing cushion and warning layer instead of sloping subgrade to maintain weir wall height; Joseph recommends relocation of marker posts and considering additional post to clearly identify area where liner is not covered, if this approach is taken
    - Will discuss with group after Bill discusses with Maria
- Trenching along western slope; road prevents specified 2-foot clearance for trench
    - Ricky proposes excavating trench with 12-inch backhoe right next to road, backfilling, and placing road subgrade material on top to transition to road – Joseph and Bill agree
- Uneven Poz-O-Pac bottom; ok if gradual transition, not ok if edges or potholes present
- Connection of liner to toe of ramp; NRT will make recommendations when ramp is exposed, will likely involve connection to base of ramp and cover with cushion and warning layer to 4 feet up ramp
- Inspect condition of Poz-O-Pac on slopes; generally in good condition and can remain in place
    - Some soft or broken spots will require excavation and backfilling with cushion material
    - Transition to upper slope must remain smooth so that no stress is put on liner
- Ash removal; varying degrees of removal and difficulty due to condition of subgrade
    - Bill and Joseph confirm removal of all measurable ash, which will likely require scraping along Poz-O-Pac and some replacement of subgrade material
- Schedule update – Terra plans to:

	- Finish dredging in 2 weeks, by 07/17/13 - Continue ash removal, removal of soft spots, and backfilling of subgrade next week, and finish in 6 week, by 08/19/13 - Have subgrade ready for liner construction by 08/19/13 • Offsite around 11:30
Scope Changes:	• Anchor trench along west slope will not have 2-foot clearance and will be covered with road subgrade material to transition to access road • Poz-O-Pac will remain on slopes, except where it does not provide suitable subgrade
Site Conditions:	Site in good condition

Signature: JRR
Joseph R. Ridgway, PE

Date: 07/08/13

South-facing view of eastern slope, Poz-O-Pac and transition in good condition, some ash remains that will be removed

South-facing view of top of western slope, anchor trench will be constructed next to road, road material to be placed on top for transition to road

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.2
Project Name: Ash Surge Basin Liner Replacement

Date:	August 12, 2013
Work Scope:	Sub-base preparation and geotextile installation
NRT Staff:	Edwards Effiong & Joseph Larson
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 80s, sunny
Equipment:	Digital camera
Field Comments:	• Arrive onsite around 07:20, check in at guard shack • Inspect Secondary Ash Settling Basin state and material on site – basin in good condition except for a small wet spot o 38 HDPE geomembrane rolls o 153 geotextile rolls and one partial roll left over from secondary basin • Status update from Erich Hetke (Terra) o Survey of basin done but results not in from surveyor • Terra commenced digging the anchor trench and completed 829.7 ft • Clean Air and Water Systems (CAAWS) commenced laying the geotextile working from the south end of the basin at 13:16 and called it a day at 16:26 o 14.5 rolls expended today • Offsite around 15:00
Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/12/13

Terra Crew digging the anchor trench around the basin (looking southwest).

CAAWS crew filling sand bags ahead of the day's work.

Heat bonding geotextile seams (looking east).

Extent of work completed on Day 1, south end of basin (looking southeast)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.2
Project Name: Ash Surge Basin Liner Replacement

Date:	August 13, 2013
Work Scope:	Geotextile Installation
NRT Staff:	Edwards Effiong, Joseph Larson
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 70s, cloudy
Equipment:	Digital camera
Field Comments:	• Arrive onsite around 06:50, check in at guard shack • CAAWS continued with laying of the geotextile o 23.5 rolls used • Brian McKeown of CAAWS was on site at 09:00 o Status check on the progress of work and his workers • Terra continued digging the anchor trench but there was equipment delays that affected the laying of HDPE o HDPE expected to start Wednesday • Offsite around 16:00
Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/13/13

Extent of the day's nonwoven geotextile installation (looking northeast).

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.2
Project Name: Ash Surge Basin Liner Replacement

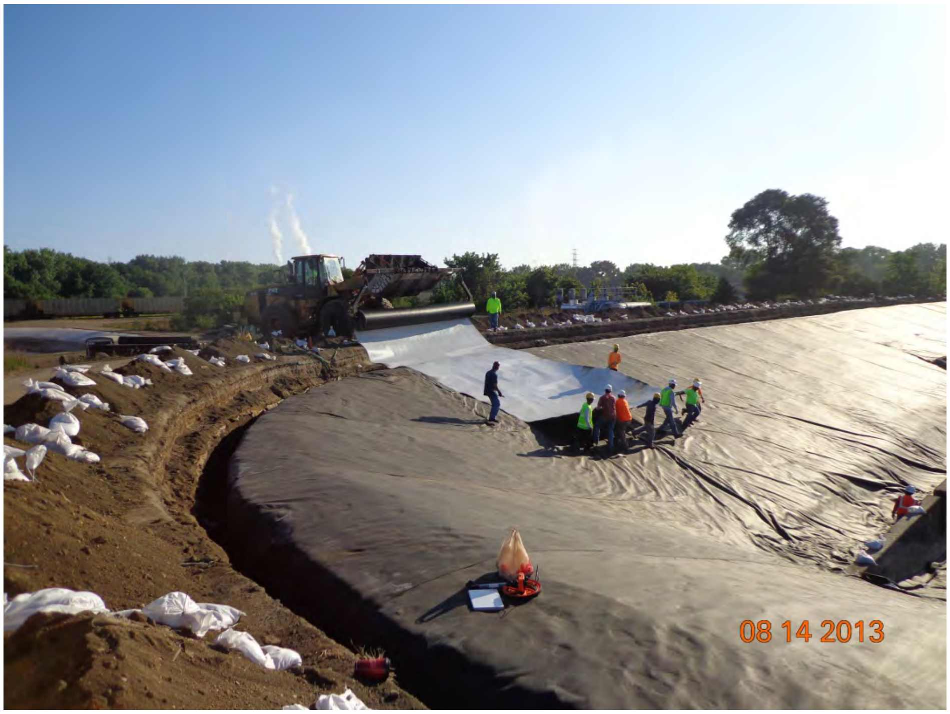
Date:	August 14, 2013
Work Scope:	Geomembrane installation
NRT Staff:	Edwards Effiong & Joseph Larson
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 70s, cloudy
Equipment:	Digital camera

Field Comments:	• Arrive onsite around 06:57, check in at guard shack
	• Tailgate meeting
	• CAAWS begins laying HDPE at 08:00 and ends at 17:00
	   o 13 rolls were used
	   o 10 out of the 13 rolls were not completely used. These partial rolls will be used on other sections of the basin
	• CAAWS also completed seaming and air testing the fusion welded geomembrane seams
	• Terra continued digging the anchor trench
	• Offsite around 17:00

Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/14/13



Rolling out the first HDPE Panel (looking northeast)

Seaming of the geomembrane panels (looking west)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.2
Project Name: Ash Surge Basin Liner Replacement

Date:	August 15, 2013
Work Scope:	Geomembrane installation
NRT Staff:	Edwards Effiong, Joseph Larson, & Joseph Ridgeway
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 70s, cloudy
Equipment:	Digital camera
Field Comments:	• Arrive onsite around 07:00, check in at guard shack • CAAWS continued with liner deployment until 13:14 o 9 HDPE (partial rolls) used o More fabric put out towards the northern reaches of the basin after the completion of HDPE installation activities o 18 rolls of nonwoven geotextile fabric deployed • CAAWS also commenced air testing of the fusion welded geomembrane seams • Terra continued digging the anchor trench • Offsite around 17:00
Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/15/13

Extent of geotextile and HDPE deployment completed (looking north)

Deployment of geotextile (looking west)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	August 16, 2013
Work Scope:	Subgrade Preparation and Geomembrane Installation
NRT Staff:	Edwards Effiong & Joseph Larson
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 70s, cloudy
Equipment:	Digital camera

Field Comments:	• Arrive onsite around 07:00, check in at guard shack
	• CAAWS concentrated on the following detail work:
	  o Extrusion welds on geomembrane repair locations
	  o Boot around risers (geomembrane liner penetrations)
	  o Batten strips on outfall and around structures
	• Terra asked for more clarification on the warning layer design for planning purposes
	• Terra continued digging the anchor trench and grading of the south end of the basin
	• Offsite around 17:00

Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/16/13

Batten strip connection along the outfall (looking south)

Extrusion weld on a repair location

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	August 17, 2013
Work Scope:	Geomembrane Installation and Subgrade Preparation
NRT Staff:	Edwards Effiong & Joseph Larson
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 70s, cloudy
Equipment:	Digital camera

Field Comments:	• Arrive onsite around 07:00, check in at guard shack
	• CAAWS concentrated on the following detail work:
	  o Extrusion welds on repair locations
	  o Boot around risers (geomembrane penetrations)
	  o Batten strips on outfall and around structures
	  o Vacuum testing geomembrane extrusion welds
	• Terra performed documentation survey of geomembrane seams and repairs in preparation for cushion layer placement
	• Terra struck a cable in the trench (Ricky notified MWG)
	• Terra continued digging the anchor trench and grading the south end of the basin
	• Offsite around 15:30

Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/17/13

Caulking liner termination on the weir wall (looking east)

Vacuum testing a repair location

Geomembrane boot installation on a riser (looking west)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	August 19, 2013
Work Scope:	Geosynthetics Installation
NRT Staff:	Edwards Effiong & Joseph Larson
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 80s, cloudy
Equipment:	Digital camera

Field Comments:	• Arrive onsite around 07:00, check in at guard shack
	• CAAWS deployed fabric to the south of the basin
	  o Liner deployment starts at 12:30 and ends at 16:00
	  o 16 rolls of fabrics used
	• Terra informed of minor repairs to be made on inlet wall concrete structure
	• Terra placed clean sand around the overflow structure to bring it up to grade
	• Terra commences repairs on damaged cable
	• Ricky asked for clarification on warning layer design
	• Offsite around 17:00

Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/19/13

Placing sand around overflow structure (looking southeast)

Extent of geosynthetics installation at close of day (looking north)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	August 20, 2013
Work Scope:	Geotextile Installation and Geomembrane Repairs & Quality Control
NRT Staff:	Edwards Effiong & Joseph Larson
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 80s, cloudy
Equipment:	Digital camera
Field Comments:	• Arrive onsite around 07:00, check in at guard shack • CAAWS deployed fabric to the south of the basin o 15 rolls of nonwoven geotextile fabric used • Non-destructive testing continued around the structures using the vacuum box to test geomembrane extrusion welds • Second layer of lining placed over new backfill to bring to grade areas around overflow structure on the east of the basin • Follow-up with Ricky; Bill backs NRT's original approach to warning layer design • Offsite around 17:00
Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/20/13

Second layer of geomembrane placed over clean, backfill sand (looking north)

Extent of fabric deployment to the south (looking southeast)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	August 21, 2013
Work Scope:	Liner deployment and detailing
NRT Staff:	Edwards Effiong & Joseph Larson
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 90s, cloudy
Equipment:	Digital camera
Field Comments:	• Arrive onsite around 07:00, check in at guard shack • Liner deployed from 07:30 to the south of the basin o The southern slope is the last area to be covered with geomembrane • Batten strip installation commenced at the ramp • Air testing performed on the geomembrane seams • Offsite around 18:00
Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/21/13

Geomembrane liner deployment towards the south of the basin (looking south)

Extent of geosynthetics deployment on the south end of the basin (looking east)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	August 22, 2013
Work Scope:	Geomembrane Installation and Repairs
NRT Staff:	Edwards Effiong & Joseph Larson
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 80s, cloudy
Equipment:	Digital camera
Field Comments:	• Arrive onsite around 07:00, check in at guard shack • CAAWS completed the deployment of geosynthetics in the Ash Surge Basin • Detail work commenced, specifically extrusion welding patches on repair locations • Offsite around 17:30
Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/22/13

Extrusion welding a geomembrane repair in progress (looking south)

Repairing geomembrane along the ramp (looking southwest)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	August 23, 2013
Work Scope:	Geomembrane Repairs and Basin Dewatering
NRT Staff:	Edwards Effiong & Joseph Larson
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 80s, cloudy
Equipment:	Digital camera

Field Comments:	• Arrive onsite around 07:00, check in at guard shack
	• Basin flooded due to failure of plug on the outlet structure
	  o Terra started pumping water from 06:00
	  o No vacuum testing on locations under water
	• CAAWS continued detail work to the south of the basin, the ramp, and along the trench (any areas not under water)
	• Update with Bill and Ricky
	  o Terra will embark on leak test on liner on Sunday
	• Offsite around 15:30

Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/23/13

The flooded basin (looking north)

Geomembrane detail work along the inlet ramp (looking northeast)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	August 26, 2013
Work Scope:	Leak location test and liner detail work
NRT Staff:	Edwards Effiong, Joseph Larson, & Joseph Ridgeway
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 90s, Clear
Equipment:	Digital camera

Field Comments:	• Joe arrive onsite around 07:00, check in at guard shack
	• Edwards on site 09:30
	• Joseph on site 11:00
	• Terra continued mopping up sediment from behind the weir
	  o Two spots on the batten strips had failed and were fixed by CAAWS
	  o One repair spot given new repair number, the other was beaded
	• CAAWS continued detail work to the south of the basin along the inlet ramp
	  o Repair locations towards the south of the basin were vacuum tested
	• Documentation survey of repair locations completed for half the basin
	• CAAWS commenced laying out fabric for warning layer
	  o Wet basin renders deployment cumbersome
	  o 9 rolls of geotextile used
	• Offsite around 15:30
	• Back on site at 20:00 to observe leak location test
	  o Offsite at 22:00

Scope Changes:	• Leak Location Test on liner added by Terra as an extra precaution (Terra wants same procedure for Secondary Basin and eliminate any chance of carrying over leaks into the warning layer preparation phase)
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/26/13

Dewatering the flooded basin (looking west)

Deploying nonwoven geotextile fabric for the warning layer (looking southwest)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	August 27, 2013
Work Scope:	Documentation survey and warning layer fabric deployment
NRT Staff:	Edwards Effiong & Joseph Larson
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 90s, Clear
Equipment:	Digital camera

Field Comments:	• Arrive onsite around 07:00, check in at guard shack
	• Leak Test from last night revealed three leak locations
	  o R35, R37, and on batten strip (Panel 2) were repaired and vacuum tested
	  o Three holes (P27, R117, and R93) made from surveyor rod were also fixed
	• Documentation survey of repair locations completed
	• CAAWS continued laying out fabric for warning layer
	  o 43 rolls used
	  o More than ¾ of the basin covered
	• Offsite around 17:10

Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/27/13

Extent of upper nonwoven geotextile installation completed to date (looking southeast)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Names: Ash Surge Basin Liner Replacement

Date:	August 28, 2013
Work Scope:	Warning layer fabric deployment
NRT Staff:	Edwards Effiong & Joseph Larson
Contractors:	Terra Contracting & Clean Air and Water System
Weather:	High 90s, Clear
Equipment:	Digital camera
Field Comments:	• Arrive onsite around 07:00, check in at guard shack o CAAWS completed laying fabric along with panel-for-panel inspection in conjunction with Terra • CAAWS, Terra, and NRT all confirm satisfaction with geosynthetics installation o 4 full and one partial roll of geotextile fabric left o 4 full and 4 partial rolls of geomembrane liner left • Offsite around 09:30
Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: ETE
Edwards T. Effiong

Date: 08/28/13

Extent of the completed geosynthetics (looking southeast)

Geosynthetics liner penetration (looking north)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	September 20, 2013
Work Scope:	Dewatering and placement of cushion layer
NRT Staff:	Joseph R. Ridgway
Contractors:	Terra Contracting
Weather:	70s, cloudy
Equipment:	Digital camera

Field Comments:	• Arrive onsite around 08:45, check in at guard shack
	• Status update from Ricky Burnett (Terra)
	  o Grading/finishing placement of cushion layer is taking much longer than Ricky anticipated
	  o Terra continuing to pump water from the basin
	  o Terra is planning to send a GPS-enabled dozer to the site to aid in placement of specified thickness of cushion and warning layers
	  o Confirm that no extra material shall be added on top of liner along sides of ramp
	  o Discuss failures of plug in discharge pipe – pressure inside plug decreased, Terra to monitor daily
	  o Ricky discusses plan for placement of warning layer – “rough out” stone in 30-ft wide sections, apply water, compact material with roller so that trucks can bring more stone into basin, use GPS dozer for final grading
	  o Ricky notes that MWG water truck has been driving on anchor trench backfill at corners of the basin
	• Notice that liner has torn from the batten strip on the north side of the weir wall, likely due to pressure from water on the liner after the plug failure – one approximately 40-ft section and two approximately 8-ft sections
	  o Terra to schedule repairs with Clean Air and Water Systems
	  o Joseph requested that connection on south side of weir wall be inspected
	  o Confirm from damaged connection that geotextile material not fastened to batten strip
	• Discuss project status with Bill Gaynor (MWG) and Ricky
	  o Discuss placement of jersey barriers at corners of basin to keep water truck off of anchor trench
	• Terra still planning to finish by 10/01/13
	• Offsite around 11:30

Scope Changes:	• Repairs to be scheduled for damaged batten bar connection at north side of weir wall • South side of weir wall to be inspected

Site Conditions:	Site in good condition

Signature: JRR
Joseph R. Ridgway, PE

Date: 09/21/13

Damaged connection to batten strip on north side of weir wall, facing southwest

Dewatering basin after plug failure, facing southwest

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	October 01, 2013
Work Scope:	Ash Surge Basin Weir Wall Repairs
NRT Staff:	Edwards Effiong
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 70s, Clear and Sunny
Equipment:	Digital camera
Field Comments:	• Arrive onsite around 06:45, check in at guard shack o CAAWS arrived with a three-man crew at 07:30 • CAAWS, Terra, and NRT do a walk-over survey of all repair locations • NRT and CAAWS agree to take off all affected batten strips and replace them. It is also agreed to cut the liner to relieve the tension in the panels behind the weir wall and add extra liner (patch) along the cut. • Grading of the warning layer proceeding. • Offsite around 17:00
Scope Changes:	• None
Site Conditions:	Site in good condition.

Signature: ETE
Edwards T. Effiong

Date: 10/01/13

Section of the torn batten strip (looking southeast)

Batten strip repairs underway (looking west)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	October 02, 2013
Work Scope:	Ash Surge Basin Weir Wall Repairs
NRT Staff:	Edwards Effiong
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 80s, Fog Advisory in the morning and Sunny afternoon
Equipment:	Digital camera

Field Comments:	• Arrived onsite around 06:55, check in at guard shack
	• The patch work along the weir wall was completed today.
	  o No vacuum test as vac-box broke
	  o Helper went home sick slowing the pace of work
	  o CAAWS ran out of extrusion rod
	• Work on two riser poles and a patch location near the ramp still undone
	• Terra could not get in the repair location survey as anticipated, survey now scheduled for Monday
	• Offsite around 17:35

Scope Changes:	• None
Site Conditions:	Site in good condition. Grading of the warning layer proceeding.

Signature: ETE
Edwards T. Effiong

Date: 10/02/13

Geomembrane sections being added to the liner to provide slack for the transition between the basin floor and weir wall (looking southeast)

Repairs on batten strip

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	October 03, 2013
Work Scope:	Ash Surge Basin Weir Wall Repairs
NRT Staff:	Edwards Effiong
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 80s, Rain in the morning and Sunny afternoon
Equipment:	Digital camera
Field Comments:	• Arrived onsite around 07:00, check in at guard shack • Work delayed due to early morning thunderstorm. • Work on two riser poles and a patch location near the ramp began. o Patch location on panel 38 completed and vac-tested o Vac-test completed on locations behind the weir wall o Riser on panel 17 completed o Riser by panel 31 flooded and repairs not completed • CAAWS broke their weld gun after trying to weld in the wet. They are getting a replacement later tonight. • Offsite around 14:35
Scope Changes:	• None
Site Conditions:	Rains made the site difficult to work. Much of the work hours were dedicated to pumping water.

Signature: ETE
Edwards T. Effiong

Date: 10/03/13

One of the riser pole geomembrane boots being fixed (looking north)

Spark testing the new repairs (looking northeast)

Vacuum testing a new patch along the weir wall (looking east)

Pumping water from riser pole after the rain (looking southeast)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	October 04, 2013
Work Scope:	Ash Surge Basin Weir Wall Repairs
NRT Staff:	Edwards Effiong
Contractors:	Terra Contracting & Clean Air and Water Systems
Weather:	High 70s, Cloudy
Equipment:	Digital camera
Field Comments:	• Arrived onsite around 07:00, check in at guard shack • Work on last riser pole located at P31 completed and spark tested • Work completion forms signed by all • Offsite around 11:00
Scope Changes:	• None
Site Conditions:	Fine morning after the thunderstorms.

Signature: ETE
Edwards T. Effiong

Date: 10/04/13

Last of the riser poles being fixed

Installing the upper nonwoven geotextile over the geomembrane pipe boot (looking east)

FIELD NOTE SUMMARY

Project Number / Task: 2113.2 / 4.3
Project Name: Ash Surge Basin Liner Replacement

Date:	October 10, 2013
Work Scope:	Final material placement and demobilization
NRT Staff:	Joseph R. Ridgway
Contractors:	Terra Contracting
Weather:	70s, sunny
Equipment:	Digital camera

Field Comments:	• Arrive onsite around 09:30, check in at guard shack
	• Inspect repairs at ramp, north side of weir wall, and overflow structures – all repairs look satisfactory
	• Status update from Ricky Burnett (Terra)
	    o Placing extra material on ramp to make gradual transition for smooth truck access
	    o Removing miscellaneous debris from basin
	    o Plan to pull pipe plug in the afternoon
	    o Demobilizing all equipment
	• Discuss project completion with Bill Gaynor and Mark Kelly (MWG) and Ricky
	• Offsite around 11:30

Scope Changes:	• None
Site Conditions:	Site in good condition

Signature: JRR
Joseph R. Ridgway, PE

Date: 10/11/13

Damaged connection to batten strip on north side of weir wall, facing southwest

Panoramic view of entire basin from northeast corner, facing southwest

ATTACHMENT B

BORROW SOURCE SAMPLES

Illinois Department of Transportation

FIELD / LAB GRADATIONS

I.D. Number

Inspector No. 940-00-0000 Inspector Name Cathy Reynolds Date Sampled 8/20/2013 Seq. No. 13

Mix Plant No. Mix Plant Name Contract No. Job No.

Responsible Loc. 94 Lab PQ Lab Name PEKIN S&G Source Name PEKIN S&G

Source	Mat. Code #	Type Insp.	Orig. I. D. #	Insp. Qty.	Spec.	Article	Sampled From	Wash / Dry
51790-39	027FA01	PRO					BELT	wash

CA / FA	75 (3) or 6.3 (1/4)	6.3 (2.5)	50 (2) 25 (1)	45 (1.75) 9.5 (3/8)	37.5 (1.5) 4.75 (4)	25 (1) 2.36 (8)	19 (3/4) 2 (10)	16 (5/8) 1.18 (16)	12.5 (1/2) 0.6 (30)	9.5 (3/8) 0.425 (40)	4.75 (4) 0.3 (50)	2.36 (8)	1.18 (16) 0.18 (80)	0.6 (30)	0.3 (50) 0.15 (100)	0.15 (100)	.075 (200) .075 (200)
				100	100			61	34		3				0		0

Wash - 0.075 0.0 PI Ratio Test Results APPR Remarks

Sieve CA	Sieve FA	Indiv. Wt. Retained	Cumul. Wt. Retained	Cumul. % Retained	Percent % Passing	Spec. Range Min	Spec. Range Max	Out Flag
63 (2.5)								
50 (2)	25 (1)							
45 (1.75)	9.5 (3/8)	0.0	0.0	0.0	100.0	100	100	In
37.5 (1.5)	4.75 (#4)	1.5	1.5	0.2	99.8	94	100	In
25 (1)	2.36 (#8)							
19 (3/4)	2 (10)							
16 (5/8)	1.18 (#16)	316.0	317.5	39.4	60.6	45	85	In
12.5 (1/2)	0.6 (#30)	215.8	533.3	66.2	33.8			
9.5 (3/8)	0.425 (#40)							
6.3 (1/4)								
4.75 (#4)	0.3 (#50)	251.7	785.0	97.5	2.5	3	29	In
2.36 (#8)								
1.18 (#16)	0.18 (#80)							
0.6 (#30)								
0.425 (#40)								
0.3 (#50)	0.15 (#100)	19.0	804.0	99.9	0.1	0	10	
0.15 (#100)								
0.075 (#200)	0.075 (#200)	0.9	804.9	100.0	0.0	0	3	
PAN		0.4	805.3					
Total Dry Wt.		805.1						
Total Washed Wt.		805.5						
Diff. -0.075 (200)		-0.4	% Washed -0.075	0.0				
Percent Error		0.0%						

Sampled From Codes

BR	Barge	RD	Road
BE	Belt Stream	SI	Silo / Bin
CF	Cold Feed	SP	Stockpile
HB	Hot Bin	TD	Truck Dump
OB	On Belt (Stopped)	TK	Truck
PR	Production	WB	Weigh Belt
RC	Rail Car		

0.075 / 0.425

(Mix Plant Only)

Lot

Bin

Copies: Tester

Agency

MISTIC INPUT

Date Entered

Initials

/FOR DTY0350

II 504M (Rev 10 / 97)

Basic Quality Statistical Summary Report

Period 01/01/2012 - 09/04/2013
Plant 0078-Newton County
Product 5000-COMM #53 / comm. CM6
Specification COMM #53

Sieve/Test	Tests	Average	St Dev	Target	Specification
1 1/2" (37.5mm)	90	100.0	0.00		100-100
1" (25mm)	90	95.3	1.81		80-100
3/4" (19mm)	90	86.3	3.39		70-90
1/2" (12.5mm)	90	71.6	5.09		55-80
3/8" (9.5mm)	90	62.0	5.58		
#4 (4.75mm)	90	43.7	5.16		35-60
#8 (2.36mm)	90	31.5	4.11		25-50
#16 (1.18mm)	90	23.3	3.43		
#30 (0.6mm)	90	18.4	3.13		12-30
#200 (75um)	90	10.32	1.603	7.2-13.9\10.5	7-14
Pan	90	0.00	0.000		

Comments

Query Query Selections
Date Created 09/04/2013
Date Range 01/01/2012 - 09/04/2013
Plant Newton County
Sample Type Shipping
Number Of Tests 90

ATTACHMENT C

GEOSYNTHETICS CERTIFICATIONS

ATTACHMENT C1

GEOMEMBRANE CERTIFICATION

GSE Roll Allocation

Order SO-069997
Customer Clean Air and Water Systems, LLC
Project Name Powerton Generating Station

Roll#	Resin Lot	Product Code	Mfg Date	Length
105165101	H8221390	HDT-060AE-WBB-B-W0	12/31/2012	520
105165498	H8221540	HDT-060AE-WBB-B-W0	1/27/2013	520
105165510	H8221542	HDT-060AE-WBB-B-W0	1/28/2013	520
105166745	13C1077	HDT-060AE-WBB-B-W0	4/12/2013	520
105166746	13C1077	HDT-060AE-WBB-B-W0	4/12/2013	520
105166977	H8231829	HDT-060AE-WBB-B-W0	4/28/2013	520
105166978	H8231829	HDT-060AE-WBB-B-W0	4/28/2013	520
105166979	H8231829	HDT-060AE-WBB-B-W0	4/28/2013	520
105166980	H8231829	HDT-060AE-WBB-B-W0	4/28/2013	520
105166981	H8231829	HDT-060AE-WBB-B-W0	4/28/2013	520
105166982	H8231829	HDT-060AE-WBB-B-W0	4/28/2013	520
105166983	H8231829	HDT-060AE-WBB-B-W0	4/28/2013	520
105166984	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520
105166985	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520
105166986	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520
105166987	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520
105166988	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520
105166989	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520

GSE Roll Allocation

Order SO-069997
Customer Clean Air and Water Systems, LLC
Project Name Powerton Generating Station

Roll#	Resin Lot	Product Code	Mfg Date	Length
105166990	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520
105166991	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520
105166992	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520
105166993	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520
105166994	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520
105166995	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520
105166996	H8231829	HDT-060AE-WBB-B-W0	4/29/2013	520
105166997	H8231659	HDT-060AE-WBB-B-W0	4/29/2013	520
105166998	H8231659	HDT-060AE-WBB-B-W0	4/29/2013	520
105166999	H8231659	HDT-060AE-WBB-B-W0	4/29/2013	520
105167000	H8231659	HDT-060AE-WBB-B-W0	4/29/2013	520
105167001	H8231659	HDT-060AE-WBB-B-W0	4/30/2013	520
105167002	H8231659	HDT-060AE-WBB-B-W0	4/30/2013	520
105167003	H8231659	HDT-060AE-WBB-B-W0	4/30/2013	520
105167004	H8231659	HDT-060AE-WBB-B-W0	4/30/2013	520
105167005	H8231659	HDT-060AE-WBB-B-W0	4/30/2013	520

GSE Roll Allocation

Order SO-069997
Customer Clean Air and Water Systems, LLC
Project Name Powerton Generating Station

Roll#	Resin Lot	Product Code	Mfg Date	Length
105167006	H8231659	HDT-060AE-WBB-B-W0	4/30/2013	520
105167007	H8231659	HDT-060AE-WBB-B-W0	4/30/2013	520

GSE ENVIRONMENTAL™

GSE Environmental, LLC

GSE QC APPROVED

ROLL TEST DATA REPORT

Report Date: Apr/29/2013

Sales Order No.	*Customer Name*	*Project Location*	*Product Name*	*BOL Number*
SO−069997	Clean Air and Water Systems, LLC	Pekin IL US	HDT−060AE−WBB−B−W0	

Roll Number	Average Thickness ASTM D5994 (mils)	Minimum Thickness ASTM D5994 (mils)	Yield Strength ASTM D6693 (ppi) MD	Yield Strength ASTM D6693 (ppi) TD	Yield Elongation ASTM D6693 (%) MD	Yield Elongation ASTM D6693 (%) TD	Break Strength ASTM D6693 (ppi) MD	Break Strength ASTM D6693 (ppi) TD	Break Elongation ASTM D6693 (%) MD	Break Elongation ASTM D6693 (%) TD	Tear Resistance ASTM D1004 (lbs) MD	Tear Resistance ASTM D1004 (lbs) TD	Puncture Resistance ASTM D4833 (lbs)	Density ASTM D1505 (g/cc)	Carbon Black Content ASTM D4218 (%)	Carbon Black Dispersion ASTM D5596 (Views in Cat1−Cat2)	Asperity Height GRI GM12 (mils) Side A	Asperity Height GRI GM12 (mils) Side B
105165101	61	58	158	166	17	17	219	202	628	583	53	51	152	0.943	2.49	10	31	19
105165498	64	61	173	182	17	16	250	235	637	628	60	57	158	0.945	2.39	10	19	21
105165510	61	57	151	156	16	17	244	204	660	567	53	52	158	0.945	2.34	10	19	20
105166745	62	59	153	166	17	16	236	202	639	581	53	51	153	0.942	2.12	10	22	24
105166746	63	60	150	154	16	17	223	214	619	643	50	53	150	0.943	2.16	10	21	21
105166977	62	58	166	175	16	16	238	189	638	524	57	57	159	0.944	2.30	10	23	25
105166978	62	60	156	164	16	16	213	211	596	604	54	51	153	0.944	2.27	10	21	23
105166979	62	59	156	164	16	16	213	211	596	604	54	51	153	0.944	2.27	10	21	23
105166980	62	58	156	164	16	16	213	211	596	604	54	51	153	0.944	2.27	10	20	20
105166981	62	58	156	164	16	16	213	211	596	604	54	51	153	0.944	2.27	10	20	20
105166982	62	59	147	157	16	16	245	223	687	659	53	49	146	0.944	2.51	10	21	22
105166983	61	58	147	157	16	16	245	223	687	659	53	49	146	0.944	2.51	10	21	22
105166984	61	59	147	157	16	16	245	223	687	659	53	49	146	0.944	2.51	10	21	21
105166985	62	59	147	157	16	16	245	223	687	659	53	49	146	0.944	2.51	10	21	21
105166986	61	58	146	149	17	16	218	164	642	432	52	50	144	0.944	2.52	10	21	21
105166987	61	55	146	149	17	16	218	164	642	432	52	50	144	0.944	2.52	10	21	21
105166988	61	56	146	149	17	16	218	164	642	432	52	50	144	0.944	2.52	10	20	23
105166989	61	59	146	149	17	16	218	164	642	432	52	50	144	0.944	2.52	10	20	23

Laboratory Manager Jane Allen

GSE Environmental, LLC

ROLL TEST DATA REPORT

GSE QC APPROVED

Report Date: Apr/30/2013

Sales Order No.	***Customer Name***	***Project Location***	***Product Name***	***BOL Number***
SO−069997	Clean Air and Water Systems, LLC	Pekin IL US	HDT−060AE−WBB−B−W0	

Roll Number	Average Thickness ASTM D5994 (mils)	Minimum Thickness ASTM D5994 (mils)	Yield Strength ASTM D6693 (ppi) MD	Yield Strength ASTM D6693 (ppi) TD	Yield Elongation ASTM D6693 (%) MD	Yield Elongation ASTM D6693 (%) TD	Break Strength ASTM D6693 (ppi) MD	Break Strength ASTM D6693 (ppi) TD	Break Elongation ASTM D6693 (%) MD	Break Elongation ASTM D6693 (%) TD	Tear Resistance ASTM D1004 (lbs) MD	Tear Resistance ASTM D1004 (lbs) TD	Puncture Resistance ASTM D4833 (lbs)	Density ASTM D1505 (g/cc)	Carbon Black Content ASTM D4218 (%)	Carbon Black Dispersion ASTM D5596 (Views in Cat1−Cat2)	Asperity Height GRI GM12 (mils) Side A	Asperity Height GRI GM12 (mils) Side B
105166990	62	58	152	161	16	16	237	213	652	612	53	49	151	0.944	2.45	10	20	21
105166991	61	57	152	161	16	16	237	213	652	612	53	49	151	0.944	2.45	10	20	21
105166992	61	56	152	161	16	16	237	213	652	612	53	49	151	0.944	2.45	10	19	20
105166993	61	59	152	161	16	16	237	213	652	612	53	49	151	0.944	2.45	10	19	20
105166994	61	56	153	153	17	16	232	215	658	658	52	50	154	0.945	2.47	10	19	21
105166995	61	57	153	153	17	16	232	215	658	658	52	50	154	0.945	2.47	10	19	21
105166996	61	56	153	153	17	16	232	215	658	658	52	50	154	0.945	2.47	10	20	20
105166997	63	59	153	153	17	16	232	215	658	658	52	50	154	0.945	2.47	10	20	20
105166998	62	58	152	161	17	16	216	212	625	627	52	50	155	0.945	2.40	10	21	21
105166999	63	58	152	161	17	16	216	212	625	627	52	50	155	0.945	2.40	10	21	21
105167000	61	59	152	161	17	16	216	212	625	627	52	50	155	0.945	2.40	10	21	21
105167001	61	58	152	161	17	16	216	212	625	627	52	50	155	0.945	2.40	10	21	21
105167002	62	56	145	151	16	16	231	208	667	615	52	50	149	0.945	2.56	10	21	21
105167003	62	56	145	151	16	16	231	208	667	615	52	50	149	0.945	2.56	10	21	21
105167004	62	57	145	151	16	16	231	208	667	615	52	50	149	0.945	2.56	10	22	21
105167005	62	55	145	151	16	16	231	208	667	615	52	50	149	0.945	2.56	10	22	21

Laboratory Manager Jane Allen

GSE Environmental, LLC

ROLL TEST DATA REPORT

GSE QC APPROVED

Report Date: May/1/2013

Sales Order No.	Customer Name	Project Location	Product Name	BOL Number
SO−069997	Clean Air and Water Systems, LLC	Pekin IL US	HDT−060AE−WBB−B−W0	

Roll Number	Average Thickness ASTM D5994 (mils)	Minimum Thickness ASTM D5994 (mils)	Yield Strength ASTM D6693 (ppi) MD	Yield Strength ASTM D6693 (ppi) TD	Yield Elongation ASTM D6693 (%) MD	Yield Elongation ASTM D6693 (%) TD	Break Strength ASTM D6693 (ppi) MD	Break Strength ASTM D6693 (ppi) TD	Break Elongation ASTM D6693 (%) MD	Break Elongation ASTM D6693 (%) TD	Tear Resistance ASTM D1004 (lbs) MD	Tear Resistance ASTM D1004 (lbs) TD	Puncture Resistance ASTM D4833 (lbs)	Density ASTM D1505 (g/cc)	Carbon Black Content ASTM D4218 (%)	Carbon Black Dispersion ASTM D5596 (Views in Cat1−Cat2)	Asperity Height GRI GM12 (mils) Side A	Asperity Height GRI GM12 (mils) Side B
105167006	62	59	156	159	17	16	247	215	637	629	55	51	151	0.945	2.49	10	19	20
105167007	61	58	156	159	17	16	247	215	637	629	55	51	151	0.945	2.49	10	19	20

Laboratory Manager Jane Allen

Report Date
5/3/2013

ENVIRONMENTAL™

Quality Assurance Laboratory Test Results

Job Name: Powerton Generating Station
Sales Order: 69997

Required Testing: ASTM D 3895 -- Standard Test Method for Oxidative Induction Time of Polyolefins by Differential Scanning Calorimetry
ASTM D 5397 -- Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test

Frequency: D 3895 - 1/200,000 lbs.
D 5397 - 1/200,000 lbs.

Specification: D 3895 - >100 Minutes
D 5397 - >300 Hours

Product Code	Resin Lot Number	Test Results
HDT-060AE-WBB-B-W0	H8221390	PASS
HDT-060AE-WBB-B-W0	H8221540	PASS
HDT-060AE-WBB-B-W0	H8221542	PASS
HDT-060AE-WBB-B-W0	13C1077	PASS
HDT-060AE-WBB-B-W0	H8231829	PASS
HDT-060AE-WBB-B-W0	H8231659	PASS

Approved By:	Debra Gortemiller
Date Approved:	April 30, 2013

Report Date
5/3/2013

GSE ENVIRONMENTAL™

Quality Assurance Laboratory Test Results

Job Name: Powerton Generating Station
SO Number: 69997

The table below summarizes additive performance of GSE Houston products as perceived by OIT retention after UV and Oven Aging per GRI Test Method GM13:

		Oven Aging @ 85° C (ASTM D 5721)				UV Resistance per GRI GM11			
		90 days per ASTM D 5885				1600 hours UV Aging per ASTM D 5885			
Product Type	**Formulation**	Initial HP OIT (min)	Final HP OIT (min)	Retained (%)	GRI Criteria (%)	Initial HP OIT (min)	Final HP OIT (min)	Retained (%)	GRI Criteria (%)
HDPE Geomembrane	Formosa HL3812	744	674	90	80	744	700	95	50

The above stated data shall not be reproduced except in full, without the written approval of the laboratory.

Report Date
5/3/2013

Quality Assurance Laboratory Test Results

Approved By:	Debra Gortemiller
Date:	April 29, 2013

The above stated data shall not be reproduced except in full, without the written approval of the laboratory.

Report Date
5/3/2013

Quality Assurance Laboratory Test Results

Job Name: Powerton Generating Station
SO Number: 69997

The table below summarizes additive performance of GSE Houston products as perceived by OIT retention after UV and Oven Aging per GRI Test Method GM13:

		Oven Aging @ 85° C (ASTM D 5721) 90 days per ASTM D 3895				UV Resistance per GRI GM11 1600 hours UV Aging per ASTM D 5885			
Product Type	**Formulation**	Initial HP OIT (min)	Final HP OIT (min)	Retained (%)	GRI Criteria (%)	Initial HP OIT (min)	Final HP OIT (min)	Retained (%)	GRI Criteria (%)
HDPE Geomembrane	Chevron Phillips Marlex® K306 + Carbon Black	697	661	94	80	697	565	81	50

The above stated data shall not be reproduced except in full, without the written approval of the laboratory.

Report Date
5/3/2013

ENVIRONMENTAL™

Quality Assurance Laboratory Test Results

Approved By:	Debra Gortemiller
Date:	April 29, 2013

Formosa Plastics

FORMOSA PLASTICS CORPORATION, TEXAS
201 FORMOSA DRIVE
PO BOX 700
POINT COMFORT TX 77978
PHONE:(888)FPCUSA3

Certificate of Analysis

CUSTOMER:GSE LINING TECHNOLOGY, IN
UP TRACK 14732 WESTFIELD

HOUSTON TX 77070
PRODUCT :HL3812
RAILCAR FPAX200075

S/O NO : SEN2B32
CUSTOMER PO : 03-072045
DATE SHIPPED: 3/20/13
LOT NO : 13C1077
WEIGHT (LB) : 199,550.00
CUSTID:FT03112 SPIDM4

Ref# : MARCH

TEST ITEM	REFERENCE METHOD	TEST VALUE
Melt Index,g/10min	ASTM D1238	.070
HLMI, g/10 min.	ASTM D1238	11.1
Density, g/cm3	ASTM D1505	.9371

Linda Kao

QC SUPERVISOR: LINDA KAO

CPChem

Certificate of Analysis

Shipped To: GSE ENVIRONMENTAL, LLC
19103 GUNDLE ROAD
WESTFIELD TX 77090
USA

Recipient: BOHAC
Fax:

Delivery #: 88567258
PO #: 03-070880
Weight: 183200 LB
Ship Date: 12/11/2012
Package: BULK
Mode: Hopper Car
Car #: CHVX890285
Seal No: 299803

Product:
MARLEX POLYETHYLENE K306 BULK

Lot Number: H8221390

Property	Test Method	Value	Unit
Melt Index	ASTM D1238	0.1	g/10mi
HLMI Flow Rate	ASTM D1238	13.0	g/10mi
Density	D1505 or D4883	0.938	g/cm3
Production Date		11/16/2012	

The data set forth herein have been carefully compiled by Chevron Phillips Chemical Company LP (CPChem). **However, there is no warranty of any kind, either expressed or implied, applicable to its use, and the user assumes all risk and liability in connection therewith.**

Troy Griffin

Troy Griffin
Quality Systems Coordinator

For CoA questions contact Customer Service Representative at 800-231-1212

CPChem

CoA Date: 01/07/2013

Certificate of Analysis

Shipped To: GSE ENVIRONMENTAL, LLC
19103 GUNDLE ROAD
WESTFIELD TX 77090
USA

Recipient: BOHAC
Fax:

Delivery #: 88579499
PO #: 03-070880
Weight: 184400 LB
Ship Date: 01/07/2013
Package: BULK
Mode: Hopper Car
Car #: CHVX898248
Seal No: 303056

Product:
MARLEX POLYETHYLENE K306 BULK

Lot Number: H8221540

Property	Test Method	Value	Unit
Melt Index	ASTM D1238	0.1	g/10mi
HLMI Flow Rate	ASTM D1238	10.7	g/10mi
Density	D1505 or D4883	0.937	g/cm3
Production Date		12/17/2012	

The data set forth herein have been carefully compiled by Chevron Phillips Chemical Company LP (CPChem). **However, there is no warranty of any kind, either expressed or implied, applicable to its use, and the user assumes all risk and liability in connection therewith.**

Troy Griffin
Quality Systems Coordinator

For CoA questions contact Customer Service Representative at 800-231-1212

CPChem

CoA Date: 01/02/2013

Certificate of Analysis

Shipped To: GSE ENVIRONMENTAL, LLC
19103 GUNDLE ROAD
WESTFIELD TX 77090
USA

Recipient: BOHAC
Fax:

Delivery #: 88577628
PO #: 03-069994
Weight: 182900 LB
Ship Date: 01/02/2013
Package: BULK
Mode: Hopper Car
Car #: PSPX006916
Seal No: 303050

Product:
MARLEX POLYETHYLENE K306 BULK

Lot Number: H8221542

Property	Test Method	Value	Unit
Melt Index	ASTM D1238	0.1	g/10mi
HLMI Flow Rate	ASTM D1238	10.9	g/10mi
Density	D1505 or D4883	0.937	g/cm3
Production Date		12/17/2012	

The data set forth herein have been carefully compiled by Chevron Phillips Chemical Company LP (CPChem). **However, there is no warranty of any kind, either expressed or implied, applicable to its use, and the user assumes all risk and liability in connection therewith.**

Troy Griffin
Quality Systems Coordinator

For CoA questions contact Customer Service Representative at 800-231-1212

Certificate of Analysis

Shipped To: GSE ENVIRONMENTAL, LLC
19103 GUNDLE ROAD
WESTFIELD TX 77090
USA

Recipient: Gibbs
Fax:

Delivery #: 88629002
PO #: 03-072384
Weight: 185100 LB
Ship Date: 04/05/2013
Package: BULK
Mode: Hopper Car
Car #: CHVX890506
Seal No: 298788

Product:
MARLEX POLYETHYLENE K306 BULK

Lot Number: H8231659

Property	Test Method	Value	Unit
Melt Index	ASTM D1238	0.1	g/10mi
HLMI Flow Rate	ASTM D1238	11.8	g/10mi
Density	D1505 or D4883	0.938	g/cm3
Production Date		02/03/2013	

The data set forth herein have been carefully compiled by Chevron Phillips Chemical Company LP (CPChem). **However, there is no warranty of any kind, either expressed or implied, applicable to its use, and the user assumes all risk and liability in connection therewith.**

Troy Griffin
Quality Systems Coordinator

For CoA questions contact Customer Service Representative at 800-231-1212

CPChem

CoA Date: 04/01/2013

Certificate of Analysis

Shipped To: GSE ENVIRONMENTAL, LLC
19103 GUNDLE ROAD
WESTFIELD TX 77090
USA

Recipient: Phouangsavanh
Fax:

Delivery #: 88626423
PO #: 03-072384
Weight: 176400 LB
Ship Date: 04/01/2013
Package: BULK
Mode: Hopper Car
Car #: CHVX889174
Seal No: 305667

Product:
MARLEX POLYETHYLENE K306 BULK

Lot Number: H8231829

Property	Test Method	Value	Unit
Melt Index	ASTM D1238	0.1	g/10mi
HLMI Flow Rate	ASTM D1238	14.9	g/10mi
Density	D1505 or D4883	0.937	g/cm3
Production Date		03/09/2013	

The data set forth herein have been carefully compiled by Chevron Phillips Chemical Company LP (CPChem). **However, there is no warranty of any kind, either expressed or implied, applicable to its use, and the user assumes all risk and liability in connection therewith.**

Troy Griffin
Quality Systems Coordinator

For CoA questions contact Customer Service Representative at 800-231-1212

ATTACHMENT C2

GEOTEXTILE CERTIFICATION

SKAPS Industries (Nonwoven Division)
335, Athena Drive
Athens, GA 30601 (U.S.A.)
Phone (706) 354-3700 Fax (706) 354-3737
E-mail: info@skaps.com

Sales Office:
Engineered Synthetic Product Inc.
Phone: (770)564-1857
Fax: (770)564-1818

May 24, 2013
Clean Air & Water Systems
123 Elem Street, P.O. Box 337
Dousman, WI 53118
Ref : Midwest Generation / Powerton Generating Station
PO : 1023-13

Dear Sir/Madam:

This is to certify that SKAPS GE116 is a high quality needle-punched nonwoven geotextile made of 100% polypropylene staple fibers, randomly networked to form a high strength dimensionally stable fabric. SKAPS GE116 resists ultraviolet deterioration, rotting, biological degradation. The fabric is inert to commonly encountered soil chemicals. Polypropylene is stable within a pH range of 2 to 13. SKAPS GE116 conforms to the property values listed below:

PROPERTY	TEST METHOD	UNITS	M.A.R.V. Minimum Average Roll Value
Weight	ASTM D 5261	oz/sy (g/m^2)	16.00 (543)
Grab Tensile	ASTM D 4632	lbs (kN)	425 (1.89)
Grab Elongation	ASTM D 4632	%	50
Trapezoidal Tear	ASTM D 4533	lbs (kN)	150 (0.67)
CBR Puncture	ASTM D 6241	lbs (kN)	1200 (5.34)
Permittivity*	ASTM D 4491	sec^{-1}	0.57
Permeability*	ASTM D 4491	cm/sec	0.25
Water Flow*	ASTM D 4491	gpm/ft^2(l/min/m^2)	45 (1834)
AOS*	ASTM D 4751	US Sieve (mm)	100 (0.15)
UV Resistance	ASTM D 4355	%/hrs	70/500

Notes:
* At the time of manufacturing. Handling may change these properties.

PALAK PATEL
QUALITY CONTROL MANAGER

Product : GE116-180

ROLL # ASTM METHOD UNITS TARGET	WEIGHT D5261 oz/sq yd 16.00	MD TENSILE D4632 lbs. 425	MD ELONG D4632 % 50	XMD TENSILE D4632 lbs 425	XMD ELONG D4632 % 50	MD TRAP D4533 lbs. 150	XMD TRAP D4533 lbs 150	CBR PUNCTURE D6241 lbs. 1200	AOS D4751 US Sieve 100	WATER FLOW D4491 gpm/ft^2 45	PERMEAB-ILITY D4491 cm/sec 0.25	PERMITT-IVITY D4491 sec^{-1} 0.57
29606.001	16.65	436	78	459	89	157	169	1232	100	47	0.29	0.63
29606.002	16.65	436	78	459	89	157	169	1232	100	47	0.29	0.63
29606.003	16.65	436	78	459	89	157	169	1232	100	47	0.29	0.63
29606.004	16.65	436	78	459	89	157	169	1232	100	47	0.29	0.63
29606.005	16.13	431	72	453	81	157	169	1232	100	47	0.29	0.63
29606.006	16.13	431	72	453	81	157	169	1232	100	47	0.29	0.63
29606.007	16.13	431	72	453	81	157	169	1232	100	47	0.29	0.63
29606.008	16.13	431	72	453	81	157	169	1232	100	47	0.29	0.63
29606.009	16.13	431	72	453	81	157	169	1232	100	47	0.29	0.63
29606.010	16.57	439	76	461	87	151	163	1206	100	47	0.29	0.63
29606.011	16.57	439	76	461	87	151	163	1206	100	47	0.29	0.63
29606.012	16.57	439	76	461	87	151	163	1206	100	47	0.29	0.63
29606.013	16.57	439	76	461	87	151	163	1206	100	47	0.29	0.63
29606.014	16.57	439	76	461	87	151	163	1206	100	47	0.29	0.63
29606.015	16.30	433	74	455	83	151	163	1206	100	47	0.29	0.63
29606.016	16.30	433	74	455	83	151	163	1206	100	47	0.29	0.63
29606.017	16.30	433	74	455	83	151	163	1206	100	47	0.29	0.63
29606.018	16.30	433	74	455	83	151	163	1206	100	47	0.29	0.63
29606.019	16.30	433	74	455	83	151	163	1206	100	47	0.29	0.63
29606.020	16.43	437	79	458	90	159	166	1227	100	47	0.29	0.63
29606.021	16.43	437	79	458	90	159	166	1227	100	47	0.29	0.63
29606.022	16.43	437	79	458	90	159	166	1227	100	47	0.29	0.63
29606.023	16.43	437	79	458	90	159	166	1227	100	47	0.29	0.63
29606.024	16.43	437	79	458	90	159	166	1227	100	47	0.29	0.63
29606.025	16.34	435	71	450	80	159	166	1227	100	47	0.29	0.63
29606.026	16.34	435	71	450	80	159	166	1227	100	47	0.29	0.63
29606.027	16.34	435	71	450	80	159	166	1227	100	47	0.29	0.63
29606.028	16.34	435	71	450	80	159	166	1227	100	47	0.29	0.63
29606.029	16.34	435	71	450	80	159	166	1227	100	47	0.29	0.63
29606.030	16.51	440	77	463	86	154	161	1211	100	47	0.29	0.63
29606.031	16.51	440	77	463	86	154	161	1211	100	47	0.29	0.63
29606.032	16.51	440	77	463	86	154	161	1211	100	47	0.29	0.63
29606.033	16.51	440	77	463	86	154	161	1211	100	47	0.29	0.63
29606.034	16.51	440	77	463	86	154	161	1211	100	47	0.29	0.63
29606.035	16.14	432	73	456	82	154	161	1211	100	47	0.29	0.63

*All values are MARV.

Product : GE116-180

ROLL # ASTM METHOD UNITS TARGET	WEIGHT D5261 oz/sq yd 16.00	MD TENSILE D4632 lbs. 425	MD ELONG D4632 % 50	XMD TENSILE D4632 lbs 425	XMD ELONG D4632 % 50	MD TRAP D4533 lbs. 150	XMD TRAP D4533 lbs 150	CBR PUNCTURE D6241 lbs. 1200	AOS D4751 US Sieve 100	WATER FLOW D4491 gpm/ft^2 45	PERMEAB-ILITY D4491 cm/sec 0.25	PERMITT-IVITY D4491 sec^{-1} 0.57
29606.036	16.14	432	73	456	82	154	161	1211	100	47	0.29	0.63
29606.037	16.14	432	73	456	82	154	161	1211	100	47	0.29	0.63
29606.038	16.14	432	73	456	82	154	161	1211	100	47	0.29	0.63
29606.039	16.14	432	73	456	82	154	161	1211	100	47	0.29	0.63
29606.040	16.56	438	80	465	88	156	170	1230	100	47	0.29	0.63
29606.041	16.56	438	80	465	88	156	170	1230	100	47	0.29	0.63
29606.042	16.56	438	80	465	88	156	170	1230	100	47	0.29	0.63
29606.043	16.56	438	80	465	88	156	170	1230	100	47	0.29	0.63
29606.044	16.56	438	80	465	88	156	170	1230	100	47	0.29	0.63
29606.045	16.21	430	70	454	84	156	170	1230	100	47	0.29	0.63
29606.046	16.21	430	70	454	84	156	170	1230	100	47	0.29	0.63
29606.047	16.21	430	70	454	84	156	170	1230	100	47	0.29	0.63
29606.048	16.21	430	70	454	84	156	170	1230	100	47	0.29	0.63
29606.049	16.21	430	70	454	84	156	170	1230	100	47	0.29	0.63
29606.050	16.48	436	76	460	90	152	164	1209	100	46	0.28	0.61
29606.051	16.48	436	76	460	90	152	164	1209	100	46	0.28	0.61
29606.052	16.48	436	76	460	90	152	164	1209	100	46	0.28	0.61
29606.053	16.48	436	76	460	90	152	164	1209	100	46	0.28	0.61
29606.054	16.48	436	76	460	90	152	164	1209	100	46	0.28	0.61
29606.055	16.19	434	72	452	81	152	164	1209	100	46	0.28	0.61
29606.056	16.19	434	72	452	81	152	164	1209	100	46	0.28	0.61
29606.057	16.19	434	72	452	81	152	164	1209	100	46	0.28	0.61
29606.058	16.19	434	72	452	81	152	164	1209	100	46	0.28	0.61
29606.059	16.19	434	72	452	81	152	164	1209	100	46	0.28	0.61
29606.060	16.42	439	78	458	87	160	168	1238	100	46	0.28	0.61
29606.061	16.42	439	78	458	87	160	168	1238	100	46	0.28	0.61
29606.062	16.42	439	78	458	87	160	168	1238	100	46	0.28	0.61
29606.063	16.42	439	78	458	87	160	168	1238	100	46	0.28	0.61
29606.064	16.42	439	78	458	87	160	168	1238	100	46	0.28	0.61
29606.065	16.33	431	74	450	83	160	168	1238	100	46	0.28	0.61
29606.066	16.33	431	74	450	83	160	168	1238	100	46	0.28	0.61
29606.067	16.33	431	74	450	83	160	168	1238	100	46	0.28	0.61
29606.068	16.33	431	74	450	83	160	168	1238	100	46	0.28	0.61
29606.069	16.33	431	74	450	83	160	168	1238	100	46	0.28	0.61
29606.070	16.50	437	80	462	89	150	162	1214	100	46	0.28	0.61

*All values are MARV.

Product : GE116-180

ROLL #	WEIGHT	MD TENSILE	MD ELONG	XMD TENSILE	XMD ELONG	MD TRAP	XMD TRAP	CBR PUNCTURE	AOS	WATER FLOW	PERMEAB-ILITY	PERMITT-IVITY
ASTM METHOD	D5261	D4632	D4632	D4632	D4632	D4533	D4533	D6241	D4751	D4491	D4491	D4491
UNITS	oz/sq yd	lbs.	%	lbs	%	lbs.	lbs	lbs.	US Sieve	gpm/ft^2	cm/sec	sec^{-1}
TARGET	16.00	425	50	425	50	150	150	1200	100	45	0.25	0.57
29606.071	16.50	437	80	462	89	150	162	1214	100	46	0.28	0.61
29606.072	16.50	437	80	462	89	150	162	1214	100	46	0.28	0.61
29606.073	16.50	437	80	462	89	150	162	1214	100	46	0.28	0.61
29606.074	16.50	437	80	462	89	150	162	1214	100	46	0.28	0.61
29606.075	16.28	435	71	457	80	150	162	1214	100	46	0.28	0.61
29606.076	16.28	435	71	457	80	150	162	1214	100	46	0.28	0.61
29606.077	16.28	435	71	457	80	150	162	1214	100	46	0.28	0.61
29606.078	16.28	435	71	457	80	150	162	1214	100	46	0.28	0.61
29606.079	16.28	435	71	457	80	150	162	1214	100	46	0.28	0.61
29606.080	16.59	440	77	465	86	158	166	1234	100	46	0.28	0.61
29606.081	16.59	440	77	465	86	158	166	1234	100	46	0.28	0.61
29606.082	16.59	440	77	465	86	158	166	1234	100	46	0.28	0.61
29606.083	16.59	440	77	465	86	158	166	1234	100	46	0.28	0.61
29606.084	16.59	440	77	465	86	158	166	1234	100	46	0.28	0.61
29606.085	16.32	432	75	453	82	158	166	1234	100	46	0.28	0.61
29606.086	16.32	432	75	453	82	158	166	1234	100	46	0.28	0.61
29606.087	16.32	432	75	453	82	158	166	1234	100	46	0.28	0.61
29606.088	16.32	432	75	453	82	158	166	1234	100	46	0.28	0.61
29606.089	16.32	432	75	453	82	158	166	1234	100	46	0.28	0.61
29606.090	16.53	436	79	461	90	153	160	1211	100	46	0.28	0.61
29606.091	16.53	436	79	461	90	153	160	1211	100	46	0.28	0.61
29606.092	16.53	436	79	461	90	153	160	1211	100	46	0.28	0.61
29606.093	16.53	436	79	461	90	153	160	1211	100	46	0.28	0.61
29606.094	16.53	436	79	461	90	153	160	1211	100	46	0.28	0.61
29606.095	16.18	434	73	451	85	153	160	1211	100	46	0.28	0.61
29606.096	16.18	434	73	451	85	153	160	1211	100	46	0.28	0.61
29606.097	16.18	434	73	451	85	153	160	1211	100	46	0.28	0.61
29606.098	16.18	434	73	451	85	153	160	1211	100	46	0.28	0.61
29606.099	16.18	434	73	451	85	153	160	1211	100	46	0.28	0.61
29606.100	16.44	439	76	463	88	156	169	1221	100	48	0.29	0.64
29606.101	16.44	439	76	463	88	156	169	1221	100	48	0.29	0.64
29606.102	16.44	439	76	463	88	156	169	1221	100	48	0.29	0.64
29606.103	16.44	439	76	463	88	156	169	1221	100	48	0.29	0.64
29606.104	16.44	439	76	463	88	156	169	1221	100	48	0.29	0.64
29606.105	16.15	430	70	454	81	156	169	1221	100	48	0.29	0.64

*All values are MARV.

Product : GE116-180

ROLL #	WEIGHT	MD TENSILE	MD ELONG	XMD TENSILE	XMD ELONG	MD TRAP	XMD TRAP	CBR PUNCTURE	AOS	WATER FLOW	PERMEAB-ILITY	PERMITT-IVITY
ASTM METHOD	D5261	D4632	D4632	D4632	D4632	D4533	D4533	D6241	D4751	D4491	D4491	D4491
UNITS	oz/sq yd	lbs.	%	lbs	%	lbs.	lbs	lbs.	US Sieve	gpm/ft^2	cm/sec	sec^{-1}
TARGET	16.00	425	50	425	50	150	150	1200	100	45	0.25	0.57
29606.106	16.15	430	70	454	81	156	169	1221	100	48	0.29	0.64
29606.107	16.15	430	70	454	81	156	169	1221	100	48	0.29	0.64
29606.108	16.15	430	70	454	81	156	169	1221	100	48	0.29	0.64
29606.109	16.15	430	70	454	81	156	169	1221	100	48	0.29	0.64
29606.110	16.59	437	78	460	86	151	165	1217	100	48	0.29	0.64
29606.111	16.59	437	78	460	86	151	165	1217	100	48	0.29	0.64
29606.112	16.59	437	78	460	86	151	165	1217	100	48	0.29	0.64
29606.113	16.59	437	78	460	86	151	165	1217	100	48	0.29	0.64
29606.114	16.59	437	78	460	86	151	165	1217	100	48	0.29	0.64
29606.115	16.10	432	72	452	84	151	165	1217	100	48	0.29	0.64
29606.116	16.10	432	72	452	84	151	165	1217	100	48	0.29	0.64
29606.117	16.10	432	72	452	84	151	165	1217	100	48	0.29	0.64
29606.118	16.10	432	72	452	84	151	165	1217	100	48	0.29	0.64
29606.119	16.10	432	72	452	84	151	165	1217	100	48	0.29	0.64
29606.120	16.67	440	80	464	89	159	167	1235	100	48	0.29	0.64
29606.121	16.67	440	80	464	89	159	167	1235	100	48	0.29	0.64
29606.122	16.67	440	80	464	89	159	167	1235	100	48	0.29	0.64
29606.123	16.67	440	80	464	89	159	167	1235	100	48	0.29	0.64
29606.124	16.67	440	80	464	89	159	167	1235	100	48	0.29	0.64
29606.125	16.14	435	74	455	82	159	167	1235	100	48	0.29	0.64
29606.126	16.14	435	74	455	82	159	167	1235	100	48	0.29	0.64
29606.127	16.14	435	74	455	82	159	167	1235	100	48	0.29	0.64
29606.128	16.14	435	74	455	82	159	167	1235	100	48	0.29	0.64
29606.129	16.14	435	74	455	82	159	167	1235	100	48	0.29	0.64
29606.130	16.69	438	77	459	87	155	160	1210	100	48	0.29	0.64
29606.131	16.69	438	77	459	87	155	160	1210	100	48	0.29	0.64
29606.132	16.69	438	77	459	87	155	160	1210	100	48	0.29	0.64
29606.133	16.69	438	77	459	87	155	160	1210	100	48	0.29	0.64
29606.134	16.69	438	77	459	87	155	160	1210	100	48	0.29	0.64
29606.135	16.11	431	71	453	80	155	160	1210	100	48	0.29	0.64
29606.136	16.11	431	71	453	80	155	160	1210	100	48	0.29	0.64
29606.137	16.11	431	71	453	80	155	160	1210	100	48	0.29	0.64
29606.138	16.11	431	71	453	80	155	160	1210	100	48	0.29	0.64
29606.139	16.11	431	71	453	80	155	160	1210	100	48	0.29	0.64
29606.140	16.41	436	79	461	90	157	170	1230	100	48	0.29	0.64

*All values are MARV.

Product : GE116-180

ROLL # ASTM METHOD	WEIGHT D5261	MD TENSILE D4632	MD ELONG D4632	XMD TENSILE D4632	XMD ELONG D4632	MD TRAP D4533	XMD TRAP D4533	CBR PUNCTURE D6241	AOS D4751	WATER FLOW D4491	PERMEAB-ILITY D4491	PERMITT-IVITY D4491
UNITS	oz/sq yd	lbs.	%	lbs	%	lbs.	lbs	lbs.	US Sieve	gpm/ft^2	cm/sec	sec^{-1}
TARGET	16.00	425	50	425	50	150	150	1200	100	45	0.25	0.57
29606.141	16.41	436	79	461	90	157	170	1230	100	48	0.29	0.64
29606.142	16.41	436	79	461	90	157	170	1230	100	48	0.29	0.64
29606.143	16.41	436	79	461	90	157	170	1230	100	48	0.29	0.64
29606.144	16.41	436	79	461	90	157	170	1230	100	48	0.29	0.64
29606.145	16.37	433	73	457	83	157	170	1230	100	48	0.29	0.64
29606.146	16.37	433	73	457	83	157	170	1230	100	48	0.29	0.64
29606.147	16.37	433	73	457	83	157	170	1230	100	48	0.29	0.64
29606.148	16.37	433	73	457	83	157	170	1230	100	48	0.29	0.64
29606.149	16.37	433	73	457	83	157	170	1230	100	48	0.29	0.64
29606.150	16.54	439	76	463	86	150	162	1215	100	46	0.29	0.62
29606.151	16.54	439	76	463	86	150	162	1215	100	46	0.29	0.62
29606.152	16.54	439	76	463	86	150	162	1215	100	46	0.29	0.62
29606.153	16.54	439	76	463	86	150	162	1215	100	46	0.29	0.62
29606.154	16.54	439	76	463	86	150	162	1215	100	46	0.29	0.62
29606.155	16.32	430	70	450	81	150	162	1215	100	46	0.29	0.62
29606.156	16.32	430	70	450	81	150	162	1215	100	46	0.29	0.62
29606.157	16.32	430	70	450	81	150	162	1215	100	46	0.29	0.62
29606.158	16.32	430	70	450	81	150	162	1215	100	46	0.29	0.62
29606.159	16.32	430	70	450	81	150	162	1215	100	46	0.29	0.62
29606.160	16.52	437	78	458	88	160	168	1224	100	46	0.29	0.62
29606.161	16.52	437	78	458	88	160	168	1224	100	46	0.29	0.62
29606.162	16.52	437	78	458	88	160	168	1224	100	46	0.29	0.62
29606.163	16.52	437	78	458	88	160	168	1224	100	46	0.29	0.62
29606.164	16.52	437	78	458	88	160	168	1224	100	46	0.29	0.62
29606.165	16.29	432	75	452	84	160	168	1224	100	46	0.29	0.62
29606.166	16.29	432	75	452	84	160	168	1224	100	46	0.29	0.62
29606.167	16.29	432	75	452	84	160	168	1224	100	46	0.29	0.62
29606.168	16.29	432	75	452	84	160	168	1224	100	46	0.29	0.62
29606.169	16.29	432	75	452	84	160	168	1224	100	46	0.29	0.62
29606.170	16.60	440	80	460	90	152	164	1213	100	46	0.29	0.62
29606.171	16.60	440	80	460	90	152	164	1213	100	46	0.29	0.62
29606.172	16.60	440	80	460	90	152	164	1213	100	46	0.29	0.62
29606.173	16.60	440	80	460	90	152	164	1213	100	46	0.29	0.62
29606.174	16.60	440	80	460	90	152	164	1213	100	46	0.29	0.62
29606.175	16.17	435	72	454	82	152	164	1213	100	46	0.29	0.62

*All values are MARV.

Product : GE116-180

ROLL #	WEIGHT	MD TENSILE	MD ELONG	XMD TENSILE	XMD ELONG	MD TRAP	XMD TRAP	CBR PUNCTURE	AOS	WATER FLOW	PERMEAB-ILITY	PERMITT-IVITY
ASTM METHOD	D5261	D4632	D4632	D4632	D4632	D4533	D4533	D6241	D4751	D4491	D4491	D4491
UNITS	oz/sq yd	lbs.	%	lbs	%	lbs.	lbs	lbs.	US Sieve	gpm/ft^2	cm/sec	sec^{-1}
TARGET	16.00	425	50	425	50	150	150	1200	100	45	0.25	0.57
29606.176	16.17	435	72	454	82	152	164	1213	100	46	0.29	0.62
29606.177	16.17	435	72	454	82	152	164	1213	100	46	0.29	0.62
29606.178	16.17	435	72	454	82	152	164	1213	100	46	0.29	0.62
29606.179	16.17	435	72	454	82	152	164	1213	100	46	0.29	0.62
29606.180	16.63	438	77	465	87	158	166	1233	100	46	0.29	0.62
29606.181	16.63	438	77	465	87	158	166	1233	100	46	0.29	0.62
29606.182	16.63	438	77	465	87	158	166	1233	100	46	0.29	0.62
29606.183	16.63	438	77	465	87	158	166	1233	100	46	0.29	0.62
29606.184	16.63	438	77	465	87	158	166	1233	100	46	0.29	0.62
29606.185	16.12	433	74	451	80	158	166	1233	100	46	0.29	0.62
29606.186	16.12	433	74	451	80	158	166	1233	100	46	0.29	0.62

*All values are MARV.

ATTACHMENT D

GEOSYNTHETICS INSTALLER SUBMITTALS

ATTACHMENT D1

FIELD TENSIOMETER CALIBRATION

Demtech Services, Inc.

Placerville, California, USA

CALIBRATION CERTIFICATE

Clean Air and Water

Tensiometer Model: Pro-Tester T-0100

Device Calibrated: S-Type load cell
Range: 0 - 750 lbs. Tension
Model No: M2405-750#
Serial No: **668204**

Calibration Apparatus: Pro-Cal unit, model TC-0100/A

A/D Module Model No: T-029
A/D Module Serial No: 2911668204
Channel No: N/A

Dead Weight:		Reference Cell:	
W1	2	R1	2
W2	152	R2	152
W3	302	R3	302

Indicator reading with no load: 0

Offset **2.675813** Scale: **3.178533**

Applied Force lbs.	Cell Response:	Deviation Error:
2	2	0.00
52	52	0.00
102	102	0.00
152	152	0.00
202	202	0.00
252	252	0.00
302	302	0.00

Total Deviation Error (%): 0.00%

Temperature at time of calibration: 73 degrees F
Exitation Voltage: 5 V DC

This calibration conforms to the standards set by ASTM E4 and is traceable to NIST standards

Note: A/D Module and load cell above have been systems calibrated and are considered a matched pair. In general, calibrated A/D Modules and load cells are not interchangeable.

AH Date: 06/05/13

Demtech Services, Inc.

Placerville, California, USA

CALIBRATION CERTIFICATE

Clean Air and Water

Tensiometer Model: Pro-Tester T-0100

Device Calibrated: S-Type load cell
Range: 0 - 750 lbs. Tension
Model No: M2405-750#
Serial No: **681558**

Calibration Apparatus:

Pro-Cal unit, model TC-0100/A

A/D Module Model No: T-029
A/D Module Serial No: 2212681558
Channel No: N/A

Dead Weight:		Reference Cell:	
W1	2	R1	2
W2	152	R2	152
W3	302	R3	302

Indicator reading with no load: 0

Offset **1.624357** Scale: **3.179799**

Applied Force lbs.	Cell Response:	Deviation Error:
2	2	0.00
52	52	0.00
102	102	0.00
152	152	0.00
202	202	0.00
252	252	0.00
302	302	0.00

Total Deviation Error (%): 0.00%

Temperature at time of calibration: 73 degrees F
Exitation Voltage: 5 V DC

This calibration conforms to the standards set by ASTM E4 and is traceable to NIST standards

Note: A/D Module and load cell above have been systems calibrated and are considered a matched pair. In general, calibrated A/D Modules and load cells are not interchangeable.

AH

Date: 06/05/13

Demtech Services, Inc.

Placerville, California, USA

CALIBRATION CERTIFICATE

Clean Air and Water

Tensiometer Model: Pro-Tester T-0100

Device Calibrated: S-Type load cell
Range: 0 - 750 lbs. Tension
Model No: M2405-750#
Serial No: 681564

Calibration Apparatus:
Pro-Cal unit, model TC-0100/A

A/D Module Model No: T-029
A/D Module Serial No: 2212681564
Channel No: N/A

Dead Weight:		Reference Cell:	
W1	2	R1	2
W2	152	R2	152
W3	302	R3	302

Indicator reading with no load: 0

Offset: 6.082425 Scale: 3.204045

Applied Force lbs.	Cell Response:	Deviation Error:
2	2	0.00
52	52	0.00
102	102	0.00
152	152	0.00
202	202	0.00
252	252	0.00
302	302	0.00

Total Deviation Error (%): 0.00%

Temperature at time of calibration: 73 degrees F
Exitation Voltage: 5 V DC

This calibration conforms to the standards set by ASTM E4 and is traceable to NIST standards

Note: A/D Module and load cell above have been systems calibrated and are considered a matched pair. In general, calibrated A/D Modules and load cells are not interchangeable.

AH

Date: 06/30/13

Electronic Filing: Received, Clerk's Office 05/11/2021 **AS 2021-002**

ATTACHMENT D2

INSTALLER CREW RESUMES

RESUME FOR: Thong Ingels

Thong has been a Superintendent in the flexible membrane liner industry for >20 years. Below is his combined total square footage of flexible membrane liners installed under his management.

EXPERIENCE: Combined Square Footage: >100,000,000

LININGS INSTALLED: HDPE, LLDPE, Polypropylene, Hypalon, PVC, Geonet, Composites, Geosynthetic Clay, Geotextiles and XR-5.

TYPES OF PROJECTS: Heap Leach Pads, Landfills, Ponds, Landfill Caps, Secondary Containment Structures, Underliners and Methane Barriers.

EQUIPMENT KNOWLEDGE: Has extensive knowledge in maintaining and/or operating the following equipment:

- Wedge Welder
- Extrusion Welder
- Sewing Machines
- Tensiometer

TRAINING:

- CPR/First Aid Certified – American Heart Association Heartsaver Course
- 40 Hour HAZMAT - OSHA 29 CFR1910.120 & 1926.65
- OSHA 8 hour refresher (annual)
- 40 Hour MSHA Training
- Hertz Heavy Equipment Training

FIELD RESUME FOR: Sengratana Sengsay

Sengratana's main duty for CAAW Systems, LLC is as Quality Control Technician, and has been in the Flexible Membrane Liner industry for over 10 years. Below is his combined total square footage of Flexible Membrane Liners installed, this number may not include previous employment square footage.

EXPERIENCE: Combined Square Footage: >10,000,000

LININGS INSTALLED: HDPE, LLDPE, Polypropylene, Hypalon, PVC, Geonet, Composites, Geosynthetic Clay, Geotextiles and XR-5.

TYPES OF PROJECTS: Heap Leach Pads, Landfills, Ponds, Landfill Caps, Secondary Containment Structures, Underliners and Methane Barriers.

EQUIPMENT KNOWLEDGE: Has extensive knowledge in maintaining and/or operating the following equipment:

- Wedge Welder
- Extrusion Welder
- Sewing Machines
- Tensiometer

TRAINING:

- In-Field QC Training
- 40 Hr HAZMAT - OSHA 20CFR1910.120

FIELD RESUME FOR: Pheth Vongphrachanh

Pheth's main duty for CAAW Systems, LLC is as a Technician, and has been in the Flexible Membrane Liner industry for over 10 years. Below is his combined total square footage of Flexible Membrane Liners installed, this number may not include previous employment square footage.

EXPERIENCE: Combined Square Footage: >10,000,000

LININGS INSTALLED: HDPE, LLDPE, Polypropylene, Hypalon, PVC, Geonet, Composites, Geosynthetic Clay, Geotextiles and XR-5.

TYPES OF PROJECTS: Heap Leach Pads, Landfills, Ponds, Landfill Caps, Secondary Containment Structures, Underliners and Methane Barriers.

EQUIPMENT KNOWLEDGE: Has extensive knowledge in maintaining and/or operating the following equipment:

- Wedge Welder
- Extrusion Welder
- Sewing Machines
- Tensiometer

TRAINING:

- In-Field Training
- 40 Hr HAZMAT - OSHA 20CFR1910.120

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FIELD RESUME FOR: So Khanthavong

So's main duty for CAAW Systems, LLC is as a Technician, and has been in the Flexible Membrane Liner industry for over 10 years. Below is his combined total square footage of Flexible Membrane Liners installed, this number may not include previous employment square footage.

EXPERIENCE: Combined Square Footage: >10,000,000

LININGS INSTALLED: HDPE, LLDPE, Polypropylene, Hypalon, PVC, Geonet, Composites, Geosynthetic Clay, Geotextiles and XR-5.

TYPES OF PROJECTS: Heap Leach Pads, Landfills, Ponds, Landfill Caps, Secondary Containment Structures, Underliners and Methane Barriers.

EQUIPMENT KNOWLEDGE: Has extensive knowledge in maintaining and/or operating the following equipment:

- Wedge Welder
- Extrusion Welder
- Sewing Machines
- Tensiometer

TRAINING:

- In-Field Training
- 40 Hr HAZMAT - OSHA 20CFR1910.120

CLEAN AIR AND WATER SYSTEMS, LLC

FIELD RESUME FOR: Phouvanh Xaysana

Phouvanh's main duty for CAAW Systems, LLC is as a Technician, and has been in the Flexible Membrane Liner industry for over 10 years. Below is his combined total square footage of Flexible Membrane Liners installed, this number may not include previous employment square footage.

EXPERIENCE: Combined Square Footage: >10,000,000

LININGS INSTALLED: HDPE, LLDPE, Polypropylene, Hypalon, PVC, Geonet, Composites, Geosynthetic Clay, Geotextiles and XR-5.

TYPES OF PROJECTS: Heap Leach Pads, Landfills, Ponds, Landfill Caps, Secondary Containment Structures, Underliners and Methane Barriers.

EQUIPMENT KNOWLEDGE: Has extensive knowledge in maintaining and/or operating the following equipment:

- Wedge Welder
- Extrusion Welder
- Sewing Machines
- Tensiometer

TRAINING:

- In-Field Training
- 40 Hr HAZMAT - OSHA 20CFR1910.120

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FIELD RESUME FOR: Khammy Kounnorath

Khammy's main duty for CAAW Systems, LLC is as a Technician, and has been in the Flexible Membrane Liner industry for over 10 years. Below is his combined total square footage of Flexible Membrane Liners installed, this number may not include previous employment square footage.

EXPERIENCE: Combined Square Footage: >10,000,000

LININGS INSTALLED: HDPE, LLDPE, Polypropylene, Hypalon, PVC, Geonet, Composites, Geosynthetic Clay, Geotextiles and XR-5.

TYPES OF PROJECTS: Heap Leach Pads, Landfills, Ponds, Landfill Caps, Secondary Containment Structures, Underliners and Methane Barriers.

EQUIPMENT KNOWLEDGE: Has extensive knowledge in maintaining and/or operating the following equipment:

- Wedge Welder
- Extrusion Welder
- Sewing Machines
- Tensiometer

TRAINING:

- In-Field Training
- 40 Hr HAZMAT - OSHA 20CFR1910.120

FIELD RESUME FOR: Heum NLN

Heum's main duty for CAAW Systems, LLC is as a Technician, and has been in the Flexible Membrane Liner industry for over 10 years. Below is his combined total square footage of Flexible Membrane Liners installed, this number may not include previous employment square footage.

EXPERIENCE: Combined Square Footage: >10,000,000

LININGS INSTALLED: HDPE, LLDPE, Polypropylene, Hypalon, PVC, Geonet, Composites, Geosynthetic Clay, Geotextiles and XR-5.

TYPES OF PROJECTS: Heap Leach Pads, Landfills, Ponds, Landfill Caps, Secondary Containment Structures, Underliners and Methane Barriers.

EQUIPMENT KNOWLEDGE: Has extensive knowledge in maintaining and/or operating the following equipment:

- Wedge Welder
- Extrusion Welder
- Sewing Machines
- Tensiometer

TRAINING:

- In-Field Training
- 40 Hr HAZMAT - OSHA 20CFR1910.120

CLEAN AIR AND WATER SYSTEMS, LLC

FIELD RESUME FOR: Ketsana Vongphanchan

Ketsana's main duty for CAAW Systems, LLC is as a Technician, and has been in the Flexible Membrane Liner industry for over 10 years. Below is his combined total square footage of Flexible Membrane Liners installed, this number may not include previous employment square footage.

EXPERIENCE: Combined Square Footage: >10,000,000

LININGS INSTALLED: HDPE, LLDPE, Polypropylene, Hypalon, PVC, Geonet, Composites, Geosynthetic Clay, Geotextiles and XR-5.

TYPES OF PROJECTS: Heap Leach Pads, Landfills, Ponds, Landfill Caps, Secondary Containment Structures, Underliners and Methane Barriers.

EQUIPMENT KNOWLEDGE: Has extensive knowledge in maintaining and/or operating the following equipment:

- Wedge Welder
- Extrusion Welder
- Sewing Machines
- Tensiometer

TRAINING:

- In-Field Training
- 40 Hr HAZMAT - OSHA 20CFR1910.120

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CLEAN AIR AND WATER SYSTEMS, LLC

FIELD RESUME FOR: Moon Kala

Moon's main duty for CAAW Systems, LLC is as a Technician, and has been in the Flexible Membrane Liner industry for over 10 years. Below is his combined total square footage of Flexible Membrane Liners installed, this number may not include previous employment square footage.

EXPERIENCE: Combined Square Footage: >10,000,000

LININGS INSTALLED: HDPE, LLDPE, Polypropylene, Hypalon, PVC, Geonet, Composites, Geosynthetic Clay, Geotextiles and XR-5.

TYPES OF PROJECTS: Heap Leach Pads, Landfills, Ponds, Landfill Caps, Secondary Containment Structures, Underliners and Methane Barriers.

EQUIPMENT KNOWLEDGE: Has extensive knowledge in maintaining and/or operating the following equipment:

- Wedge Welder
- Extrusion Welder
- Sewing Machines
- Tensiometer

TRAINING:

- In-Field Training
- 40 Hr HAZMAT - OSHA 20CFR1910.120

FIELD RESUME FOR: Bounloth Lounnarath

Bounloth's main duty for CAAW Systems, LLC is as a Technician, and has been in the Flexible Membrane Liner industry for over 10 years. Below is her combined total square footage of Flexible Membrane Liners installed, this number may not include previous employment square footage.

EXPERIENCE: Combined Square Footage: >10,000,000

LININGS INSTALLED: HDPE, LLDPE, Polypropylene, Hypalon, PVC, Geonet, Composites, Geosynthetic Clay, Geotextiles and XR-5.

TYPES OF PROJECTS: Heap Leach Pads, Landfills, Ponds, Landfill Caps, Secondary Containment Structures, Underliners and Methane Barriers.

EQUIPMENT KNOWLEDGE: Has extensive knowledge in maintaining and/or operating the following equipment:

- Wedge Welder
- Extrusion Welder
- Sewing Machines
- Tensiometer

TRAINING:

- In-Field QC Training
- 40 Hr HAZMAT - OSHA 20CFR1910.120

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FIELD RESUME FOR: Detphongsone Outhaaphay

Detphongsone's main duty for CAAW Systems, LLC is as a Technician, and has been in the Flexible Membrane Liner industry for over 10 years. Below is her combined total square footage of Flexible Membrane Liners installed, this number may not include previous employment square footage.

EXPERIENCE: Combined Square Footage: >10,000,000

LININGS INSTALLED: HDPE, LLDPE, Polypropylene, Hypalon, PVC, Geonet, Composites, Geosynthetic Clay, Geotextiles and XR-5.

TYPES OF PROJECTS: Heap Leach Pads, Landfills, Ponds, Landfill Caps, Secondary Containment Structures, Underliners and Methane Barriers.

EQUIPMENT KNOWLEDGE: Has extensive knowledge in maintaining and/or operating the following equipment:

- Wedge Welder
- Extrusion Welder
- Sewing Machines
- Tensiometer

TRAINING:

- In-Field QC Training
- 40 Hr HAZMAT - OSHA 20CFR1910.120

ATTACHMENT D3

SUBGRADE ACCEPTANCE

CERTIFICATE OF ACCEPTANCE OF SUBGRADE SURFACE PREPARATION FOR GEOMEMBRANE INSTALLATION

PROJECT NAME: MWG - Powerton - Ash Surge Basin

LOCATION: Pekin, IL

JOB NUMBER: 201330 CLIENT:

AREA ACCEPTED: 391,842 sq ft

COMMENTS: subgrade accepted of Geotextile and Geomembrane deployment

INSTALLER: The undersigned authorized representative of CAAW Systems certifies that he or she has visually inspected the subgrade surface of the area described above and has found the surface to be acceptable for installation of the geosynthetic materials.

CAAW Systems shall be responsible for the integrity of finished geosynthetic material until completion of the installation or demobilization from site.

This certification is based on observations of the subgrade surface conditions only. CAAW Systems has made no sub-terrain inspections or tests and makes no representations or warranties as to the conditions that may exist below the surface of the subgrade.

CERTIFICATE APPROVED BY:

Installers Acceptance	Inspectors Acceptance
Company: Clear Air And Water Systems, LLC	Company: Natural Resource Technology
By: [signature]	By: Joseph A Larson
Title: QAQC	Title: Environmental Scientist
Date: 8-14-13	Date: 8/14/13

ATTACHMENT D4

GEOSYNTHETIC MATERIAL INSTALLATION CERTIFICATE

November 14, 2013

Midwest Generation, LLC
Powerton Generating Station
13082 East Manito Road
Pekin IL 61554-8587

RE: Geosynthetic material installation certification

To Whom It May Concern

The HDPE geomembrane and geotextiles installed in the Ash Surge Basin were installed in accordance with the project specifications and manufactures recommendations.

Sincerely,

Matt Albert

Matt Albert
Project Estimator
CAAW Systems, LLC.

Corporate Office
123 Elm Street
P.O. Box 337
Dousman, WI. 53118-0337
(262) 965-4366 Fax (262) 965-4369

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Regional Office
2727 W. 2nd St., Ste 235
Hastings, NE 68901
(402) 463-0857 Fax (402) 463-0858

ATTACHMENT D5

GEOMEMBRANE INSTALLATION WARRANTIES

INSTALLATION WARRANTY- GEOMEMBRANE LINERS

PROJECT NAME: Powerton Generating Station

Subject to the terms and conditions set forth below, Clean Air And Water Systems, LLC warrants to Purchaser, _Midwest Generation, LLC_, that the _60 mil HDPE White Textured Geomembrane_ installed in the _Ash Surge Basin_, was installed by Clean Air And Water Systems, LLC, in accordance with the specifications in a good and workmanlike manner and that the installation of the liner is free from defects in workmanship for a period of two (2) years from the date upon which the material was installed.

This warranty covers only defects in workmanship occurring during the installation of the liner. This warranty does not cover ay damage to, or defects in the liner found to have been a result of misuse, abuse or conditions existing after it was installed, including, but not limited to, rough handling; malicious mischief; vandalism; sabotage; fire; acts of God; acts of the public enemy; acts of war, public rebellion, severe weather conditions of all types; damage due to ice; excessive stress from any source; floating debris; damage due to machinery; foreign objects or animals. Nor does this warranty cover any defects which are found to have been a result of improper or defective design or engineering unless the design or engineering was performed by Clean Air And Water Systems, LLC. In the event circumstances are found to exist which purchaser believes may give rise to a claim under this warranty, the following procedure shall be followed:

a) Purchaser shall give Clean Air And Water Systems, LLC written notice of the facts and circumstances of said claim within ten (10) days of becoming aware of said facts and circumstances. Said notice shall be by registered or certified mail, return receipt requested, postage prepaid, addressed to Member, Clean Air And Water Systems, LLC, 123 Elm Street, PO Box 337, Dousman, Wisconsin 53118. The words "WARRANTY CLAIM" shall be clearly marked on the face of envelope in the lower right hand corner. Said notice shall contain, at a minimum, the name and address of the owner, the name and address of the installation, the name and address of the installer, the date upon which the material was purchased and the facts known to Purchaser upon which the claim is based. Failure to strictly comply with all the requirements of this paragraph shall void this warranty.
b) Within twenty days after receipt of the notice described in paragraph a., above, Clean Air And Water Systems, LLC shall notify Purchaser either that it will send a representative to inspect the allegedly defective liner or that it does not wish to do so. Purchaser shall pay the expenses incurred by Clean Air And Water Systems, LLC in making the inspection, including current per diem rates for personnel involved in making the inspection, in the event Clean Air And Water Systems, LLC determines that the claim is not covered by this warranty.
c) Purchaser SHALL NOT REPAIR, REPLACE, REMOVE, ALTER OR DISTURB ANY LINER, NOR SHALL Purchaser ALLOW ANYONE ELSE TO REPAIR, REPLACE, REMOVE, ALTER, OR DISTURB ANY LINER PRIOR TO SUCH INSPECTION OR RECEIPT OF CLEAN AIR AND WATER SYSTEMS, LLC.'S NOTICE THAT IT ELECTS NOT TO INSPECT. A FAILURE TO STRICTLY COMPLY WITH THIS PARAGRAPH SHALL VOID THIS WARRANTY OR MAY LEAD TO A DETERMINATION THAT THE ALLEGED DEFECTS ARE NOT WITHIN THE SCOPE OF THIS WARRANTY.
d) If Clean Air And Water Systems, LLC determines that the alleged defects are covered by this warranty, Clean Air And Water Systems, LLC shall, in its sole discretion, either repair the defective liner or provide Purchaser with replacement liner. THE REMEDIES PROVIDED HEREIN ARE THE EXCLUSIVE REMEDIES AVAILABLE UNDER THIS WARRANTY. Any determination as to whether a particular defect is covered by this warranty will be made by Clean Air And Water Systems, LLC in its sole and complete discretion.

e) Purchaser agrees that it shall provide Clean Air And Water Systems, LLC with clean, dry and unobstructed access to the liner in order for Clean Air And Water Systems, LLC to perform the inspections and warranty work which may be required pursuant to this warranty.

THE REMEDIES PROVIDED TO Purchaser HEREIN ARE THE EXCLUSIVE REMEDIES AVAILABLE UNDER THIS WARRANTY AND ARE INTENDED FOR THE SOLE BENEFIT OF Purchaser. NEITHER THIS WARRANTY NOR ANY RIGHTS HEREUNDER SHALL BE ASSIGNABLE. CLEAN AIR AND WATER SYSTEMS, LLC SHALL HAVE NO LIABILITY UNDER THIS WARRANTY TO THIRD PARTIES OR STRANGERS TO THIS AGREEMENT. THE WARRANTY SET FORTH ABOVE IS THE ONLY WARRANTY APPLICABLE TO THE LINER AND ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL CLEAN AIR AND WATER SYSTEMS, LLC BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL OR CONSEQUENTIAL DAMAGES FOR, RESULTING FROM, OR IN CONNECTION WITH, ANY LOSS RESULTING FROM THE USE OF THE LINER. IN THE EVENT THE EXCLUSIVE REMEDY PROVIDED HEREIN FAILS IN ITS ESSENTIAL PURPOSE, AND IN THAT EVENT ONLY, Purchaser SHALL BE ENTITLED TO RETURN OF THE PURCHASE PRICE FOR SO MUCH OF THE MATERIAL AS CLEAN AIR AND WATER SYSTEMS, LLC DETERMINES IN ITS SOLE DISCRETION, TO HAVE VIOLATED THE WARRANTY PROVIDED HEREIN. EXCEPT FOR THE WARRANTY SET FORTH ABOVE, NO REPRESENTATION OR WARRANTY MADE BY ANY SALES OR OTHER REPRESENTATIVE CLEAN AIR AND WATER SYSTEMS, LLC, OR ANY OTHER PERSON, CONCERNING THE LINER SHALL BE BINDING UPON CLEAN AIR AND WATER SYSTEMS, LLC.

Any waiver of the terms and conditions of this warranty shall be in writing signed by CLEAN AIR AND WATER SYSTEMS, LLC the failure to insist upon strict compliance with any of the terms and conditions contained herein shall not act as a waiver of strict compliance with all of the remaining terms and conditions or this warranty and shall not operate as a waiver as to any of the terms and conditions of this warranty as to future claims under this warranty.

CLEAN AIR AND WATER SYSTEMS, LLC

BY: Brian McKeown

Brian K. McKeown/ Member

I have read and agree to be bound by the terms and conditions of the foregoing warranty.

By: ______________________________

Title: ______________________________

Company: ___________________________

Date: ______________________________

ATTACHMENT E

GEOSYNTHETICS INSTALLATION

ATTACHMENT E1

TRIAL WELD SUMMARY

NATURAL RESOURCE TECHNOLOGY

Trial Weld Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Project Specifications: Fusion Peel: 91 ppi Extrusion Peel: 78 ppi Shear: 120 ppi

Test No.	Date	Time	Weather (Cloudy/ Sunny)	Amb. Temp. (°F)	Welder I.D.	Machine Number	Temp. Setting/ Speed	Weld Type	PEEL (ppi) Outside Weld			PEEL (ppi) Inside Weld			SHEAR (ppi)			Test Result (P/F)	Comments
									1	2	3	1	2	3	1	2	3		
T1	8/14/2013	8:00	Sunny	70	KK	140	850/5.0	Fus	148	137	132	136	128	136	178	175	192	P	
T2	8/14/2013	7:54	Sunny	70	HN	69	850/5.3	Fus	146	137	146	150	135	128	181	171	173	P	
T3	8/14/2013	12:58	Sunny	80	HN	69	850/5.3	Fus	120	122	128	123	101	110	143	141	140	P	
T4	8/14/2013	13:00	Sunny	80	KK	140	850/5.0	Fus	127	109	120	119	121	116	149	148	130	P	
T5	8/15/2013	8:15	Cloudy	60	KK	140	850/5.0	Fus	132	124	129	122	129	132	171	175	175	P	
T6	8/15/2013	8:18	Cloudy	60	HN	69	850/5.3	Fus	149	134	138	125	136	124	181	168	169	P	
T7	8/15/2013	13:20	Pt. Cldy	72	KK	140	850/5.0	Fus	116	103	114	112	113	125	156	155	159	P	
T8	8/15/2013	13:17	Pt. Cldy	72	HN	69	850/5.3	Fus	126	113	115	148	139	129	157	151	159	P	
T9	8/16/2013	7:45	Sunny	60	VK	46	515/400	Ext	--	--	--	130	139	138	170	176	171	P	
T10	8/16/2013	7:34	Sunny	60	PX	88	500/500	Ext	--	--	--	113	123	123	165	171	180	P	
T11	8/16/2013	7:40	Sunny	60	BL	10	515/400	Ext	--	--	--	114	109	96	161	167	166	P	
T12	8/16/2013	13:10	Pt. Cldy	77	PX	88	500/500	Ext	--	--	--	93	99	98	121	139	133	P	
T13	8/16/2013	13:30	Pt. Cldy	77	VK	46	515/400	Ext	--	--	--	124	129	136	145	155	156	P	
T14	8/16/2013	13:30	Pt. Cldy	77	BL	10	515/400	Ext	--	--	--	138	121	130	171	170	165	P	
T15	8/17/2013	7:41	Pt. Cldy	70	PX	46	500/400	Ext	--	--	--	118	124	138	171	178	174	P	
T16	8/17/2013	7:50	Pt. Cldy	70	BL	10	515/500	Ext	--	--	--	121	133	128	167	173	165	P	
T17	8/17/2013	7:40	Pt. Cldy	70	VP	10	515/500	Ext	--	--	--	133	121	138	171	165	165	P	
T18	8/19/2013	12:30	Pt. Cldy	80	KK	140	850/5.5	Fus	169	106	107	119	117	118	134	140	144	P	
T19	8/19/2013	12:32	Pt. Cldy	80	HN	69	850/5.4	Fus	119	115	127	123	138	111	160	148	159	P	
T20	8/19/2013	13:30	Pt. Cldy	85	VP	10	515/500	Ext	--	--	--	123	119	111	164	155	149	P	
T21	8/20/2013	7:34	Pt. Cldy	70	VP	88	500/400	Ext	--	--	--	128	128	129	163	170	168	P	

Trial Weld Summary

NATURAL RESOURCE TECHNOLOGY

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Project Specifications: Fusion Peel: 91 ppi Extrusion Peel: 78 ppi Shear: 120 ppi

Test No.	Date	Time	Weather (Cloudy/ Sunny)	Amb. Temp. (°F)	Welder I.D.	Machine Number	Temp. Setting/ Speed	Weld Type	PEEL (ppi) Outside Weld 1	PEEL Outside Weld 2	PEEL Outside Weld 3	PEEL Inside Weld 1	PEEL Inside Weld 2	PEEL Inside Weld 3	SHEAR (ppi) 1	SHEAR (ppi) 2	SHEAR (ppi) 3	Test Result (P/F)	Comments
T22	8/20/2013	12:37	Pt. Cldy	85	HN	69	850/6.5	Fus	142	141	138	127	140	135	157	152	162	P	
T23	8/20/2013	12:45	Pt. Cldy	85	KK	140	850/6.5	Fus	154	146	145	144	146	145	152	156	147	P	
T24	8/20/2013	13:00	Pt. Cldy	85	VP	88	500/400	Ext	--	--	--	98	112	102	161	158	156	P	
T25	8/21/2013	7:28	Sunny	70	HN	69	850/6.3	Fus	129	128	129	138	131	126	173	162	175	P	
T26	8/21/2013	7:30	Sunny	70	KK	140	850/6.5	Fus	117	121	116	128	111	126	163	164	165	P	
T27	8/21/2013	12:51	Sunny	80	HN	69	850/6.3	Fus	125	116	120	119	119	110	138	135	135	P	
T28	8/21/2013	13:00	Sunny	80	KK	140	850/6.5	Fus	135	135	122	118	112	127	150	154	148	P	
T29	8/21/2013	13:00	Sunny	80	VP	88	850/700	Ext	--	--	--	101	109	110	141	145	152	P	
T30	8/21/2013	13:15	Sunny	80	HN	69	850/7.0	Fus	119	136	134	118	126	140	160	151	148	P	
T31	8/22/2013	7:45	Cloudy	70	KK	140	850/6.0	Fus	126	132	135	141	138	135	176	179	179	P	
T32	8/22/2013	7:50	Cloudy	70	VK	46	515/400	Ext	--	--	--	108	109	91	168	163	167	P	
T33	8/22/2013	8:30	Cloudy	70	BL	10	515/425	Ext	--	--	--	133	122	115	165	166	168	P	
T34	8/22/2013	13:10	Cloudy	80	VK	46	515/400	Ext	--	--	--	141	138	135	156	153	155	P	
T35	8/22/2013	12:50	Cloudy	80	BL	10	515/400	Ext	--	--	--	141	138	135	156	153	155	P	
T36	8/22/2013	12:55	Cloudy	80	VP	88	500/400	Ext	--	--	--	118	124	131	163	161	168	P	
T37	8/23/2013	7:30	Sunny	70	VK	46	515/400	Ext	--	--	--	108	110	99	176	174	174	P	
T38	8/23/2013	7:30	Sunny	70	BL	10	515/400	Ext	--	--	--	135	129	143	171	168	176	P	
T39	8/23/2013	7:10	Sunny	70	VP	88	500/400	Ext	--	--	--	142	146	103	170	168	177	P	
T40	8/23/2013	13:00	Sunny	80	VK	88	500/400	Ext	--	--	--	128	131	121	158	161	165	P	
T41	8/26/2013	8:00	Pt. Cldy	75	VK	46	515/400	Ext	--	--	--	130	126	137	180	181	178	P	
T42	8/26/2013	8:20	Pt. Cldy	75	PX	88	500/400	Ext	--	--	--	109	127	127	177	171	183	P	

Trial Weld Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Project Specifications: Fusion Peel: 91 ppi Extrusion Peel: 78 ppi Shear: 120 ppi

Test No.	Date	Time	Weather (Cloudy/ Sunny)	Amb. Temp. (°F)	Welder I.D.	Machine Number	Temp. Setting/ Speed	Weld Type	PEEL (ppi) Outside Weld 1	2	3	Inside Weld 1	2	3	SHEAR (ppi) 1	2	3	Test Result (P/F)	Comments
T43	8/26/2013	14:15	Pt. Cldy	95	VP	88	500/400	Ext	--	--	--	128	98	101	181	167	161	P	
T44	8/27/2013	7:30	Hazy	75	VP	88	500/400	Ext	--	--	--	128	98	101	161	162	170	P	
T45	9/12/2013	13:50	--	92	VP	46	500/400	Ext	--	--	--	160	159	174	193	191	200	P	
T46	10/1/2013	13:10	Sunny	73	PX	76	500/500	Ext	--	--	--	122	115	150	124	147	125	P	
T47	10/2/2013	8:20	Fog	64	VP	76	530/500	Ext	--	--	--	149	143	145	139	194	159	P	
T48	10/2/2013	13:20	Sunny	80	VP	76	530/500	Ext	--	--	--	131	106	155	127	138	129	P	
T49	10/3/2013	9:05	Clear	69	VP	76	500/500	Ext	--	--	--	157	142	146	143	153	171	P	
T50	10/4/2013	8:00	Clear	69	VP	39	500/500	Ext	--	--	--	135	145	146	133	134	167	P	

ATTACHMENT E2

PANEL PLACEMENT SUMMARY

Panel Placement Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Panel Number	Date	Time	Roll Number	Mat. Id.	Final Length (Feet)	Width	Thickness (mils)						Final Area (Sq. Ft.)	COMMENTS
P1	8/14/2013	8:00	6444	HDPE	60	22	--	--	--	--	--	--	1,320	
P2	8/14/2013	8:06	6444	HDPE	60	22	--	--	--	--	--	--	1,320	
P3	8/14/2013	8:09	6444	HDPE	60	22	--	--	--	--	--	--	1,320	
P4	8/14/2013	8:15	6444	HDPE	60	22	--	--	--	--	--	--	1,320	
P5	8/14/2013	8:20	6444	HDPE	60	22	--	--	--	--	--	--	1,320	
P6	8/14/2013	8:28	6444	HDPE	60	22	--	--	--	--	--	--	1,320	
P7	8/14/2013	8:35	6444	HDPE	60	22	--	--	--	--	--	--	1,320	
P8	8/14/2013	8:40	7001	HDPE	60	22	--	--	--	--	--	--	1,320	
P9	8/14/2013	9:00	7001	HDPE	60	22	--	--	--	--	--	--	1,320	
P10	8/14/2013	9:02	7001	HDPE	60	22	--	--	--	--	--	--	1,320	
P11	8/14/2013	9:07	7001	HDPE	57	22	--	--	--	--	--	--	1,254	
P12	8/14/2013	9:11	7001	HDPE	57	22	--	--	--	--	--	--	1,254	
P13	8/14/2013	9:15	7001	HDPE	52	21	--	--	--	--	--	--	1,092	
P14	8/14/2013	9:25	7001	HDPE	24	21	--	--	--	--	--	--	504	
P15	8/14/2013	9:29	7001	HDPE	27	22	--	--	--	--	--	--	594	
P16	8/14/2013	9:35	7001	HDPE	43	22	--	--	--	--	--	--	946	
P17	8/14/2013	10:10	6450	HDPE	351	22	--	--	--	--	--	--	7,722	
P18	8/14/2013	10:18	6450	HDPE	34	22	--	--	--	--	--	--	748	
P19	8/14/2013	10:20	6450	HDPE	11	8	--	--	--	--	--	--	88	
P20	8/14/2013	10:25	6994	HDPE	351	22	--	--	--	--	--	--	7,722	
P21	8/14/2013	10:58	5979	HDPE	360	22	--	--	--	--	--	--	7,920	
P22	8/14/2013	11:15	6984	HDPE	363	22	--	--	--	--	--	--	7,986	
P23	8/14/2013	13:05	6995	HDPE	363	22	80	75	--	--	--	--	7,986	
P24	8/14/2013	13:25	6993	HDPE	363	22	76	75	--	--	--	--	7,986	
P25	8/14/2013	14:01	7004	HDPE	360	22	76	82	--	--	--	--	7,920	
P26	8/14/2013	14:30	6977	HDPE	347	22	80	88	--	--	--	--	7,634	
P27	8/14/2013	15:01	6997	HDPE	361	22	79	74	--	--	--	--	7,942	
P28	8/14/2013	15:38	7003	HDPE	358	22	84	80	--	--	--	--	7,876	
P29	8/14/2013	16:09	6992	HDPE	368	22	77	80	--	--	--	--	8,096	
P30	8/15/2013	8:34	6978	HDPE	355	22	80	85	--	--	--	--	7,810	
P31	8/15/2013	9:00	7007	HDPE	361	22	80	83	--	--	--	--	7,942	
P32	8/15/2013	9:25	6990	HDPE	359	22	80	80	--	--	--	--	7,898	
P33	8/15/2013	9:55	6998	HDPE	361	22	79	80	--	--	--	--	7,942	
P34	8/15/2013	10:13	6983	HDPE	361	22	80	81	--	--	--	--	7,942	
P35	8/15/2013	10:45	6999	HDPE	361	22	75	81	--	--	--	--	7,942	
P36	8/15/2013	11:10	7000	HDPE	360	22	78	82	--	--	--	--	7,920	
P37	8/15/2013	13:30	7006	HDPE	363	22	80	81	--	--	--	--	7,986	
P38	8/15/2013	13:47	6980	HDPE	363	22	76	79	--	--	--	--	7,986	
P39	8/19/2013	12:30	5510	HDPE	360	22	79	80	--	--	--	--	7,920	
P40	8/19/2013	12:35	5101	HDPE	228	22	75	78	--	--	--	--	5,016	
P41	8/19/2013	13:30	5101	HDPE	135	22	75	78	--	--	--	--	2,970	
P42	8/19/2013	14:00	5101	HDPE	289	22	79	80	--	--	--	--	6,358	
P43	8/19/2013	14:05	6994	HDPE	79	22	80	75	--	--	--	--	1,738	
P44	8/19/2013	14:07	6994	HDPE	44	22	76	75	--	--	--	--	968	
P45	8/19/2013	14:18	7004	HDPE	39	22	76	82	--	--	--	--	858	

Panel Placement Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Panel Number	Date	Time	Roll Number	Mat. Id.	Final Length (Feet)	Width	Thickness (mils)						Final Area (Sq. Ft.)	COMMENTS
P46	8/19/2013	14:20	7004	HDPE	30	22	79	79	--	--	--	--	660	
P47	8/19/2013	14:22	7004	HDPE	24	22	84	81	--	--	--	--	528	
P48	8/19/2013	14:24	7004	HDPE	16	22	80	85	--	--	--	--	352	
P49	8/19/2013	14:26	7004	HDPE	10	22	80	83	--	--	--	--	220	
P50	8/19/2013	14:28	7004	HDPE	5	22	79	80	--	--	--	--	110	
P51	8/19/2013	14:59	6979	HDPE	152	22	77	80	--	--	--	--	3,344	
P52	8/19/2013	15:17	6980	HDPE	151	22	75	76	--	--	--	--	3,322	
P53	8/19/2013	15:30	7006	HDPE	160	22	79	82	--	--	--	--	3,520	
P54	8/19/2013	15:47	6999	HDPE	148	22	80	81	--	--	--	--	3,256	
P55	8/20/2013	12:30	6997	HDPE	154	22	79	80	--	--	--	--	3,388	
P56	8/20/2013	13:00	6993	HDPE	150	22	83	76	--	--	--	--	3,300	
P57	8/20/2013	13:15	6980	HDPE	150	22	76	83	--	--	--	--	3,300	
P58	8/20/2013	13:40	6983	HDPE	156	22	84	80	--	--	--	--	3,432	
P59	8/20/2013	13:40	6983	HDPE	6	22	80	80	--	--	--	--	132	
P60	8/20/2013	13:58	7003	HDPE	18	22	79	77	--	--	--	--	396	
P61	8/20/2013	14:04	7003	HDPE	139	22	79	77	--	--	--	--	3,058	
P62	8/20/2013	14:35	6985	HDPE	192	22	81	82	--	--	--	--	4,224	
P63	8/20/2013	14:45	6985	HDPE	288	22	70	73	--	--	--	--	6,336	
P64	8/20/2013	15:16	6977	HDPE	164	22	79	81	--	--	--	--	3,608	
P65	8/20/2013	15:31	7001	HDPE	154	22	75	79	--	--	--	--	3,388	
P66	8/20/2013	16:06	6984	HDPE	49	22	75	77	--	--	--	--	1,078	
P67	8/20/2013	16:10	6984	HDPE	29	22	76	79	--	--	--	--	638	
P68	8/21/2013	7:30	7002	HDPE	349	22	71	70	--	--	--	--	7,678	
P69	8/21/2013	8:02	7002	HDPE	160	22	73	75	--	--	--	--	3,520	
P70	8/21/2013	8:20	6992	HDPE	158	22	70	77	--	--	--	--	3,476	
P71	8/21/2013	8:22	6984	HDPE	36	22	79	79	--	--	--	--	792	
P72	8/21/2013	8:30	6978	HDPE	168	22	80	85	--	--	--	--	3,696	
P73	8/21/2013	9:00	6996	HDPE	187	22	75	74	--	--	--	--	4,114	
P74	8/21/2013	9:17	6996	HDPE	292	22	80	82	--	--	--	--	6,424	
P75	8/21/2013	9:51	6990	HDPE	60	22	76	76	--	--	--	--	1,320	
P76	8/21/2013	9:58	6982	HDPE	353	22	86	84	--	--	--	--	7,766	
P77	8/21/2013	10:43	6982	HDPE	156	22	75	77	--	--	--	--	3,432	
P78	8/21/2013	11:09	6988	HDPE	196	22	70	74	--	--	--	--	4,312	
P79	8/21/2013	12:59	6988	HDPE	290	22	75	73	--	--	--	--	6,380	
P80	8/21/2013	13:17	6991	HDPE	60	22	86	85	--	--	--	--	1,320	
P81	8/21/2013	13:25	6991	HDPE	360	22	76	79	--	--	--	--	7,920	
P82	8/21/2013	13:53	6981	HDPE	350	22	78	75	--	--	--	--	7,700	
P83	8/21/2013	14:22	6981	HDPE	163	22	79	83	--	--	--	--	3,586	
P84	8/21/2013	14:37	6987	HDPE	194	22	75	76	--	--	--	--	4,268	
P85	8/21/2013	14:52	6987	HDPE	293	22	77	80	--	--	--	--	6,446	
P86	8/21/2013	15:25	6991	HDPE	58	22	82	80	--	--	--	--	1,276	
P87	8/21/2013	15:37	6986	HDPE	348	22	74	73	--	--	--	--	7,656	
P88	8/21/2013	16:02	6986	HDPE	159	22	90	85	--	--	--	--	3,498	
P89	8/21/2013	16:16	6989	HDPE	148	22	76	80	--	--	--	--	3,256	
P90	8/21/2013	16:30	6989	HDPE	293	22	75	76	--	--	--	--	6,446	
P91	8/21/2013	16:49	6998	HDPE	57	22	75	73	--	--	--	--	1,254	

NATURAL RESOURCE TECHNOLOGY

Panel Placement Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Panel Number	Date	Time	Roll Number	Mat. Id.	Final Length (Feet)	Width	Thickness (mils)						Final Area (Sq. Ft.)	COMMENTS
P92	8/21/2013	16:51	6998	HDPE	45	22	79	80	--	--	--	--	990	
P93	8/21/2013	16:54	6998	HDPE	30	22	75	75	--	--	--	--	660	
P94	8/21/2013	17:01	6990	HDPE	37	22	74	77	--	--	--	--	814	
P95	8/21/2013	17:10	6990	HDPE	39	22	73	71	--	--	--	--	858	
P96	8/21/2013	17:18	6995	HDPE	39	22	77	75	--	--	--	--	858	
P97	8/21/2013	17:24	6995	HDPE	14	21	79	74	--	--	--	--	294	
P98	8/22/2013	7:30	6998	HDPE	31	10	75	71	--	--	--	--	310	
P99	8/22/2013	7:32	6998	HDPE	31	11	75	71	--	--	--	--	341	
P100	8/22/2013	7:35	6998	HDPE	26	9	75	71	--	--	--	--	234	
P101	8/22/2013	7:38	6998	HDPE	21	10	75	71	--	--	--	--	210	
P102	8/22/2013	7:40	6996	HDPE	28	9	74	75	--	--	--	--	252	
P103	8/22/2013	7:43	6996	HDPE	28	12	74	75	--	--	--	--	336	
P104	8/22/2013	7:45	6984	HDPE	33	10	73	70	--	--	--	--	330	
P105	8/22/2013	7:47	6984	HDPE	35	9	73	70	--	--	--	--	315	
P106	8/22/2013	8:00	6984	HDPE	14	9	73	71	--	--	--	--	126	
													369,720	TOTAL

ATTACHMENT E3

PANEL SEAMING SUMMARY

NATURAL RESOURCE TECHNOLOGY

Panel Seaming Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number			Date Seamed	Final Seam Length (Feet)	Welder Id.	Weld Type	Machine Number	Machine Temp/ Speed or Preheat	Time Start	Time Stop	Ambient Temp. (°F)	Comments
P1	/	P2	8/14/13	60	KK	Fus	140	850/5.0	8:15	8:20	70	Machine 140
P1	/	P16	8/14/13	20	KK	Fus	140	850/5.0	11:00	11:05	75	
P1	/	P18	8/14/13	21	KK	Fus	140	850/5.0	10:56	11:00	75	
P1	/	P19	8/14/13	6	KK	Fus	140	850/5.0	10:55	10:56	75	3 segments - west
P2	/	P3	8/14/13	60	HN	Fus	69	850/5.3	8:17	8:27	70	
P3	/	P4	8/14/13	60	HN	Fus	69	850/5.3	8:30	8:39	70	
P4	/	P5	8/14/13	60	KK	Fus	140	850/5.0	8:30	8:40	70	Burnout
P5	/	P6	8/14/13	34	KK	Fus	140	850/5.0	8:45	8:55	70	seam cenered on concrete outlet - batten strip
P6	/	P7	8/14/13	60	HN	Fus	69	850/5.3	8:44	8:51	70	
P7	/	P8	8/14/13	60	HN	Fus	69	850/5.3	8:56	9:16	70	
P8	/	P9	8/14/13	60	KK	Fus	140	850/5.0	9:00	9:10	70	
P9	/	P10	8/14/13	60	KK	Fus	140	850/5.0	9:15	9:25	75	
P10	/	P11	8/14/13	57	HN	Fus	69	850/5.3	9:21	9:26	75	
P11	/	P12	8/14/13	57	HN	Fus	69	850/5.3	9:32	9:36	75	
P12	/	P13	8/14/13	57	KK	Fus	140	850/5.0	9:30	9:40	75	
P13	/	P14	8/14/13	21	HN	Fus	69	850/5.3	9:59	10:02	75	
P13	/	P15	8/14/13	22	HN	Fus	69	850/5.3	9:56	9:59	75	22' not trimmed
P13	/	P17	8/14/13	15	HN	Fus	69	850/5.3	10:18	10:23	75	
P14	/	P15	8/14/13	24	HN	Fus	69	850/5.3	9:39	9:44	75	
P15	/	P17	8/14/13	24	HN	Fus	69	850/5.3	10:23	10:27	75	
P16	/	P17	8/14/13	42	KK	Fus	140	850/5.0	10:20	10:25	75	

Natural Resource Technology

Panel Seaming Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number			Date Seamed	Final Seam Length (Feet)	Welder Id.	Weld Type	Machine Number	Machine Temp/ Speed or Preheat	Time Start	Time Stop	Ambient Temp. (°F)	Comments
P16	/	P18	8/14/13	36	KK	Fus	140	850/5.0	10:30	10:35	75	
P17	/	P20	8/14/13	62	HN	Fus	69	850/5.3	10:47	10:56	75	between risers
P17	/	P20	8/14/13	74	HN	Fus	69	850/5.3	11:24	11:36	75	burn thru slope 14' W of E trench
P17	/	P20	8/14/13	216	HN	Fus	69	850/5.3	10:56	11:24	75	east of east riser
P18	/	P19	8/14/13	13	KK	Fus	140	850/5.0	10:50	10:52	75	
P20	/	P21	8/14/13	353	KK	Fus	140	850/5.0	11:10	12:00	75	
P21	/	P22	8/14/13	357	HN	Fus	69	850/5.3	13:16	14:00	80	
P22	/	P23	8/14/13	355	KK	Fus	140	850/5.0	13:15	14:05	80	excess panel trimmed
P23	/	P24	8/14/13	354	HN	Fus	69	850/5.3	14:09	14:59	80	excess panel trimmed
P24	/	P25	8/14/13	352	KK	Fus	140	850/5.0	14:30	15:15	80	panel trimed; burn thru west floor edge
P25	/	P26	8/14/13	346	HN	Fus	69	850/5.3	15:12	15:52	80	east wall outlet structure
P26	/	P27	8/14/13	351	KK	Fus	140	850/5.0	15:20	16:08	80	burn through west toe
P27	/	P28	8/14/13	351	HN	Fus	69	850/5.3	15:56	16:47	80	excess panel trimmed
P28	/	P29	8/14/13	354	KK	Fus	140	850/5.0	16:15	17:00	80	excess panel trimmed
P29	/	P30	8/15/13	350	KK	Fus	140	850/5.0	8:40	9:30	60	panel trimmed short of anchor trench
P30	/	P31	8/15/13	73	HN	Fus	69	850/5.3	9:43	9:53	60	riser to east trench
P30	/	P31	8/15/13	281	HN	Fus	69	850/5.3	9:15	9:45	60	
P31	/	P32	8/15/13	356	KK	Fus	140	850/5.0	9:35	10:20	60	excess panel trimmed
P32	/	P33	8/15/13	356	HN	Fus	69	850/5.3	10:13	10:53	65	excess panel trimmed
P33	/	P34	8/15/13	354	KK	Fus	140	850/5.0	10:30	11:20	65	excess panel trimmed
P34	/	P35	8/15/13	350	HN	Fus	69	850/5.3	11:16	11:54	65	excess panel trimmed

NATURAL RESOURCE TECHNOLOGY

Panel Seaming Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Date Seamed	Final Seam Length (Feet)	Welder Id.	Weld Type	Machine Number	Machine Temp/ Speed or Preheat	Time Start	Time Stop	Ambient Temp. (°F)	Comments
P35 / P36	8/15/13	356	KK	Fus	140	850/5.0	11:25	12:05	65	excess panel trimmed
P36 / P37	8/15/13	360	KK	Fus	140	850/5.0	13:35	14:30	72	riser cut from west end 69'
P37 / P38	8/15/13	360	HN	Fus	69	850/5.3	13:59	14:44	72	excess panel trimmed
P38 / P39	8/19/13	360	KK	Fus	140	850/5.0	12:45	13:30	80	
P39 / P40	8/19/13	135	HN	Fus	69	850/5.3	14:10	14:32	80	excess panel trimmed
P39 / P41	8/19/13	138	HN	Fus	69	850/5.3	13:37	14:10	80	
P40 / P41	8/19/13	22	KK	Fus	140	850/5.0	13:35	13:40	80	
P40 / P42	8/19/13	67	KK	Fus	140	850/5.0	14:55	15:05	85	riser to east trench
P40 / P42	8/19/13	143	KK	Fus	140	850/5.0	14:45	14:55	80	P41 to riser
P41 / P42	8/19/13	53	KK	Fus	140	850/5.0	14:25	14:45	85	
P41 / P43	8/19/13	79	KK	Fus	140	850/5.0	14:15	14:25	85	
P42 / P43	8/19/13	22	KK	Fus	140	850/5.0	14:05	14:10	80	
P42 / P51	8/19/13	17	KK	Fus	140	850/5.0	15:33	15:35	85	cut at riser to west (ramp)
P42 / P51	8/19/13	129	KK	Fus	140	850/5.0	15:35	15:50	85	east of riser
P42 / P52	8/19/13	154	KK	Fus	140	850/5.0	15:50	16:15	85	
P43 / P44	8/19/13	48	HN	Fus	69	850/5.3	14:34	14:42	85	
P43 / P51	8/19/13	11	KK	Fus	140	850/5.0	15:30	15:33	85	
P44 / P45	8/19/13	40	HN	Fus	69	850/5.3	14:45	14:51	85	
P45 / P46	8/19/13	33	HN	Fus	69	850/5.3	14:53	15:00	85	
P46 / P47	8/19/13	26	HN	Fus	69	850/5.3	15:01	15:06	85	
P47 / P48	8/19/13	19	HN	Fus	69	850/5.3	15:07	15:13	85	

NATURAL RESOURCE TECHNOLOGY

Panel Seaming Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Date Seamed	Final Seam Length (Feet)	Welder Id.	Weld Type	Machine Number	Machine Temp/ Speed or Preheat	Time Start	Time Stop	Ambient Temp. (°F)	Comments
P48 / P49	8/19/13	12	HN	Fus	69	850/5.3	15:14	15:16	85	
P49 / P50	8/19/13	6	HN	Fus	69	850/5.3	15:18	15:19	85	
P51 / P52	8/19/13	22	KK	Fus	140	850/5.0	15:20	15:25	85	
P51 / P53	8/19/13	156	HN	Fus	69	850/5.3	15:42	16:03	85	
P52 / P53	8/19/13	3	HN	Fus	69	850/5.3	16:03	16:04	85	
P52 / P54	8/19/13	148	HN	Fus	69	850/5.3	16:09	16:42	85	
P53 / P54	8/19/13	22	HN	Fus	69	850/5.3	16:05	16:08	85	
P53 / P55	8/20/13	154	KK	Fus	140	850/6.5	12:55	13:20	85	
P53 / P56	8/20/13	3	KK	Fus	140	850/6.5	13:25	13:26	85	
P53 / P59	8/20/13	6	KK	Fus	140	850/6.5	13:20	13:25	85	
P54 / P56	8/20/13	149	KK	Fus	140	850/6.5	13:26	13:40	85	
P55 / P57	8/20/13	150	HN	Fus	69	850/6.3	13:25	13:51	85	
P55 / P59	8/20/13	22	KK	Fus	140	850/6.5	13:50	13:55	85	
P55 / P60	8/20/13	22	HN	Fus	69	850/6.3	14:16	14:17	85	
P56 / P58	8/20/13	152	HN	Fus	69	850/6.3	14:19	14:35	85	
P56 / P59	8/20/13	22	KK	Fus	140	850/6.5	14:00	14:04	85	
P57 / P60	8/20/13	22	HN	Fus	69	850/6.3	14:09	14:13	85	
P57 / P61	8/20/13	150	KK	Fus	140	850/6.5	14:20	14:39	85	
P57 / P62	8/20/13	14	KK	Fus	140	850/6.5	14:45	14:50	85	
P58 / P59	8/20/13	6	HN	Fus	69	850/6.3	14:18	14:19	85	
P58 / P60	8/20/13	22	HN	Fus	69	850/6.3	14:00	14:02	85	

NATURAL RESOURCE TECHNOLOGY

Panel Seaming Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Date Seamed	Final Seam Length (Feet)	Welder Id.	Weld Type	Machine Number	Machine Temp/ Speed or Preheat	Time Start	Time Stop	Ambient Temp. (°F)	Comments
P58 / P62	8/20/13	158	KK	Fus	140	850/6.5	14:53	15:10	85	
P60 / P62	8/20/13	18	KK	Fus	140	850/6.5	14:50	14:53	85	
P61 / P62	8/20/13	22	KK	Fus	140	850/6.5	14:40	14:45	85	
P61 / P63	8/20/13	93	HN	Fus	69	850/6.3	15:09	15:21	85	
P61 / P66	8/20/13	48	HN	Fus	69	850/6.3	16:09	16:15	85	
P62 / P63	8/20/13	192	HN	Fus	69	850/6.3	15:21	15:41	85	
P63 / P64	8/20/13	115	HN	Fus	69	850/6.3	16:32	16:44	85	
P63 / P65	8/20/13	154	KK	Fus	140	850/6.0	15:55	16:15	85	
P63 / P66	8/20/13	22	HN	Fus	69	850/6.3	16:18	16:23	85	
P63 / P67	8/20/13	29	KK	Fus	140	850/6.5	16:35	16:40	85	
P64 / P66	8/20/13	54	HN	Fus	69	850/6.3	16:25	16:44	85	
P64 / P67	8/20/13	22	KK	Fus	140	850/6.5	16:20	16:23	85	Temp 85
P64 / P68	8/21/13	168	HN	Fus	69	850/6.3	7:58	8:15	70	
P65 / P67	8/20/13	22	KK	Fus	140	850/6.5	16:30	16:32	85	
P65 / P68	8/21/13	156	HN	Fus	69	850/6.3	8:18	8:38	70	
P67 / P68	8/21/13	29	HN	Fus	69	850/6.3	8:15	8:18	70	
P68 / P69	8/21/13	156	KK	Fus	140	850/6.5	9:05	9:25	70	P68/P69
P68 / P70	8/21/13	159	KK	Fus	140	850/6.5	8:45	9:00	70	
P68 / P71	8/21/13	36	KK	Fus	140	850/6.5	9:00	9:05	70	
P69 / P71	8/21/13	22	KK	Fus	140	850/6.5	8:35	8:40	70	P69/P71
P69 / P72	8/21/13	62	HN	Fus	69	850/6.3	9:10	9:19	70	riser to east trench

Panel Seaming Summary

NATURAL RESOURCE TECHNOLOGY

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Date Seamed	Final Seam Length (Feet)	Welder Id.	Weld Type	Machine Number	Machine Temp/ Speed or Preheat	Time Start	Time Stop	Ambient Temp. (°F)	Comments
P69 / P72	8/21/13	95	HN	Fus	69	850/6.3	9:01	9:10	70	riser west to P73
P70 / P71	8/21/13	22	KK	Fus	140	850/6.5	8:25	8:30	70	
P70 / P73	8/21/13	160	HN	Fus	69	850/6.3	9:24	9:43	75	
P71 / P72	8/21/13	3	HN	Fus	69	850/6.3	9:00	9:01	70	
P71 / P73	8/21/13	36	HN	Fus	69	850/6.3	9:43	9:47	75	
P72 / P73	8/21/13	**22**	KK	Fus	140	850/6.0	9:35	9:40	70	
P72 / P74	8/21/13	166	KK	Fus	140	850/6.5	10:00	10:15	80	
P73 / P74	8/21/13	130	KK	Fus	140	850/6.5	9:45	10:00	75	
P73 / P75	8/21/13	60	HN	Fus	69	850/6.3	10:04	10:12	75	
P74 / P75	8/21/13	22	HN	Fus	69	850/6.3	9:57	10:02	80	
P74 / P76	8/21/13	290	KK	Fus	140	850/6.5	10:35	11:10	80	
P75 / P76	8/21/13	62	KK	Fus	140	850/6.5	10:30	10:35	80	
P76 / P77	8/21/13	158	HN	Fus	69	850/6.3	10:57	11:16	80	
P76 / P78	8/21/13	198	KK	Fus	140	850/6.5	11:15	11:35	80	
P77 / P78	8/21/13	22	HN	Fus	69	850/6.3	11:22	11:26	80	
P77 / P79	8/21/13	155	KK	Fus	140	850/6.5	13:30	13:45	87	
P78 / P79	8/21/13	137	KK	Fus	140	850/6.5	13:15	13:30	87	
P78 / P80	8/21/13	60	HN	Fus	69	850/6.3	13:26	13:27	87	
P79 / P80	8/21/13	22	HN	Fus	69	850/6.3	13:16	13:21	87	
P79 / P81	8/21/13	292	HN	Fus	69	850/6.3	13:58	14:23	87	
P80 / P81	8/21/13	61	HN	Fus	69	850/6.3	13:49	13:58	87	

NATURAL RESOURCE TECHNOLOGY

Panel Seaming Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Date Seamed	Final Seam Length (Feet)	Welder Id.	Weld Type	Machine Number	Machine Temp/ Speed or Preheat	Time Start	Time Stop	Ambient Temp. (°F)	Comments
P81 / P82	8/21/13	350	KK	Fus	140	850/6.5	14:15	14:55	87	
P82 / P83	8/21/13	163	HN	Fus	69	850/6.3	14:33	14:49	87	
P82 / P84	8/21/13	187	HN	Fus	69	850/6.3	14:58	15:16	87	panels were measured before trimming
P83 / P84	8/21/13	22	KK	Fus	140	850/6.5	15:00	15:05	87	
P83 / P85	8/21/13	163	KK	Fus	140	850/6.5	15:25	15:45	87	
P84 / P85	8/21/13	135	KK	Fus	140	850/6.5	15:15	15:25	87	
P84 / P86	8/21/13	58	HN	Fus	69	850/6.3	15:35	15:43	87	
P85 / P86	8/21/13	22	HN	Fus	69	850/6.3	15:29	15:33	87	
P85 / P87	8/21/13	290	KK	Fus	140	850/6.5	16:05	16:35	87	
P86 / P87	8/21/13	58	KK	Fus	140	850/6.5	16:00	16:05	87	
P87 / P88	8/21/13	159	HN	Fus	69	850/6.3	16:12	16:27	87	
P87 / P89	8/21/13	198	HN	Fus	69	850/6.3	16:36	16:55	87	
P88 / P89	8/21/13	22	KK	Fus	140	850/6.5	16:45	16:50	87	
P88 / P90	8/21/13	62	HN	Fus	69	850/6.3	17:39	17:45	87	E riser to E trench
P88 / P90	8/21/13	94	KK	Fus	140	850/6.5	17:27	17:39	87	
P89 / P90	8/21/13	14	HN	Fus	69	850/6.3	17:00	17:10	87	W riser to P91
P89 / P90	8/21/13	121	HN	Fus	69	850/6.3	17:15	17:27	87	
P89 / P91	8/21/13	58	HN	Fus	69	850/6.3	16:55	17:00	87	
P90 / P91	8/21/13	22	KK	Fus	140	850/6.5	16:55	17:00	87	
P90 / P96	8/21/13	42	KK	Fus	140	850/6.5	17:37	17:42	87	
P90 / P98	8/22/13	22	KK	Fus	140	850/6.0	8:49	8:51	70	

Panel Seaming Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Date Seamed	Final Seam Length (Feet)	Welder Id.	Weld Type	Machine Number	Machine Temp/ Speed or Preheat	Time Start	Time Stop	Ambient Temp. (°F)	Comments
P90 / P99	8/22/13	31	KK	Fus	140	850/6.0	8:51	9:00	70	
P90 / P100	8/22/13	26	KK	Fus	140	850/6.0	9:00	9:03	75	
P90 / P101	8/22/13	27	KK	Fus	140	850/6.0	9:03	9:05	75	
P90 / P102	8/22/13	27	KK	Fus	140	850/6.0	9:05	9:10	75	
P90 / P103	8/22/13	28	KK	Fus	140	850/6.0	9:10	9:15	75	
P90 / P104	8/22/13	33	KK	Fus	140	850/6.0	9:15	9:20	75	
P90 / P105	8/22/13	33	KK	Fus	140	850/6.0	9:20	9:25	75	
P90 / P106	8/22/13	13	KK	Fus	140	850/6.0	9:25	9:30	75	
P91 / P92	8/21/13	48	KK	Fus	140	850/6.5	17:05	17:10	87	
P91 / P98	8/22/13	6	KK	Fus	140	850/6.0	8:47	8:49	70	
P92 / P93	8/21/13	22	KK	Fus	140	850/6.5	17:25	17:30	87	
P92 / P94	8/21/13	16	KK	Fus	140	850/6.5	17:30	17:35	87	
P92 / P98	8/22/13	9	KK	Fus	140	850/6.0	8:45	8:47	70	
P93 / P94	8/21/13	30	KK	Fus	140	850/6.5	17:15	17:20	87	
P95 / P96	8/21/13	18	KK	Fus	140	850/6.5	17:50	17:52	87	
P95 / P97	8/21/13	26	KK	Fus	140	850/6.5	17:45	17:47	87	
P96 / P97	8/21/13	15	KK	Fus	140	850/6.5	17:52	18:00	87	
P96 / P106	8/22/13	8	KK	Fus	140	850/6.0	8:38	8:40	70	Capped
P98 / P99	8/22/13	8	KK	Fus	140	850/6.0	7:52	7:55	70	
P99 / P100	8/22/13	8	KK	Fus	140	850/6.0	7:55	8:00	70	
P100 / P101	8/22/13	8	KK	Fus	140	850/6.0	8:03	8:05	70	

Panel Seaming Summary

NATURAL RESOURCE TECHNOLOGY

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Date Seamed	Final Seam Length (Feet)	Welder Id.	Weld Type	Machine Number	Machine Temp/ Speed or Preheat	Time Start	Time Stop	Ambient Temp. (°F)	Comments
P101 / P102	8/22/13	8	KK	Fus	140	850/6.0	8:08	8:10	70	
P102 / P103	8/22/13	8	KK	Fus	140	850/6.0	8:13	8:15	70	
P103 / P104	8/22/13	8	KK	Fus	140	850/6.0	8:18	8:20	70	
P104 / P105	8/22/13	8	KK	Fus	140	850/6.0	8:25	8:30	70	
P105 / P106	8/22/13	8	KK	Fus	140	850/6.0	8:33	8:35	70	

ATTACHMENT E4

REPAIR SUMMARY

NATURAL RESOURCE TECHNOLOGY

Repair Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Repair Number	Date	Time	Oper./Mach.	Repair Location North East	Description	Size of Repair	Date Vacuum Tested	Vac. Test Results (P/F)
R1	8/20/2013	9:00	VP / 88	P6/P7, Structure N	Structure	2'x70'	8/20/2013	P
R2	8/16/2013	14:00	VK / 46	P9/P10, North near trench	Patch	4'x2'	8/17/2013	ELIS
R3	8/16/2013	11:45	BL / 10	P17/P20, Riser 65' W	Boot	6'x5'	8/17/2013	P
R4	8/16/2013	11:15	VK / 46	P17/P20, Riser 74' E	Boot	5'x3'	8/17/2013	P
R5	8/16/2013	8:25	VK / 46	P20/P21, 13' E	Patch	6'x3'	8/17/2013	P
R6	8/16/2013	13:38	BL / 10	P26, Structure E	Patch	14'x6'	8/17/2013	P
R7	8/16/2013	11:30	PX / 88	P24/P25, 75' W	Patch	4'x2'	8/17/2013	P
R8	8/16/2013	11:15	PX / 88	P26/P27, 55' W	Patch	3'x4'	8/17/2013	P
R9	8/16/2013	10:00	PX / 88	P27/P28, 42' W	Patch	5'x2'	8/17/2013	P
R10	8/16/2013	10:10	PX / 88	P27/P28, 9' E of R29	Patch	4'x2'	8/17/2013	P
R11	8/16/2013	7:50	VK / 46	P17, 2' E R17	Patch	1'x1'	8/17/2013	P
R12	8/16/2013	10:25	VK / 46	P30/P31, Riser 73' W	Boot	7'x2'	8/17/2013	P
R13	8/16/2013	9:00	PX / 88	P36/P37, Riser 76' E	Boot	6'x2'	8/17/2013	P
R14	8/16/2013	8:00	VK / 46	P13/P15/P17	Tee	2'x2'	8/17/2013	P
R15	8/16/2013	8:05	VK / 46	P13/P14/P15	Tee	2'x2'	8/17/2013	P
R16	8/16/2013	8:47	VK / 46	P22/P23, E near trench	Patch	2'x1'	8/17/2013	P
R17	8/16/2013	8:55	VK / 46	P23/P24, E near trench	Patch	1'x1'	8/17/2013	P
R18	8/16/2013	8:30	BL / 10	P18/P19, Trench N	Patch	3'x4'	8/17/2013	P
R19	8/16/2013	8:25	BL / 10	P1/P18/P19, Joint N 4'	Tee	1'x2'	8/17/2013	P
R20	8/16/2013	8:20	BL / 10	P1/P16/P18, Joint N 25'	Tee	1'x2'	8/17/2013	P
R21	8/16/2013	8:45	BL / 10	P16/P17, Trench	Patch	2'x4'	8/17/2013	P
R22	8/16/2013	9:00	BL / 10	P17/P20, Trench W 4' across	Patch	2'x4'	8/17/2013	P

ELIS: Electrical Liner Integrity Survey

NATURAL RESOURCE TECHNOLOGY

Repair Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Repair Number	Date	Time	Oper./Mach.	Repair Location North East	Description	Size of Repair	Date Vacuum Tested	Vac. Test Results (P/F)
R23	8/16/2013	9:11	VK / 46	P26/P27, Trench E	Patch	3'x3'	8/26/2013	P
R24	8/16/2013	9:30	VK / 46	P29/P30, 2' from trench	Patch	1'x2'	8/26/2013	P
R25	8/16/2013	9:15	BL / 10	P22/P23, 1' from trench W	Patch	1'x2'	8/26/2013	P
R26	8/16/2013	10:00	BL / 10	P23/P24, 2' from trench W	Patch	1'x2'	8/26/2013	P
R27	8/16/2013	10:30	BL / 10	P24/P25, Trench W	Patch	3'x5'	8/26/2013	P
R28	8/16/2013	9:05	PX / 88	P34/P35, 2' from W trench	Patch	4'x2'	8/26/2013	P
R29	8/16/2013	9:20	PX / 88	P29/P30, 1' from W trench	Patch	2'x5'	8/26/2013	P
R30	8/16/2013	9:45	PX / 88	P27/P28, 2' from W trench	Patch	1'x2'	8/26/2013	P
R31	8/16/2013	13:52	VK / 46	P10/P11, 1' from N trench	Patch	1'x1'	8/26/2013	P
R32	8/16/2013	11:40	VK / 46	P17, 2' E trench	Patch	1'x1'	8/26/2013	P
R33	8/16/2013	15:20	PX / 88	P4/P5, 5' N trench	Patch	7'x2'	8/27/2013	ELIS
R34	8/16/2013	15:13	VK / 46	P12/P13	Outfall	4'x2'	8/27/2013	ELIS
R35	8/16/2013	14:55	VK / 46	P12	Outfall	2'x1'	8/27/2013	ELIS
R36	8/16/2013	14:43	VK / 46	P11/P12	Outfall	1'x1'	8/27/2013	ELIS
R37	8/16/2013	14:40	VK / 46	P10/P11	Outfall	3'x2'	8/27/2013	ELIS
R38	8/16/2013	15:30	VK / 46	P7/P8	Outfall	2'x1'	8/27/2013	ELIS
R39	8/16/2013	13:40	PX / 88	P1/P2	Outfall	3'x2'	8/27/2013	ELIS
R40	8/16/2013	14:50	PX / 88	P1/P16, 2' from outfall	Outfall	1'x1'	8/17/2013	P
R41	8/16/2013	14:45	PX / 88	P16/P17	Outfall	3'x3'	8/17/2013	P
R42	8/17/2013	8:40	VK / 46	P13/P17	Outfall	2'x3'	8/27/2013	ELIS
R43	8/17/2013	8:30	VK / 46	P17	Outfall	8'x1'	8/27/2013	ELIS
R44	8/20/2013	13:30	VP / 88	E Structure	Second Layer	4'x4'	8/20/2013	P

ELIS: Electrical Liner Integrity Survey

NATURAL RESOURCE TECHNOLOGY

Repair Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Repair Number	Date	Time	Oper./Mach.	Repair Location North East	Description	Size of Repair	Date Vacuum Tested	Vac. Test Results (P/F)
R45	8/20/2013	14:00	VP / 88	E Structure	Second Layer	7'x5'	8/20/2013	P
R46	8/22/2013	8:30	VK / 46	P39/P40/P41, 138 E trench	Tee	1'x1'	8/27/2013	ELIS
R47	8/22/2013	8:37	VK / 46	P40/P41/P42, 138 E trench	Tee	1'x2'	8/27/2013	ELIS
R48	8/22/2013	8:45	VK / 46	P42/P51/P52, 154 E trench	Tee	2'x2'	8/27/2013	ELIS
R49	8/22/2013	8:47	VK / 46	P51/P52/P53/P54, 154 E trench	Tee	5'x2'	8/27/2013	ELIS
R50	8/22/2013	9:20	VK / 46	P53/P54/P56/P59, 151 E trench	Tee	2'x21'	8/27/2013	ELIS
R51	8/22/2013	9:22	VK / 46	P53/P54/P56/P59, 152 E trench	Tee	2'x13'	8/27/2013	ELIS
R52	8/22/2013	9:55	VK / 46	P56/P58/P59 154 E trench	Tee	2'x2'	8/27/2013	ELIS
R53	8/22/2013	10:00	VK / 46	P55/P58/P59/P60, 161 E trench	Tee	2'x3'	8/27/2013	ELIS
R54	8/22/2013	10:10	VK / 46	P58/P60/P62, 161 E trench	Tee	2'x2'	8/27/2013	ELIS
R55	8/22/2013	10:15	VK / 46	P57/P60/P62, 180 E trench	Tee	2'x2'	8/27/2013	ELIS
R56	8/22/2013	10:05	VK / 46	P55/P57/P60, 180 E trench	Tee	2'x2'	8/27/2013	ELIS
R57	8/22/2013	10:20	VK / 46	P57/P61/P62, 195 E trench	Tee	3'x2'	8/27/2013	ELIS
R58	8/22/2013	10:25	VK / 46	P62, 195 E trench	Patch	2'x1'	8/27/2013	ELIS
R59	8/22/2013	10:30	VK / 46	P61/P62/P63, 195 E trench	Tee	2'x2'	8/27/2013	ELIS
R60	8/22/2013	8:45	BL / 10	P41/P42/P43, 79 W trench	Tee	2'x2'	8/27/2013	ELIS
R61	8/22/2013	8:50	BL / 10	P43, 76 W trench	Patch	2'x2'	8/27/2013	ELIS
R62	8/22/2013	8:55	BL / 10	P43, 72 W trench	Patch	1'x1'	8/27/2013	ELIS
R63	8/21/2013	14:00	VP / 88	P43, 43 W trench	Patch	2'x1'	8/27/2013	ELIS
R64	8/22/2013	9:45	BL / 10	P42/P51, 20 W ramp	Bad Seam	10'x6'	8/27/2013	ELIS
R65	8/22/2013	10:00	BL / 10	P61/P63/P66, 48 W ramp	Tee	6'x2'	8/27/2013	ELIS
R66	8/22/2013	10:10	BL / 10	P63/P64/P66, 55 W ramp	Tee	2'x1'	8/27/2013	ELIS

ELIS: Electrical Liner Integrity Survey

NATURAL RESOURCE TECHNOLOGY

Repair Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Repair Number	Date	Time	Oper./Mach.	Repair Location North East	Description	Size of Repair	Date Vacuum Tested	Vac. Test Results (P/F)
R67	8/22/2013	10:25	BL / 10	P63/P64, 107 W ramp	Patch	2'x2'	8/27/2013	ELIS
R68	8/22/2013	10:50	BL / 10	P63/P64/P67, 167 W ramp	Tee	2'x2'	8/27/2013	ELIS
R69	8/22/2013	11:00	BL / 10	P63/P65/P67, 196 W ramp	Tee	7'x1'	8/27/2013	ELIS
R70	8/22/2013	10:45	BL / 10	P64/P67/P68, 169 W ramp	Tee	2'x1'	8/27/2013	ELIS
R71	8/22/2013	11:15	BL / 10	P65/P67/P68, 199 W ramp	Tee	2'x2'	8/27/2013	ELIS
R72	8/22/2013	13:15	VK / 46	P38/P39, E trench, 1'	Patch	1'x1'	8/27/2013	ELIS
R73	8/22/2013	13:20	VK / 46	P40/P42, 1' E trench	Patch	1'x1'	8/27/2013	ELIS
R74	8/22/2013	11:25	VK / 46	P40/P42, Riser, 67' E trench	Boot	9'x3'	8/27/2013	ELIS
R75	8/22/2013	13:35	VK / 46	P54/P56, E trench	Patch	1'x2'	8/27/2013	ELIS
R76	8/22/2013	11:20	BL / 10	P68/P69/P71, 164' E trench	Patch	2'x1'	8/27/2013	ELIS
R77	8/22/2013	13:00	BL / 10	P69/P71/P72/P73, 164' E trench	Tee	7'x2'	8/27/2013	ELIS
R78	8/22/2013	13:08	BL / 10	P73, 164' E trench	Patch	2'x1'	8/27/2013	ELIS
R79	8/22/2013	13:15	BL / 10	P72/P73/P74, 163' E trench	Tee	2'x2'	8/27/2013	ELIS
R80	8/22/2013	13:40	BL / 10	P73, 174' E trench	Patch	2'x2'	8/27/2013	ELIS
R81	8/22/2013	13:50	BL / 10	P73, 182' E trench	Patch	2'x2'	8/27/2013	ELIS
R82	8/22/2013	14:00	VK / 46	P56/P58, 1' E trench	Patch	1'x1'	8/27/2013	ELIS
R83	8/22/2013	14:00	BL / 10	P70/P71/P73, 158' W trench	Tee	2'x1'	8/27/2013	ELIS
R84	8/22/2013	14:05	BL / 10	P68/P70/P71, 158' W trench	Tee	2'x2'	8/27/2013	ELIS
R85	8/22/2013	14:15	BL / 10	P73/P74/P75, 62' W trench	Tee	2'x2'	8/27/2013	ELIS
R86	8/22/2013	14:25	BL / 10	P74/P75/P76, 62' W trench	Tee	1'x1'	8/27/2013	ELIS
R87	8/22/2013	15:20	VK / 46	P69/P72, 65' E trench	Boot	8'x3'	8/27/2013	ELIS
R88	8/22/2013	15:15	VK / 46	P72, 71' E trench	Patch	1'x1'	8/27/2013	ELIS

ELIS: Electrical Liner Integrity Survey

NATURAL RESOURCE TECHNOLOGY

Repair Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Repair Number	Date	Time	Oper./Mach.	Repair Location North East	Description	Size of Repair	Date Vacuum Tested	Vac. Test Results (P/F)
R89	8/22/2013	14:55	BL / 10	P78/P79/P80, 62' W trench	Tee	3'x3'	8/27/2013	ELIS
R90	8/22/2013	15:00	BL / 10	P79/P80/P81, 63' W trench	Tee	2'x1'	8/27/2013	ELIS
R91	8/22/2013	15:40	VK / 46	P76/P77/P78, 153' E trench	Tee	8'x2'	8/27/2013	ELIS
R92	8/22/2013	15:50	VK / 46	P77/P78/P79, 153' E trench	Tee	2'x2'	8/27/2013	ELIS
R93	8/22/2013	15:10	BL / 10	P84/P85/P86, 59' W trench	Tee	5'x3'	8/27/2013	ELIS
R94	8/22/2013	15:20	BL / 10	P85/P86/P87, 59' W trench	Tee	2'x1'	8/27/2013	ELIS
R95	8/22/2013	16:25	BL / 10	P87/P89, 45' W trench	Patch	3'x2'	8/27/2013	ELIS
R96	8/22/2013	16:15	BL / 10	P89/P90, 72' W trench riser	Boot	8'x4'	8/27/2013	ELIS
R97	8/22/2013	16:00	VK / 46	P82/P83/P84, 158' E trench	Tee	2'x2'	8/27/2013	ELIS
R98	8/22/2013	16:05	VK / 46	P83/P84/P85, 158' E trench	Tee	2'x2'	8/27/2013	ELIS
R99	8/22/2013	16:22	VK / 46	P87/P88/P89, 154' E trench	Tee	5'x3'	8/27/2013	ELIS
R100	8/22/2013	16:30	VK / 46	P88/P89/P90, 155' E trench	Tee	2'x1'	8/27/2013	ELIS
R101	8/22/2013	16:25	VK / 46	P89, 80' E trench	Patch	2'x1'	8/27/2013	ELIS
R102	8/22/2013	16:15	VP / 88	P42/P43/P51, 12' W ramp	Tee	1'x1'	8/27/2013	ELIS
R103	8/22/2013	16:02	VP / 88	P43, East side ramp	Patch	5'x2'	8/27/2013	ELIS
R104	8/22/2013	15:50	VP / 88	P53, East side ramp	Patch	1'x1'	8/27/2013	ELIS
R105	8/22/2013	15:45	VP / 88	P53, East side ramp	Patch	2'x2'	8/27/2013	ELIS
R106	8/22/2013	15:55	VP / 88	P53, East side ramp	Patch	4'x1'	8/27/2013	ELIS
R107	8/22/2013	15:40	VP / 88	P53/P55, East side ramp	Patch	19'x1'	8/27/2013	ELIS
R108	8/22/2013	15:35	VP / 88	P53/P55, East side ramp	Patch	4'x1'	8/27/2013	ELIS
R109	8/22/2013	15:30	VP / 88	P55/P57, East side ramp	Patch	17x3'	8/27/2013	ELIS
R110	8/22/2013	16:30	VP / 88	P57, East side ramp	Patch	1'x1'	8/27/2013	ELIS

ELIS: Electrical Liner Integrity Survey

Repair Summary

Natural Resource Technology

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Repair Number	Date	Time	Oper./Mach.	Repair Location North East	Description	Size of Repair	Date Vacuum Tested	Vac. Test Results (P/F)
R111	8/22/2013	16:35	VP / 88	P57, East side ramp	Patch	1'x1'	8/27/2013	ELIS
R112	8/22/2013	16:55	VP / 88	P57/P61, East side ramp	Patch	2'x3'	8/27/2013	ELIS
R113	8/22/2013	16:25	BL / 10	P87/P89, 45' W trench	Patch	2'x1'	8/27/2013	ELIS
R114	8/23/2013	7:50	BL / 10	P89/P90/P91, 59' W trench	Tee	2'x2'	8/27/2013	ELIS
R115	8/23/2013	8:50	BL / 10	P92/P93/P94, 24' W trench	Tee	2'x2'	8/27/2013	ELIS
R116	8/23/2013	8:00	BL / 10	P91/P92/P98, 48' W trench	Tee	3'x2'	8/27/2013	ELIS
R117	8/23/2013	8:05	BL / 10	P90/P91/P98, 8' E of R 116	Tee	2'x2'	8/27/2013	ELIS
R118	8/23/2013	8:10	BL / 10	P90/P98/P99, 22' E of R117	Tee	2'x2'	8/27/2013	ELIS
R119	8/23/2013	8:15	BL / 10	P90/P99/P100, 32' E of R118	Tee	2'x2'	8/27/2013	ELIS
R120	8/23/2013	8:23	BL / 10	P90/P100/P101, 26' E of R120	Tee	2'x1'	8/27/2013	ELIS
R121	8/23/2013	8:30	BL / 10	P90/P101/P102, 27' E of R120	Tee	2'x2'	8/27/2013	ELIS
R122	8/23/2013	8:40	VK / 46	P90/P102/P103, 156' E trench	Tee	2'x1'	8/27/2013	ELIS
R123	8/23/2013	8:45	VK / 46	P90/P103/P104, 127' E trench	Tee	1'x1'	8/27/2013	ELIS
R124	8/23/2013	8:50	VK / 46	P90/P104/P105, 93' E trench	Tee	2'x1'	8/27/2013	ELIS
R125	8/23/2013	8:55	VK / 46	P90/P105/P106, 54' E trench	Tee	1'x1'	8/27/2013	ELIS
R126	8/23/2013	9:20	VK / 46	P90/P96/P106, 42' E trench	Tee	4'x3'	8/27/2013	ELIS
R127	8/23/2013	8:30	VK / 46	P88/P90, 60' E trench	Patch	7'x3'	8/27/2013	ELIS
R128	8/23/2013	9:25	VK / 46	P95/P96/P97, 14' E trench	Tee	2'x1'	8/27/2013	ELIS
R129	8/23/2013	9:43	VK / 46	P85, 2' E trench	Patch	2'x2'	8/27/2013	ELIS
R130	8/23/2013	9:45	VK / 46	P82/P83, 1' E trench	Patch	1'x1'	8/27/2013	ELIS
R131	8/23/2013	9:00	BL / 10	P92/P93, trench	Patch	6'x2'	8/27/2013	ELIS
R132	8/23/2013	9:10	BL / 10	P91/P92, W trench	Patch	3'x1'	8/27/2013	ELIS

ELIS: Electrical Liner Integrity Survey

Repair Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Repair Number	Date	Time	Oper./Mach.	Repair Location North East	Description	Size of Repair	Date Vacuum Tested	Vac. Test Results (P/F)
R133	8/23/2013	9:15	BL / 10	P89/P91, W trench	Patch	2'x2'	8/27/2013	ELIS
R134	8/23/2013	9:20	BL / 10	P87/P89, 1' W trench	Patch	2'x2'	8/27/2013	ELIS
R135	8/23/2013	9:40	BL / 10	P86/P87, 1' W trench	Patch	2'x2'	8/27/2013	ELIS
R136	8/23/2013	9:50	BL / 10	P84/P86, 1' W trench	Patch	3'x3'	8/27/2013	ELIS
R137	8/23/2013	10:05	BL / 10	P82/P84, 1' W trench	Patch	2'x2'	8/27/2013	ELIS
R138	8/23/2013	10:15	BL / 10	P81/P82, 1' W trench	Patch	2'x2'	8/27/2013	ELIS
R139	8/23/2013	10:23	BL / 10	P80/P81, 1' W trench	Patch	2'x2'	8/27/2013	ELIS
R140	8/23/2013	10:30	BL / 10	P78/P80, 1' W trench	Patch	2'x2'	8/27/2013	ELIS
R141	8/23/2013	11:00	BL / 10	P76/P78, 1' W trench	Patch	2'x2'	8/27/2013	ELIS
R142	8/23/2013	11:03	BL / 10	P75/P76, 1' W trench	Patch	2'x2'	8/27/2013	ELIS
R143	8/23/2013	11:07	BL / 10	P73/P75, 1' W trench	Patch	2'x2'	8/27/2013	ELIS
R144	8/23/2013	11:10	BL / 10	P70/P73, 1' W trench	Patch	2'x3'	8/27/2013	ELIS
R145	8/23/2013	11:20	BL / 10	P68/P70, 1' W trench	Patch	1'x1'	8/27/2013	ELIS
R146	8/23/2013	8:39	VP / 88	P68, East side ramp	Patch	3'x2'	8/27/2013	ELIS
R147	8/23/2013	8:00	VP / 88	P64/P68, East side ramp	Patch	3'x2'	8/27/2013	ELIS
R148	8/23/2013	7:33	VP / 88	P64/P66, East side ramp	Patch	8'x2'	8/27/2013	ELIS
R149	8/23/2013	10:40	VK / 46	P38/P39, 1' W ramp	Patch	1'x1'	8/27/2013	ELIS
R150	8/23/2013	10:47	VK / 46	P39/P41, 1' W ramp	Patch	1'x1'	8/27/2013	ELIS
R151	8/23/2013	10:55	VK / 46	P41/P43, 1' W ramp	Patch	1'x1'	8/27/2013	ELIS
R152	8/23/2013	11:00	VK / 46	P43/P44, 1' W ramp	Patch	1'x1'	8/27/2013	ELIS
R153	8/23/2013	11:05	VK / 46	P44/P45, 1' W ramp	Patch	2'x1'	8/27/2013	ELIS
R154	8/23/2013	11:12	VK / 46	P45/P46, 1' W ramp	Patch	2'x1'	8/27/2013	ELIS

ELIS: Electrical Liner Integrity Survey

NATURAL RESOURCE TECHNOLOGY

Repair Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Repair Number	Date	Time	Oper./Mach.	Repair Location North East	Description	Size of Repair	Date Vacuum Tested	Vac. Test Results (P/F)
R155	8/23/2013	11:20	VK / 46	P46/P47, 1' W ramp	Patch	2'x2'	8/27/2013	ELIS
R156	8/23/2013	11:25	VK / 46	P47/P48, 1' W ramp	Patch	2'x1'	8/27/2013	ELIS
R157	8/23/2013	11:35	VK / 46	P48/P49, 1' W ramp	Patch	2'x1'	8/27/2013	ELIS
R158	8/23/2013	11:40	VK / 46	P49/P50, 1' W ramp	Patch	1'x1'	8/27/2013	ELIS
R159	8/23/2013	13:58	VK / 88	P100/P101, 6' South R120 (inlet)	Patch	4'x1'	8/27/2013	ELIS
R160	8/23/2013	14:26	VK / 88	P92/P98, south inlet ramp	Patch	10'x2'	8/27/2013	ELIS
R161	8/23/2013	11:00	VK / 46	P45/P46, W ramp	Patch	1'x1'	8/27/2013	ELIS
R162	8/26/2013	8:30	PX / 88	P94, inlet structure, W	Boot	19'x4'	8/27/2013	ELIS
R163	8/26/2013	11:11	PX / 88	P95, inlet structure/trench	Structure	10'x7'	8/26/2013	P
R164	8/26/2013	15:54	VP / 88	P8, weir wall	Patch	10'x2'	8/26/2013	P
R165	8/27/2013	9:35	VP / 88	P85, 2' E trench	Patch	2'x2'	8/27/2013	P
R166	8/26/2013	10:35	PX / 88	P96, 38' E trench	Patch	2'x2'	8/26/2013	P
---	9/12/2013	---	VP / 46	---	Patch	2'x4'	9/12/2013	P
R167	10/1/2013	16:05	PX / 76	Batten strip near weir wall	Strips and patch	102'x3'	10/3/2013	P
R168	10/2/2013	10:30	VP / 76	Patch along weir wall	Patch runs east to west	134'x2'	10/3/2013	P
R169	10/2/2013	17:00	VP / 76	Weir wall	Batton strip	11'x3'	10/3/2013	P
R170	10/2/2013	16:30	VP / 76	P1/P16	Patch	34'x3'	10/3/2013	P
R171	10/3/2013	10:20	VP / 76	P38, 11' from warning layer	Patch	2'x2'	10/3/2013	P
R172	10/3/2013	11:00	VP / 76	Riser on P17, west	Boot	--	Spark Test	P
R173	10/4/2013	9:30	VP / 37	Riser on P31, east	Boot	--	Spark Test	P

ELIS: Electrical Liner Integrity Survey

ATTACHMENT E5

NON-DESTRUCTIVE TEST SUMMARY

NATURAL RESOURCE TECHNOLOGY

Non-Destructive Test Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Distance/ Location	Air Test: 27-30 psi for 5 min, < 3 psi loss						Vacuum Test		Comments
		Date Air Tested	Air Pressure				Air Test Results	Date Vacuum Tested	Vac. Test Results (P/F)	
			Start		End					
			PSI	Time	PSI	Time				
P1 / P2	BOS - EOS	8/14/2013	30	14:46	30	14:51	P			
P1 / P16	BOS - EOS	8/14/2013	30	14:06	28	14:11	P			
P1 / P18	BOS - EOS	8/14/2013	30	14:17	30	14:22	P			
P1 / P19	BOS - EOS	8/14/2013	30	14:22	30	14:27	P			P1/P19
P2 / P3	BOS - EOS	8/14/2013	30	14:53	30	14:58	P			
P3 / P4	BOS - EOS	8/14/2013	30	14:54	30	14:59	P			
P4 / P5	South 46'	8/14/2013	30	15:05	30	15:10	P			burnout
P4 / P5	North 14'	8/14/2013	30	15:06	30	15:11	P			
P5 / P6	BOS - EOS	8/14/2013	30	15:16	30	15:21	P			
P6 / P7	BOS - EOS	8/14/2013	30	15:23	30	15:28	P			
P7 / P8	BOS - EOS	8/14/2013	30	15:22	28	15:27	P			
P8 / P9	BOS - EOS	8/14/2013	30	15:32	28	15:37	P			
P9 / P10	BOS - EOS	8/14/2013	30	15:33	30	15:38	P			
P10 / P11	BOS - EOS	8/14/2013	30	15:38	30	15:43	P			
P11 / P12	BOS - EOS	8/14/2013	30	15:39	30	15:44	P			
P12 / P13	BOS - EOS	8/14/2013	30	15:46	30	15:51	P			
P13 / P14	BOS - EOS	8/14/2013	30	16:06	29	16:11	P			
P13 / P15	BOS - EOS	8/14/2013	30	16:00	30	16:05	P			
P13 / P17	BOS - EOS	8/14/2013	30	15:52	28	15:57	P			
P14 / P15	BOS - EOS	8/14/2013	30	16:02	28	16:07	P			

BOS: Beginning of Seam
EOS: End of Seam

NATURAL RESOURCE TECHNOLOGY

Non-Destructive Test Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number			Distance/ Location	Air Test: 27-30 psi for 5 min, < 3 psi loss						Vacuum Test		Comments
				Date Air Tested	Air Pressure				Air Test Results	Date Vacuum Tested	Vac. Test Results (P/F)	
					Start		End					
					PSI	Time	PSI	Time				
P15	/	P17	BOS - EOS	8/14/2013	30	15:53	29	15:58	P			
P16	/	P17	BOS - EOS	8/14/2013	30	14:05	30	14:10	P			
P16	/	P18	BOS - EOS	8/14/2013	30	14:16	30	14:21	P			
P17	/	P20	west of west riser	8/15/2013	30	9:20	30	9:25	P			62'
P17	/	P20	between risers	8/15/2013	30	9:21	30	9:26	P			216'
P17	/	P20	east of east riser	8/15/2013	30	9:22	30	9:27	P			74'
P18	/	P19	BOS - EOS	8/14/2013	30	14:21	28	14:26	P			
P20	/	P21	east trench to 14' W	8/15/2013	30	9:33	28	9:38	P			14'
P20	/	P21	west of 14' W of E trench	8/15/2013	30	9:34	28	9:39	P			340'
P21	/	P22	BOS - EOS	8/15/2013	30	9:35	29	9:40	P			
P22	/	P23	BOS - EOS	8/15/2013	30	8:48	30	8:53	P			
P23	/	P24	BOS - EOS	8/15/2013	30	9:50	30	9:55	P			
P24	/	P25	R7 BOS - EOS west end	8/15/2013	30	10:03	30	10:08	P			63'
P24	/	P25	east end to R7	8/15/2013	30	10:04	30	10:09	P			289'
P25	/	P26	BOS - EOS	8/15/2013	30	10:07	30	10:12	P			
P26	/	P27	west end to R8	8/15/2013	30	10:14	30	10:19	P			56'
P26	/	P27	R8 to east end	8/15/2013	30	10:15	30	10:20	P			295'
P27	/	P28	west end to R9	8/15/2013	30	10:18	28	10:23	P			40'
P27	/	P28	R9 to R10	8/15/2013	30	10:23	30	10:28	P			5'
P27	/	P28	R10 to east end	8/15/2013	30	10:24	28	10:29	P			

BOS: Beginning of Seam
EOS: End of Seam

NATURAL RESOURCE TECHNOLOGY

Non-Destructive Test Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Distance/ Location	Air Test: 27-30 psi for 5 min, < 3 psi loss						Vacuum Test		Comments
		Date Air Tested	Air Pressure				Air Test Results	Date Vacuum Tested	Vac. Test Results (P/F)	
			Start		End					
			PSI	Time	PSI	Time				
P28 / P29	BOS - EOS	8/15/2013	30	10:53	30	10:58	P			
P29 / P30	BOS - EOS	8/15/2013	30	11:47	30	11:52	P			
P30 / P31	east end to riser	8/15/2013	30	13:11	30	13:16	P			68'
P30 / P31	riser to west end	8/15/2013	30	13:10	30	13:15	P			280'
P31 / P32	BOS - EOS	8/15/2013	30	11:49	29	11:54	P			
P32 / P33	BOS - EOS	8/15/2013	30	13:18	30	13:23	P			
P33 / P34	BOS - EOS	8/15/2013	30	13:19	30	13:24	P			
P34 / P35	BOS - EOS	8/15/2013	30	14:26	30	14:31	P			
P35 / P36	BOS - EOS	8/15/2013	30	14:27	28	14:32	P			
P36 / P37	east end to riser	8/15/2013	30	14:39	30	14:44	P			291'
P36 / P37	riser to west end	8/15/2013	30	14:57	30	15:02	P			69'
P37 / P38	BOS - EOS	8/15/2013	30	14:50	29	14:55	P			
P38 / P39	BOS - EOS	8/20/2013	30	11:03	30	11:08	P			
P39 / P40	BOS - EOS	8/20/2013	30	10:47	30	10:52	P			
P39 / P41	BOS - EOS	8/20/2013	30	10:46	30	10:51	P			
P40 / P41	BOS - EOS	8/20/2013	30	10:39	30	10:44	P			
P40 / P42	BOS - EOS	8/20/2013	30	10:37	30	10:42	P			
P41 / P42	BOS - EOS	8/20/2013	30	10:38	30	10:43	P			
P41 / P43	BOS - EOS	8/20/2013	30	11:02	30	11:07	P			
P42 / P43	BOS - EOS	8/20/2013	30	11:01	30	11:06	P			

BOS: Beginning of Seam
EOS: End of Seam

NATURAL RESOURCE TECHNOLOGY

Non-Destructive Test Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Distance/ Location	Air Test: 27-30 psi for 5 min, < 3 psi loss						Vacuum Test		Comments
		Date Air Tested	Air Pressure Start PSI	Air Pressure Start Time	Air Pressure End PSI	Air Pressure End Time	Air Test Results	Date Vacuum Tested	Vac. Test Results (P/F)	
P42 / P51	17' from P43 - EOS	--	--	--	--	--	--			Capped, R64
P42 / P51	BOS - 17' from P43	8/20/2013	30	10:36	30	10:41	P			
P42 / P52	BOS - EOS	8/20/2013	30	10:28	30	10:33	P			
P43 / P44	BOS - EOS	8/20/2013	30	12:07	30	12:12	P			
P43 / P51	BOS - EOS	8/20/2013	30	10:50	28	10:55	P			
P44 / P45	BOS - EOS	8/20/2013	30	12:08	30	12:13	P			
P45 / P46	BOS - EOS	8/20/2013	30	12:09	28	12:14	P			
P46 / P47	BOS - EOS	8/20/2013	30	12:10	30	12:15	P			
P47 / P48	BOS - EOS	8/20/2013	30	12:16	28	12:21	P			
P48 / P49	BOS - EOS	8/20/2013	30	12:17	30	12:22	P			
P49 / P50	BOS - EOS	8/20/2013	30	12:18	28	12:23	P			
P51 / P52	BOS - EOS	8/20/2013	30	10:27	28	10:32	P			
P51 / P53	BOS - EOS	8/20/2013	30	10:26	30	10:31	P			
P52 / P53	--	--	--	--	--	--	--	8/26/13	P	3' cap
P52 / P54	BOS - EOS	8/20/2013	30	10:13	30	10:18	P			
P53 / P54	BOS - EOS	8/20/2013	30	10:14	29	10:19	P			
P53 / P55	BOS - EOS	8/21/2013	30	11:24	30	11:29	P			
P53 / P56	--	--	--	--	--	--	--	8/26/13	P	3' cap
P53 / P59	--	--	--	--	--	--	--	8/26/13	P	5' cap
P54 / P56	20' E of P53 to E trench	8/21/2013	30	16:24	30	16:29	P			west 20' capped

BOS: Beginning of Seam
EOS: End of Seam

Natural Resource Technology

Non-Destructive Test Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number			Distance/ Location	Air Test: 27-30 psi for 5 min, < 3 psi loss						Vacuum Test		Comments
				Date Air Tested	Air Pressure				Air Test Results	Date Vacuum Tested	Vac. Test Results (P/F)	
					Start		End					
					PSI	Time	PSI	Time				
P55	/	P57	BOS - EOS	8/21/2013	30	11:25	30	11:30	P			
P55	/	P59	BOS - EOS	8/21/2013	30	13:42	30	13:47	P			
P55	/	P60	BOS - EOS	8/21/2013	30	13:40	30	13:45	P			
P56	/	P58	BOS - EOS	8/21/2013	30	16:17	30	16:22	P			
P56	/	P59	BOS - EOS	8/21/2013	30	13:47	28	13:52	P			
P57	/	P60	BOS - EOS	8/21/2013	30	13:39	30	13:44	P			
P57	/	P61	BOS - EOS	8/21/2013	30	11:26	30	11:31	P			
P57	/	P62	BOS - EOS	8/21/2013	30	13:49	30	13:54	P			
P58	/	P59	BOS - EOS	8/21/2013	30	13:41	28	13:46	P			
P58	/	P60	BOS - EOS	8/21/2013	30	13:48	28	13:53	P			
P58	/	P62	BOS - EOS	8/21/2013	30	16:11	30	16:16	P			
P60	/	P62	BOS - EOS	8/21/2013	30	13:49	30	13:54	P			
P61	/	P62	BOS - EOS	8/21/2013	30	13:57	28	14:02	P			
P61	/	P63	BOS - EOS	8/21/2013	30	13:58	30	14:03	P			
P61	/	P66	BOS - EOS	8/21/2013	30	11:28	30	11:33	P			
P62	/	P63	BOS - EOS	8/21/2013	30	16:10	30	16:15	P			
P63	/	P64	P67 to R67	8/21/2013	30	13:59	30	14:04	P			east 53'
P63	/	P64	R67 to P66	8/21/2013	30	13:59	30	14:04	P			west 48'
P63	/	P65	BOS - EOS	8/21/2013	30	16:09	28	16:14	P			
P63	/	P66	BOS - EOS	8/21/2013	30	14:11	28	14:16	P			

BOS: Beginning of Seam
EOS: End of Seam

NATURAL RESOURCE TECHNOLOGY

Non-Destructive Test Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Distance/ Location	Air Test: 27-30 psi for 5 min, < 3 psi loss						Vacuum Test		Comments
		Date Air Tested	Air Pressure				Air Test Results	Date Vacuum Tested	Vac. Test Results (P/F)	
			Start		End					
			PSI	Time	PSI	Time				
P63 / P67	BOS - EOS	8/21/2013	30	14:28	29	14:33	P			
P64 / P66	BOS - EOS	8/21/2013	30	11:34	29	11:39	P			
P64 / P67	BOS - EOS	8/21/2013	30	14:27	30	14:32	P			
P64 / P68	BOS - EOS	8/21/2013	30	11:36	30	11:41	P			
P65 / P67	BOS - EOS	8/21/2013	30	14:29	30	14:34	P			
P65 / P68	BOS - EOS	8/21/2013	30	16:08	28	16:13	P			
P67 / P68	BOS - EOS	8/21/2013	30	14:30	30	14:35	P			
P68 / P69	BOS - EOS	8/21/2013	30	16:34	30	16:39	P			
P68 / P70	BOS - EOS	8/21/2013	30	16:40	29	16:45	P			
P68 / P71	BOS - EOS	8/21/2013	30	16:33	30	16:38	P			
P69 / P71	BOS - EOS	8/21/2013	30	16:35	28	16:40	P			
P69 / P72	riser west to P71	8/21/2013	30	16:42	30	16:47	P			
P69 / P72	riser east to trench	8/21/2013	30	16:53	30	16:58	P			
P70 / P71	BOS - EOS	8/21/2013	30	16:41	30	16:46	P			
P70 / P73	BOS - EOS	8/21/2013	30	16:50	30	16:55	P			
P71 / P72	BOS - EOS	--	--	--	--	--	--	8/26/2013	P	capped
P71 / P73	BOS - EOS	8/21/2013	30	14:42	30	14:47	P			
P72 / P73	BOS - EOS	8/21/2013	30	16:51	28	16:56	P			
P72 / P74	BOS - EOS	8/21/2013	30	17:02	30	17:07	P			
P73 / P74	BOS - EOS	8/21/2013	30	17:03	30	17:08	P			

BOS: Beginning of Seam
EOS: End of Seam

NATURAL RESOURCE TECHNOLOGY

Non-Destructive Test Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Distance/ Location	Air Test: 27-30 psi for 5 min, < 3 psi loss						Vacuum Test		Comments
		Date Air Tested	Air Pressure				Air Test Results	Date Vacuum Tested	Vac. Test Results (P/F)	
			Start		End					
			PSI	Time	PSI	Time				
P73 / P75	BOS - EOS	8/21/2013	30	17:04	30	17:09	P			
P74 / P75	BOS - EOS	8/21/2013	30	17:05	30	17:10	P			
P74 / P76	BOS - EOS	8/21/2013	30	17:06	30	17:11	P			
P75 / P76	BOS - EOS	8/21/2013	30	17:05	30	17:10	P			
P76 / P77	BOS - EOS	8/21/2013	30	17:14	30	17:19	P			
P76 / P78	BOS - EOS	8/21/2013	30	17:12	30	17:17	P			
P77 / P78	BOS - EOS	8/22/2013	30	8:47	30	8:52	P			
P77 / P79	BOS - EOS	8/22/2013	30	8:49	30	8:54	P			
P78 / P79	BOS - EOS	8/22/2013	30	8:46	30	8:51	P			
P78 / P80	BOS - EOS	8/22/2013	30	8:50	30	8:55	P			
P79 / P80	BOS - EOS	8/22/2013	30	8:54	29	8:59	P			
P79 / P81	BOS - EOS	8/22/2013	30	8:57	30	9:02	P			
P80 / P81	BOS - EOS	8/22/2013	30	8:55	30	9:00	P			
P81 / P82	BOS - EOS	8/22/2013	30	9:02	30	9:07	P			
P82 / P83	BOS - EOS	8/22/2013	30	11:21	30	11:26	P			
P82 / P84	BOS - EOS	8/22/2013	30	9:04	30	9:09	P			
P83 / P84	BOS - EOS	8/22/2013	30	11:22	29	11:27	P			
P83 / P85	BOS - EOS	8/22/2013	30	11:13	30	11:18	P			
P84 / P85	BOS - EOS	8/22/2013	30	11:12	30	11:17	P			
P84 / P86	BOS - EOS	8/22/2013	30	11:10	30	11:15	P			

BOS: Beginning of Seam
EOS: End of Seam

NATURAL RESOURCE TECHNOLOGY

Non-Destructive Test Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Distance/ Location	Air Test: 27-30 psi for 5 min, < 3 psi loss						Vacuum Test		Comments
		Date Air Tested	Air Pressure				Air Test Results	Date Vacuum Tested	Vac. Test Results (P/F)	
			Start		End					
			PSI	Time	PSI	Time				
P85 / P86	BOS - EOS	8/22/2013	30	11:11	30	11:16	P			
P85 / P87	BOS - EOS	8/22/2013	30	11:24	30	11:29	P			
P86 / P87	BOS - EOS	8/22/2013	30	11:23	30	11:28	P			
P87 / P88	BOS - EOS	8/22/2013	30	11:33	30	11:38	P			
P87 / P89	BOS - EOS	8/22/2013	30	11:42	30	11:47	P			
P88 / P89	BOS - EOS	8/22/2013	30	11:39	30	11:44	P			
P88 / P90	BOS - 14'	8/22/2013	30	11:43	30	11:48	P			E riser W to P89
P88 / P90	14' - EOS	8/22/2013	30	14:37	29	14:42	P			E riser to E trench
P89 / P90	BOS - EOS	8/22/2013	30	12:40	30	12:45	P			W riser E to P88
P89 / P90	BOS - EOS	8/22/2013	30	11:31	30	11:36	P			W riser W to P91
P89 / P91	BOS - EOS	8/22/2013	30	11:30	30	11:35	P			
P90 / P91	BOS - EOS	8/22/2013	30	11:40	30	11:45	P			
P90 / P96	BOS - EOS	8/22/2013	30	14:34	30	14:39	P			
P90 / P98	BOS - EOS	8/22/2013	30	1:10	30	1:15	P			
P90 / P99	BOS - EOS	8/22/2013	30	1:19	30	1:24	P			
P90 / P100	BOS - EOS	8/22/2013	30	1:28	30	1:33	P			
P90 / P101	BOS - EOS	8/22/2013	30	1:35	30	1:40	P			
P90 / P102	BOS - EOS	8/22/2013	30	12:54	30	12:59	P			
P90 / P103	BOS - EOS	8/22/2013	30	12:52	28	12:57	P			
P90 / P104	BOS - EOS	8/22/2013	30	14:46	30	14:51	P			

BOS: Beginning of Seam
EOS: End of Seam

NATURAL RESOURCE TECHNOLOGY

Non-Destructive Test Summary

Project Number: 2113.2 / 4.2 Powerton Ash Surge Basin

Seam Number	Distance/ Location	Air Test: 27-30 psi for 5 min, < 3 psi loss						Vacuum Test		Comments
		Date Air Tested	Air Pressure				Air Test Results	Date Vacuum Tested	Vac. Test Results (P/F)	
			Start		End					
			PSI	Time	PSI	Time				
P90 / P105	BOS - EOS	8/22/2013	30	14:44	30	14:49	P			
P90 / P106	BOS - EOS	8/22/2013	30	14:35	28	14:40	P			
P91 / P92	BOS - EOS	8/22/2013	30	11:44	30	11:49	P			
P91 / P98	BOS - EOS	8/22/2013	30	12:45	28	12:50	P			
P92 / P93	BOS - EOS	8/22/2013	30	1:08	30	1:13	P			
P92 / P94	BOS - EOS	8/22/2013	30	1:00	30	1:05	P			
P92 / P98	BOS - EOS	8/22/2013	30	12:59	28	13:04	P			
P93 / P94	BOS - EOS	8/22/2013	30	1:09	30	1:14	P			
P95 / P96	BOS - EOS	8/22/2013	30	14:27	30	14:32	P			
P95 / P97	BOS - EOS	8/22/2013	30	14:26	30	14:31	P			
P96 / P97	BOS - EOS	8/22/2013	30	14:25	30	14:30	P			
P96 / P106	BOS - EOS	--	--	--	--	--	--			Capped
P98 / P99	BOS - EOS	8/22/2013	30	1:12	30	1:17	P			
P99 / P100	BOS - EOS	8/22/2013	30	1:20	30	1:25	P			
P100 / P101	BOS - EOS	8/22/2013	30	1:28	30	1:33	P			
P101 / P102	BOS - EOS	8/22/2013	30	1:34	30	1:39	P			
P102 / P103	BOS - EOS	8/22/2013	30	12:53	28	12:58	P			
P103 / P104	BOS - EOS	8/22/2013	30	14:47	28	14:52	P			
P104 / P105	BOS - EOS	8/22/2013	30	14:45	28	14:50	P			
P105 / P106	BOS - EOS	8/22/2013	30	14:36	30	14:41	P			

BOS: Beginning of Seam
EOS: End of Seam

ATTACHMENT F

LINER INTEGRITY SURVEY REPORTS

ATTACHMENT F1

BARE LINER INTEGRITY SURVEY REPORT

LEAK LOCATION SERVICES, INC.
16124 UNIVERSITY OAK ● SAN ANTONIO, TEXAS 78249 ● (210) 408-1241 / FAX (210) 408-1242

November 25, 2013

Sheila Keltsch
Terra Contracting Services, LLC
5787 Stadium Drive
Kalamazoo, MI 49009

e-mail: skeltsch@terracontracting.net

Subject: Revised Report for "Leak Location Survey of the Ash Surge Basin located at the MWG Powerton Generating Station near Pekin, Illinois"
LLSI Project 1904A

Dear Mr. Keltsch:

On August 26, 2013, Thane Hefley of Leak Location Services, Inc. (LLSI) conducted a leak location survey of the Ash Surge Basin at the Midwest Generating Powerton Station near Pekin, Illinois. The basin has an area of approximately 279,000 square feet. The basin is lined from the bottom up with a prepared subgrade, existing hypalon liner, 12-inches of existing Poz-O-Pac, 16 ounce nonwoven geotextile and a 60-mil HDPE white textured geomembrane. This report documents the results of this survey.

I. RESULTS

A. Survey

Two leaks were found during the testing of the Ash Surge Basin . Table 1 lists the approximate locations and descriptions of the leaks found in the basin. Figure 1 shows the approximate location of the leaks found in the basin. The leaks were marked for repair by LLSI before leaving the site.

B . Leak Detection Sensitivity Test

The leak location equipment was tested to document the leak detection sensitivity by placing a 1mm hole in a scrap piece of geomembrane with a thickness approximating the thickness of the liner installed. This test was conducted by placing the scrap piece of geomembrane on the soil subgrade near the lagoon. The leak location probe was then scanned near the test hole as a small amount of water is sprayed on the scrap piece of geomembrane to verify the proper operation of the equipment. This test was done with a greater than 100 percent scale deflection.

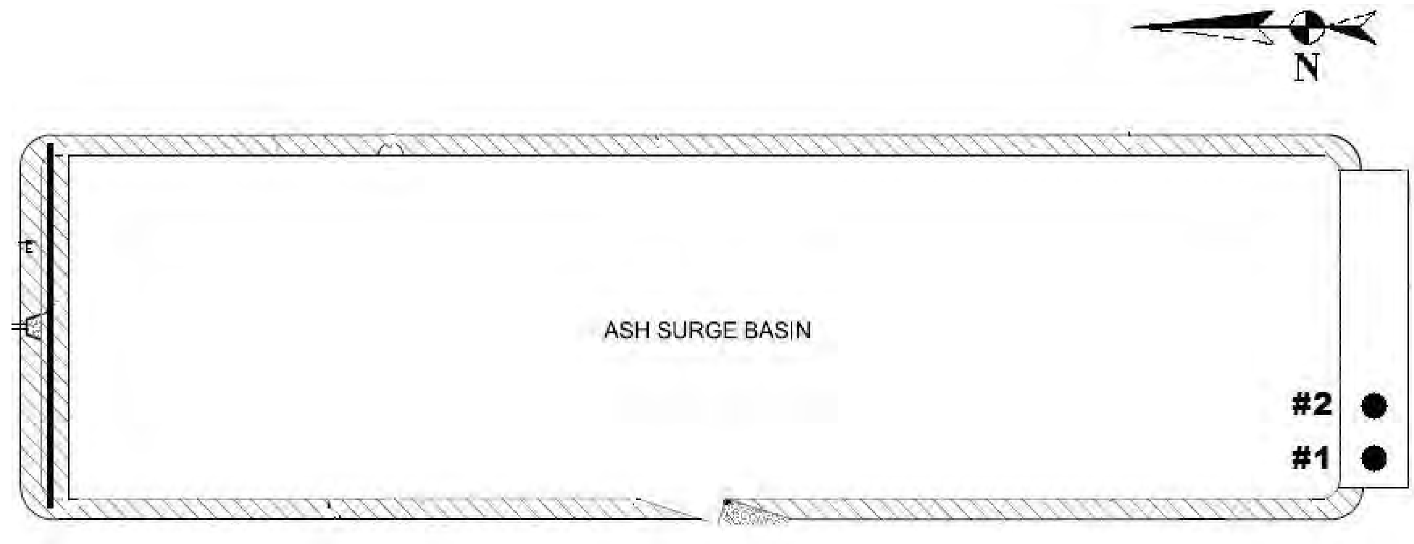


FIGURE 1. APPROXIMATE LOCATIONS OF THE LEAKS FOUND IN THE ASH SURGE BASIN

Table 1. Approximate Locations and Descriptions of the Leaks Found in the Ash Surge Basin

Leak Number	Leak Location	Leak Description
1	On a patch behind the concrete wall.	Extrusion weld on a patch.
2	In the northwest corner of the basin.	Extrusion weld

II. TECHNIQUE

A. Principles of the Electrical Leak Location Method

The principle of the electrical survey method for geomembrane liners is to impress a high DC voltage across the geomembrane and measure the resulting potential gradients on or in the conducting material on the geomembrane. If any holes are present, characteristic anomalies in the potential caused by electrical current flowing through the holes indicate their location.

B. Surveys with Bare Liner

The bare liner survey method detects electrical current that will flow through any holes in the geomembrane liner that are filled with water. A squeegee device is used to push a small amount of water over the liner providing the electrical conduction pathway. A low voltage electrical supply is connected to earth ground and to the squeegee. When a hole in the liner is encountered, electrical current will flow through water in the leak contacting earth ground. This current is monitored using an electronic detector that converts the increase in the current to an audible tone indication. Only the area immediately in front of the squeegee is temporarily covered with water.

If there are any questions regarding the electrical survey or this report, please contact us at (210) 408-1241. We appreciate the opportunity to have been of service to Terra Contracting Services, LLC.

Respectfully,

Edgardo Barraza
Project Manager

Approved by:

Matthew Kemnitz
Senior Project Manager

ATTACHMENT F2

SOIL COVERED LINER INTEGRITY SURVEY REPORT

LEAK LOCATION SERVICES, INC.
16124 UNIVERSITY OAK ● SAN ANTONIO, TEXAS 78249 ● (210) 408-1241 / FAX (210) 408-1242

October 15, 2013

Sheila Keltsch
Terra Contracting Services, LLC
5787 Stadium Drive
Kalamazoo, MI 49009

Email: skeltsch@terracontracting.net

Subject: Report for "Geomembrane Leak Location Survey of the Ash Surge Basin at the Midwest Powerton Generating Station near Pekin, Illinois; "
LLSI Project 1904A

Dear Ms. Keltsch:

On October 7 and 8, 2013, John Ortiz and Dale Kemnitz of Leak Location Services, Inc. (LLSI) conducted a geomembrane leak location survey of the Ash Surge Basin at the Midwest Powerton Generating Station. The basin has an area of approximately 279,000 square feet with a floor area of approximately 205,000 square feet. The basin is lined, from the bottom up, with a prepared subgrade, existing Hypalon liner, 12-inches existing Poz-O-Pac, 16 ounce nonwoven geotextile, 60-mil HDPE white textured geomembrane, 16 ounce nonwoven geotextile, 12-inch cushion soil layer and a 6-inch warning layer. A soil-covered survey was conducted on the floor area. The batten strips connecting the liner to the concrete weir, overflow structure, concrete ramp, and the concrete apron were visually inspected. This report documents the results of the survey.

I. RESULTS

A. Survey

No leaks were found during the soil survey of the floor area of the basin. Three leaks were found during the visual inspection of the concrete structures. Figure 1 shows the approximate locations of the leaks and Table 1 lists the approximate locations and descriptions of the leaks found.

B. Leak Detection Sensitivity

The leak location equipment was tested for sensitivity and proper operation. This procedure was conducted at the beginning and end of each day by LLSI personnel to verify equipment functionality. For a soil-covered survey, a 0.25-inch diameter artificial leak was buried under the cover material and leak location survey lines were run along both sides of the artificial leak. Leak location survey measurements were collected to determine the maximum distance that the simulated leak could be reliably detected. Figure 2 shows plots of data taken with the artificial leak. The leak detection distance was more than 10 feet. Thus, the leak location survey lines could have been spaced 20 feet apart. However, for thoroughness, the survey was conducted on survey lines spaced 10 feet apart.

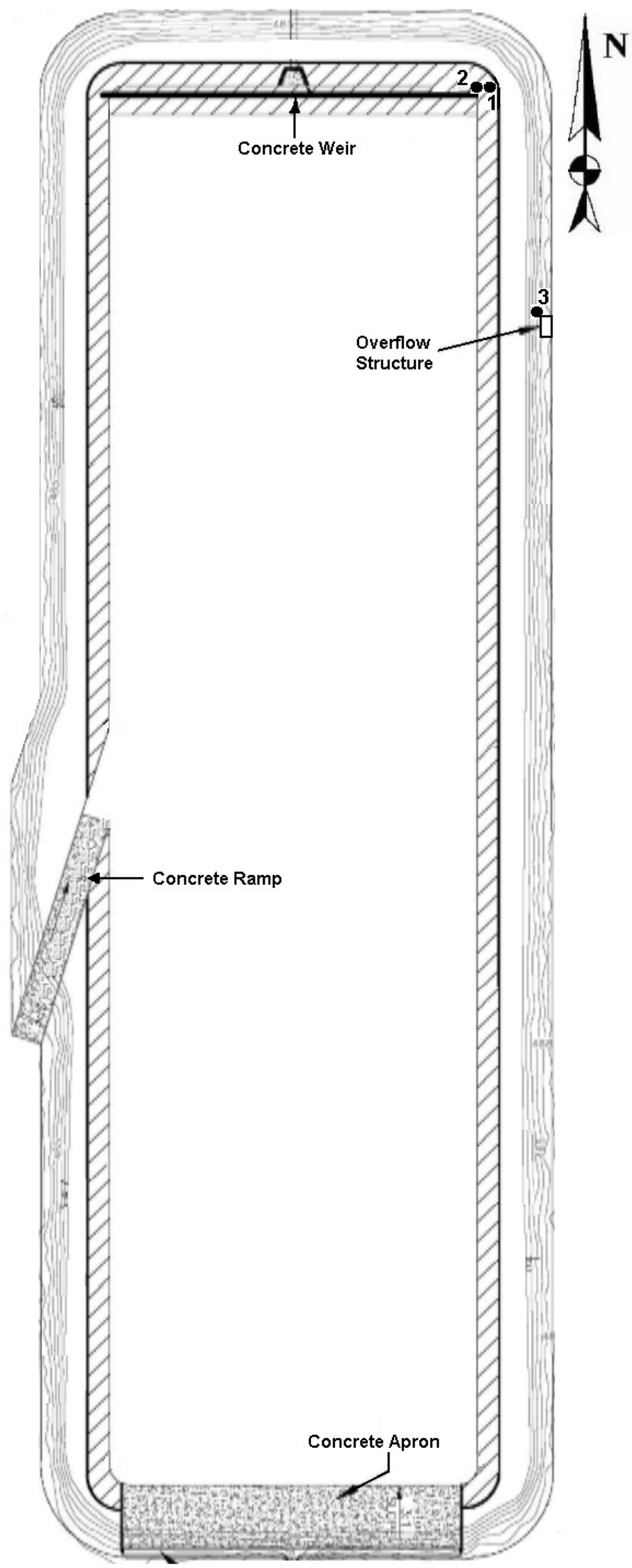


FIGURE 1. APPROXIMATE LOCATIONS OF LEAKS FOUND IN THE BASIN

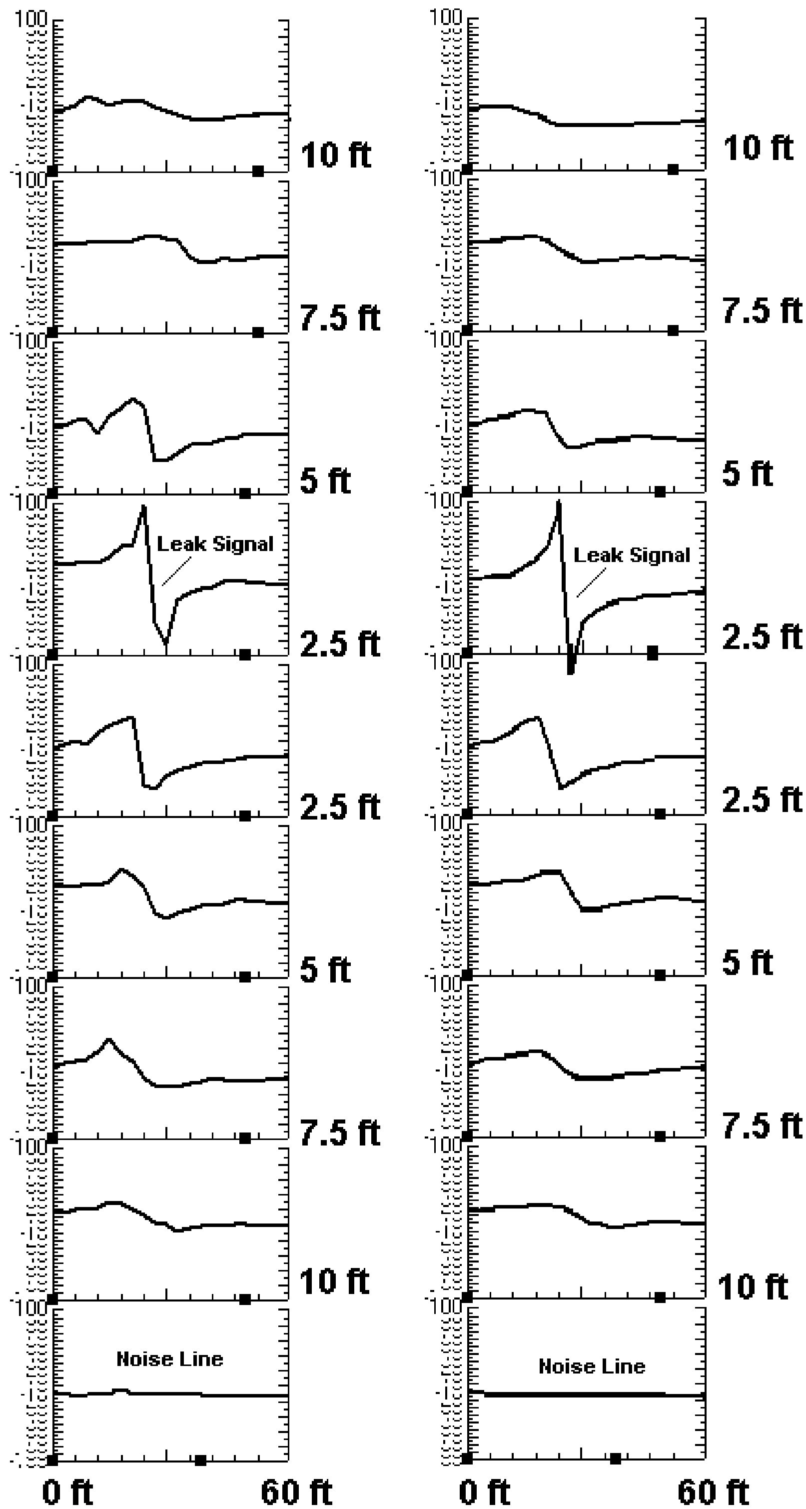


FIGURE 2. PLOTS OF DATA TAKEN WITH A 0.25-INCH ARTIFICIAL LEAKS

Table 1. Approximate Locations and Descriptions of Leaks Found in the Basin

LEAK	LOCATION	DESCRIPTION
1	On the northeast corner of the weir, beneath the batten strip	0.25-inch hole
2	On the northeast corner of the weir	1.0-inch linear slit
3	On the northeast corner of the overflow structure	1.0-inch linear slit

II. PRINCIPLE OF THE ELECTRICAL SURVEY METHOD

A. General

The electrical leak location method detects electrical paths through the liner caused by water or moisture in the leaks. For a single-geomembrane lined system a voltage is connected to one electrode placed in the conductive material covering the liner and returned to a second electrode connected to earth ground. Electrical current flowing through the leaks in the liner produces localized anomalous areas of high current density near the leaks. These areas are located by making electrical potential measurement scans in or on the electrically conductive material covering the geomembrane.

B. Soil-Covered Survey

A high voltage isolated DC power supply was used to impress a voltage across the geomembrane using one electrode placed in the protective cover layer on top of the primary geomembrane and a second electrode placed in the electrically conducting material under the geomembrane. Therefore, the geomembrane liner provides an electrical barrier between the electrodes except where there are holes in the geomembrane. Electrical current flowing through the holes in the geomembrane produces localized anomalous areas of high current density near the holes. This electrical current path is provided by electrically conducting material such as water, sand, rock or soil.

The survey was conducted by making potential gradient measurements on the moist sand material with measurement electrodes spaced approximately 3 feet apart. These measurements were made approximately every 3 feet along numbered survey lines that were spaced approximately 10 feet apart. A portable digital data logger was used to collect the data. The data was then downloaded into a portable computer for display, plotting, and analysis.

When a leak signal is detected, manual measurements are made to locate the position of the leak between the survey lines. The leaks are excavated by others and the leak is isolated from the materials covering the geomembrane. Additional measurements are made to make sure there are no additional leaks in the area.

If there are any questions regarding leak location surveys or this report, please contact us at (210) 408-1241. We appreciate this opportunity to have been of service to Terra Contracting Services, LLC on this important service requirement.

Respectfully,

John Ortiz
Project Manager

Approved by:

Glenn Darilek
Principal Engineer

ATTACHMENT G

CONSTRUCTION DOCUMENTATION DRAWING SET

ASH SURGE BASIN LINER REPLACEMENT
MIDWEST GENERATION
POWERTON GENERATING STATION
PEKIN, ILLINOIS

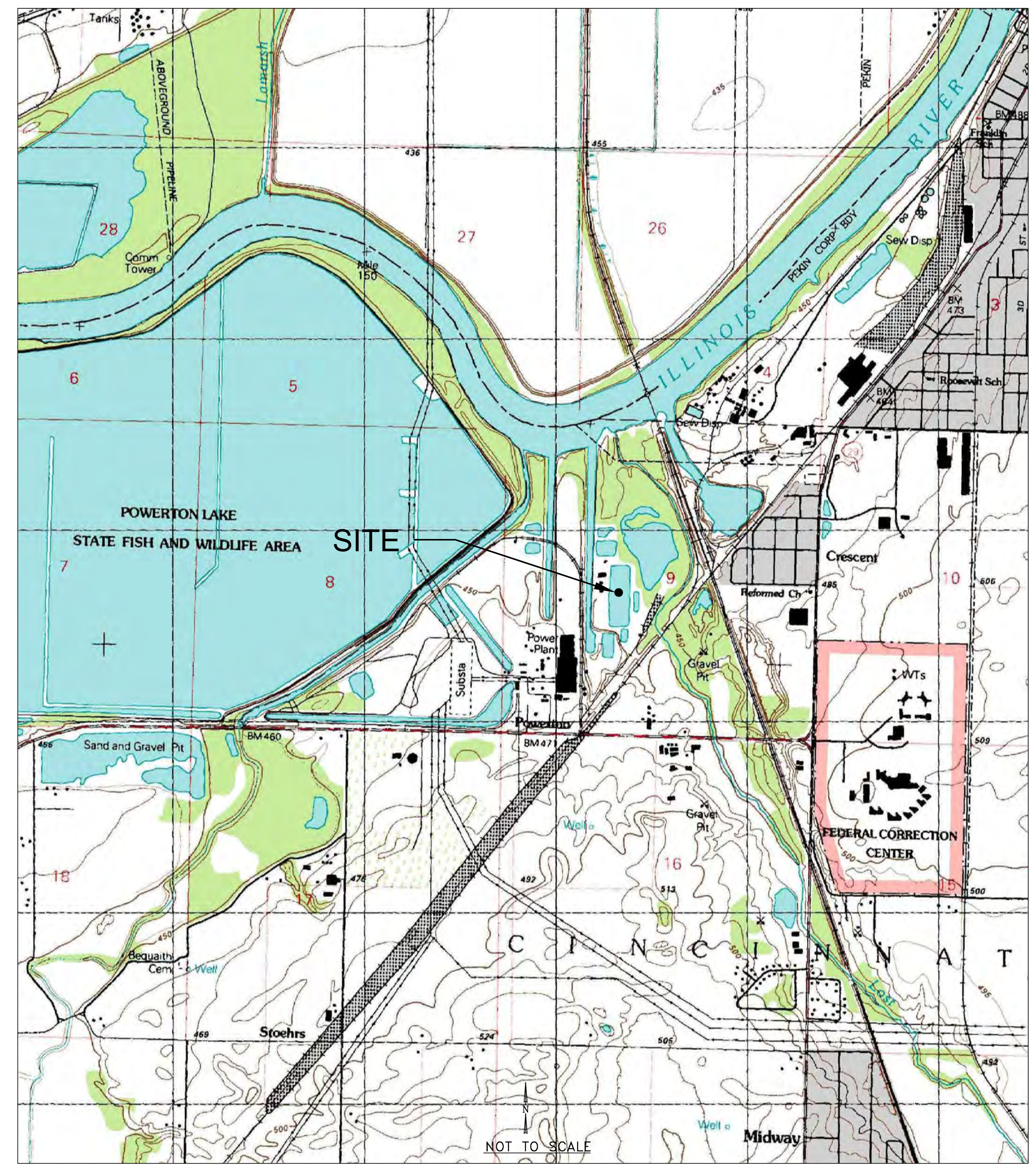
LIST OF DRAWINGS

SHEET NO.	TITLE	DRAWING NO.
TS	TITLE SHEET	D21132TS-03
C010	PRE-CONSTRUCTION SITE CONDITIONS	D21132C010-03
C020	LINER SUBGRADE PREPARATION	D21132C020-03
C021	GEOMEMBRANE PANEL LAYOUT	D21132C021-00
C030	WARNING LAYER PLAN	D21132C030-03
C031	DETAILS AND SECTIONS	D21132C031-03
C032	DETAILS AND SECTIONS	D21132C032-03

RECORD DRAWING LEGEND

~~PROPOSED~~	CROSSED OUT TEXT INDICATES CHANGES FROM THE FINAL DESIGN TO RECORD CONSTRUCTION
PRE–CONSTRUCTION	UNDERLINED TEXT INDICATES ADDED NOTES OR COMMENTS, AND DOCUMENTS CHANGES FROM THE FINAL DESIGN TO RECORD CONSTRUCTION
(cloud)	"CLOUDS" DOCUMENT ADDITIONS AND/OR CHANGES FROM THE FINAL DESIGN TO RECORD CONSTRUCTION
X	"CROSS OUTS" DOCUMENT OBJECTS REMOVED FROM THE FINAL DESIGN TO RECORD CONSTRUCTION

ILLINOIS



SITE LOCATION

PREPARED FOR:
MIDWEST GENERATION, LLC
13082 EAST MANITO RAOD
PEKIN, IL 61554

JULY 2014

REVISION:	DATE:	APP'D BY:
6.		
5.		
4.		
3. ISSUED FOR RECORD DOCUMENTATION	07/02/14	EJT
2. ISSUED FOR CONSTRUCTION	06/25/13	HMS
1. ISSUED FOR BID	03/28/13	EJT
0. ISSUED FOR PERMIT	01/15/13	HMS

NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 2113.2/POWER/BID
DRAWN BY: RLH 01/14/13
CHECKED BY: HMS 01/14/13
APPROVED BY: HMS 01/15/13

TITLE SHEET
ASH SURGE BASIN LINER REPLACEMENT DOCUMENTATION
MIDWEST GENERATION
POWERTON GENERATING STATION
PEKIN, ILLINOIS

DRAWING NO: D21132TS-03
REFERENCE:
SHEET NO. TS

Jul 17, 2014 12:56pm PLOTTED BY: dduda SAVED BY: dduda
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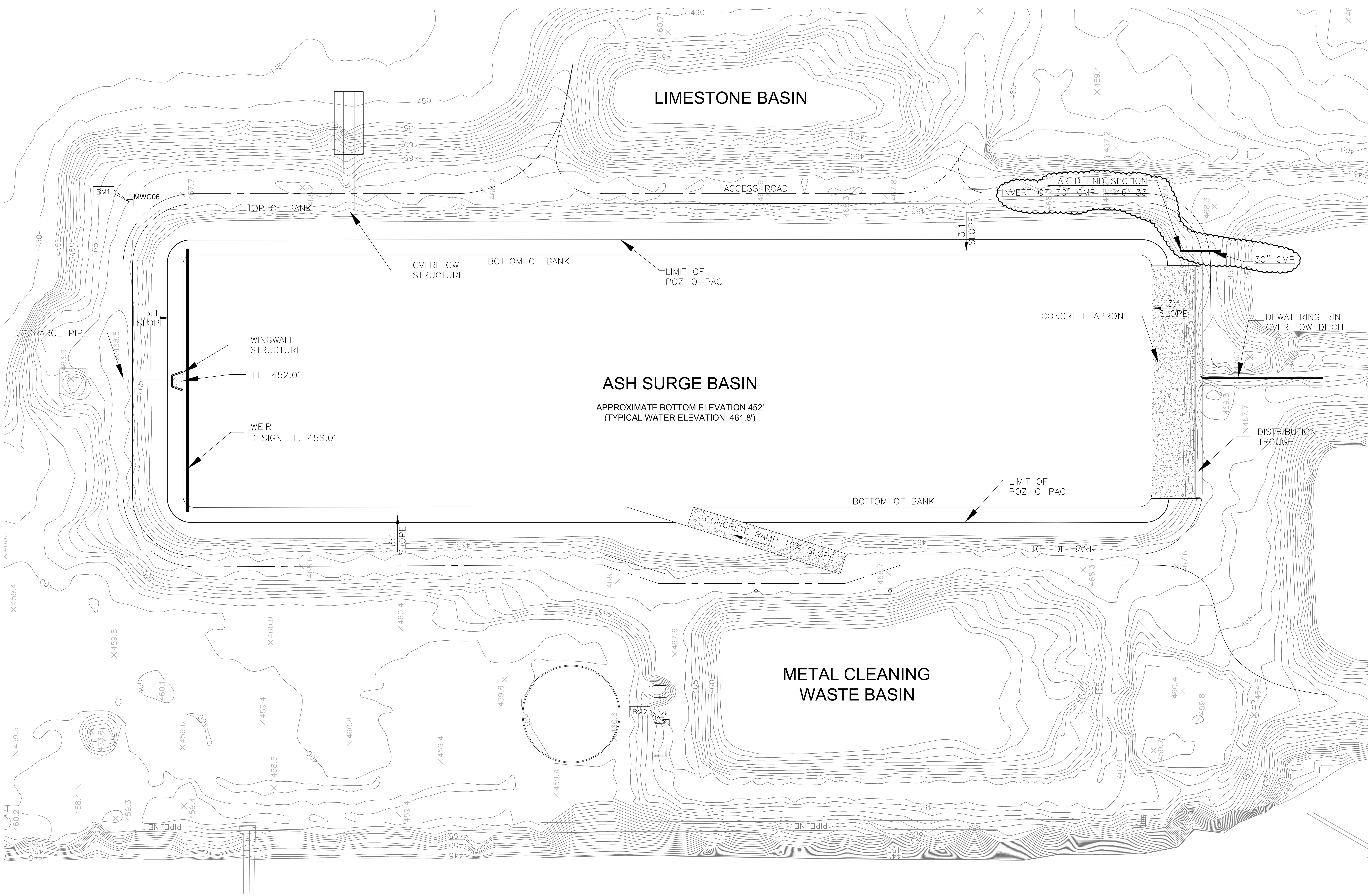

EXISTING GROUND SURFACE CONTOURS
LIMIT OF POZ-O-PAC
LIGHT POLE
ACCESS ROAD
CONCRETE
BENCHMARK LOCATION

NOTES:
1. SITE BENCHMARK 1 (MWG06) - BRONZE DISK ON STEEL ROD W/ ACCESS COVER IS AT ELEVATION 466.79 FEET (NGVD 29).
2. BENCHMARK 2 - SE CORNER TOP CONCRETE WALL, ELEVATION 468.09 FEET (NGVD 29).

CONTRACTOR NOTES: COMPLETED DURING CONSTRUCTION
1. ACCUMULATED ASH, SLUDGE/SEDIMENT, AND DEBRIS TO BE REMOVED BY CONTRACTOR, AS DIRECTED BY OWNER.

HORIZONTAL DATUM:
ILLINOIS STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD83 FEET.

VERTICAL DATUM:
PLANT DATUM

N

0 25 50 100
SCALE IN FEET

SOURCE NOTES:
1. TOPOGRAPHIC SURVEY BY AERO-METRIC, INC. DATED 6-19-2008, PROJECT NO. 1080611, PROVIDED BY MIDWEST GENERATION.
2. ASH SURGE BASIN FEATURES TAKEN FROM MIDWEST GENERATION DRAWING TITLED WASTE WATER TREATMENT FACILITY, DETAIL PLAN, ASH SURGE BASIN, NO. 3B-0-2071, DATED 5-12-78.
3. LOCATION OF 30" CMP PIPE FROM SURVEY BY RIDGELINE CONSULTANTS, PROJECT NUMBER 2013-0340, DATED SEPTEMBER 3, 2013, PROVIDED BY TERRA CONTRACTING SERVICES.

REVISION:		DATE:	APP'D BY:
6.			
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3.	ISSUED FOR RECORD DOCUMENTATION	07/02/14	EJT
2.	ISSUED FOR CONSTRUCTION	06/18/13	HMS
1.	ISSUED FOR BID	03/28/13	EJT
0.	ISSUED FOR PERMIT	01/15/13	HMS

NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 2113.2
DRAWN BY: RLH 01/14/13
CHECKED BY: HMS 01/14/13
APPROVED BY: HMS 01/15/13

PRE-CONSTRUCTION SITE CONDITIONS

ASH SURGE BASIN LINER REPLACEMENT
POWERTON GENERATING STATION
MIDWEST GENERATION
PEKIN, ILLINOIS

DRAWING NO: D21132C010-03
REFERENCE: .
SHEET NO. C010

Jul 17, 2014 12:57pm PLOTTED BY: dduda SAVED BY: dduda
Y:\ACAData\Projects\21\2113\2132_Powerton\ASH SURGE BASIN\RECORD DWGS\Record 070214\D21132C010-03.dwg C010
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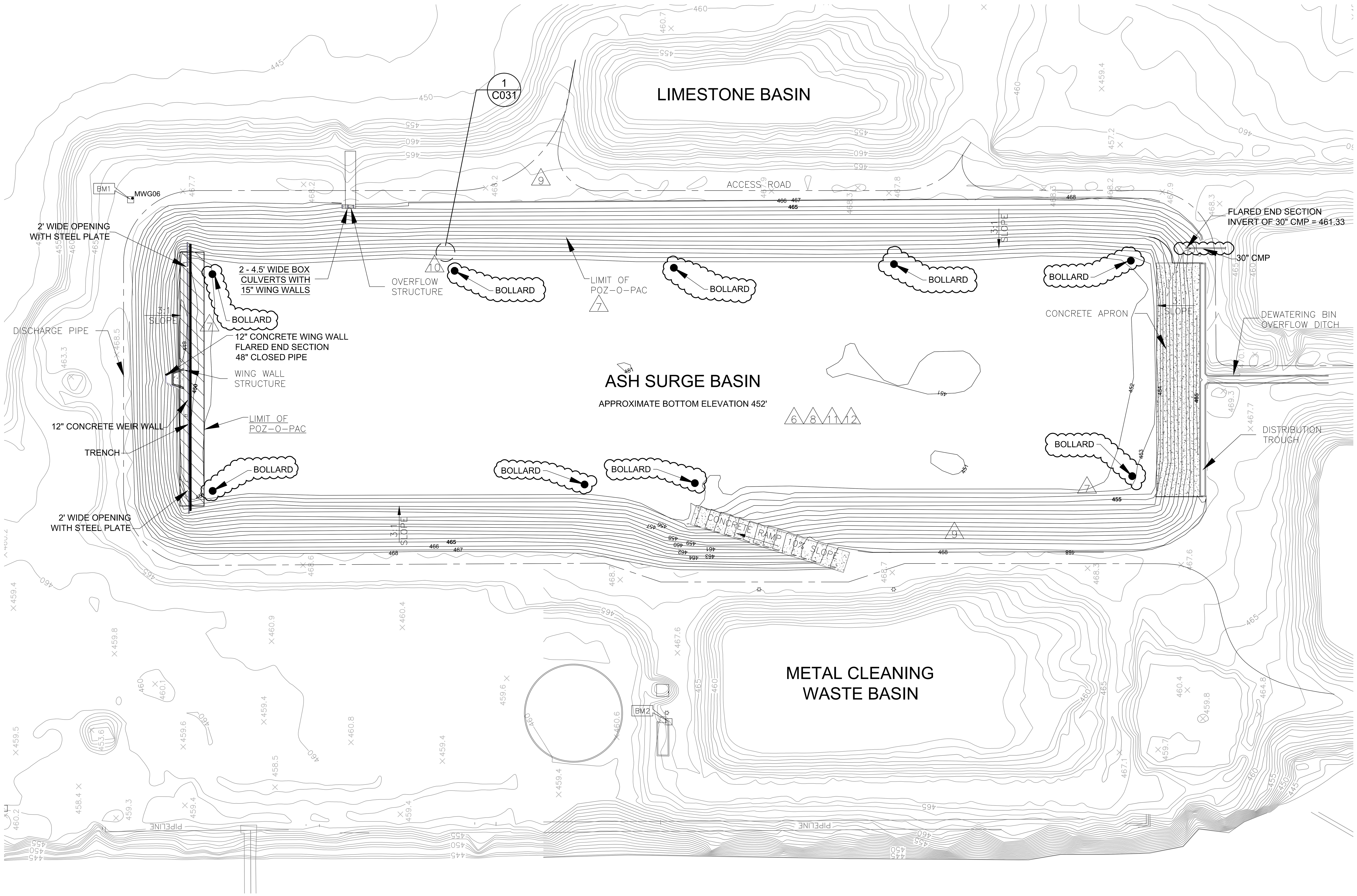
XREFS:



LEGEND

- ~~EXISTING~~ PREVIOUS GROUND SURFACE CONTOURS
- SUBGRADE SURFACE CONTOUR
- LIMIT OF POZ-O-PAC
- LIGHT POLE
- ACCESS ROAD
- MARKER POST LOCATION
- POZ-O-PAC REMOVAL AREA
- CONCRETE
- BENCHMARK LOCATION

NOTES:

1. SITE BENCHMARK 1 (MWG06) - BRONZE DISK ON STEEL ROD W/ ACCESS COVER IS AT ELEVATION 466.79 FEET (NGVD 29).
2. BENCHMARK 2 - SE CORNER TOP CONCRETE WALL, ELEVATION 468.09 FEET (NGVD 29).

CONTRACTOR NOTES: △ COMPLETED DURING CONSTRUCTION

1. CONTRACTOR SHALL FIELD VERIFY LOCATION OF UNDERGROUND PIPES WITH ASSISTANCE OF OWNER'S UTILITY LOCATOR.
2. CONTRACTOR SHALL FIELD VERIFY LOCATION OF CONCRETE APRON, CONCRETE STRUCTURES, AND ABOVE GROUND PIPING.
3. CLEAR AND GRUB ALL BRUSH ALONG TOP OF SLOPE OF BASIN.
4. CONTRACTOR SHALL STORE ALL GEOSYNTHETICS AND SUBGRADE MATERIALS IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.
5. CONTRACTOR SHALL STORE AND STAGE EQUIPMENT AT LOCATION APPROVED BY OWNER.
6. PROTECT ALL CONCRETE AND UTILITY STRUCTURES THROUGHOUT PROJECT DURATION.
7. ~~REMOVE EXISTING 12-INCH POZ-O-PAC LAYER ALONG SIDE SLOPES.~~ POZ-O-PAC LAYER AT BASE OF BASIN TO REMAIN IN PLACE, EXCEPT NORTH OF WEIR AND 20 FOOT SECTION SOUTH OF WEIR, AS SHOWN. CONTRACTOR SHALL REMOVE AN ADDITIONAL 6 INCHES OF SUBGRADE MATERIAL LOCATED BETWEEN THE WEIR AND THE WING WALL STRUCTURE ALONG THE NORTH TOE OF SLOPE, AS SHOWN ON SHEET C032. REMOVE AT LEAST 18 INCHES OF POZ-O-PAC LAYER AND SUBGRADE MATERIAL AT BASE OF WEIR TO THE SOUTH AND GRADE AT A ~~1%~~ 7.5% SLOPE. REFER TO SHEET C032.
8. CONTRACTOR SHALL REMOVE ALL VEGETATION, ROCKS, AND OTHER DEBRIS FROM EXISTING LINER AND DISPOSE OF IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS.
9. CONTRACTOR SHALL RESHAPE SIDE SLOPES AS NECESSARY TO MAINTAIN 3:1 SIDE SLOPES, AND REMOVE "SOFT" SUBGRADE MATERIAL AS DIRECTED BY OWNER AND/OR ENGINEER. BACKFILL AREAS WITH FILL IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS. EXISTING HYPALON GEOMEMBRANE MAY REMAIN IN PLACE ALONG THE SIDE SLOPES, EXCEPT IN SOFT OR LOW/HIGH (RELATIVE TO GEOMEMBRANE SUBGRADE) AREAS, AS DIRECTED BY ENGINEER AND/OR OWNER.
10. CONTRACTOR SHALL INSTALL MARKER POSTS ALONG THE TOE OF SLOPE AS SHOWN AND IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS AND DETAIL 1 ON SHEET C031.
11. SUBGRADE MUST BE APPROVED BY OWNER AND/OR ENGINEER PRIOR TO INSTALLATION OF GEOMEMBRANE.
12. CONTRACTOR SHALL PROVIDE MEANS TO PROTECT SUBGRADE LAYER FROM EROSION, STORM WATER, AND HEAVY EQUIPMENT TRAFFIC. DAMAGE TO SUBGRADE LAYER SHALL BE REPAIRED AT THE CONTRACTOR'S EXPENSE.

HORIZONTAL DATUM:
ILLINOIS STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD83 FEET.

VERTICAL DATUM:
PLANT DATUM

N

0 25 50 100
SCALE IN FEET

SOURCE NOTES:

1. TOPOGRAPHIC SURVEY BY AERO-METRIC, INC. DATED 6-19-2008, PROJECT NO. 1080611, PROVIDED BY MIDWEST GENERATION.
2. ASH SURGE BASIN FEATURES TAKEN FROM MIDWEST GENERATION DRAWING TITLED WASTE WATER TREATMENT FACILITY, DETAIL PLAN, ASH SURGE BASIN, NO. 3B-0-2071, DATED 5-12-78.
3. SUBGRADE CONTOURS AND FEATURE LOCATIONS FROM SURVEY BY RIDGELINE CONSULTANTS, PROJECT NUMBER 2013-0340, DATED SEPTEMBER 3, 2013, PROVIDED BY TERRA CONTRACTING SERVICES.

REVISION:		DATE:	APP'D BY:
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3.	ISSUED FOR RECORD DOCUMENTATION	07/18/14	EJT
2.	ISSUED FOR CONSTRUCTION	06/18/13	HMS
1.	ISSUED FOR BID	03/28/13	EJT
0.	ISSUED FOR PERMIT	01/15/13	HMS

NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 2113.2
DRAWN BY: RLH 01/14/13
CHECKED BY: HMS 01/14/13
APPROVED BY: HMS 01/15/13

LINER SUBGRADE PREPARATION

ASH SURGE BASIN LINER REPLACEMENT
POWERTON GENERATING STATION
MIDWEST GENERATION
PEKIN, ILLINOIS

DRAWING NO: D21132C020-03
REFERENCE: .
SHEET NO. C020

Jul 18, 2014 12:21pm PLOTTED BY: dduda SAVED BY: dduda
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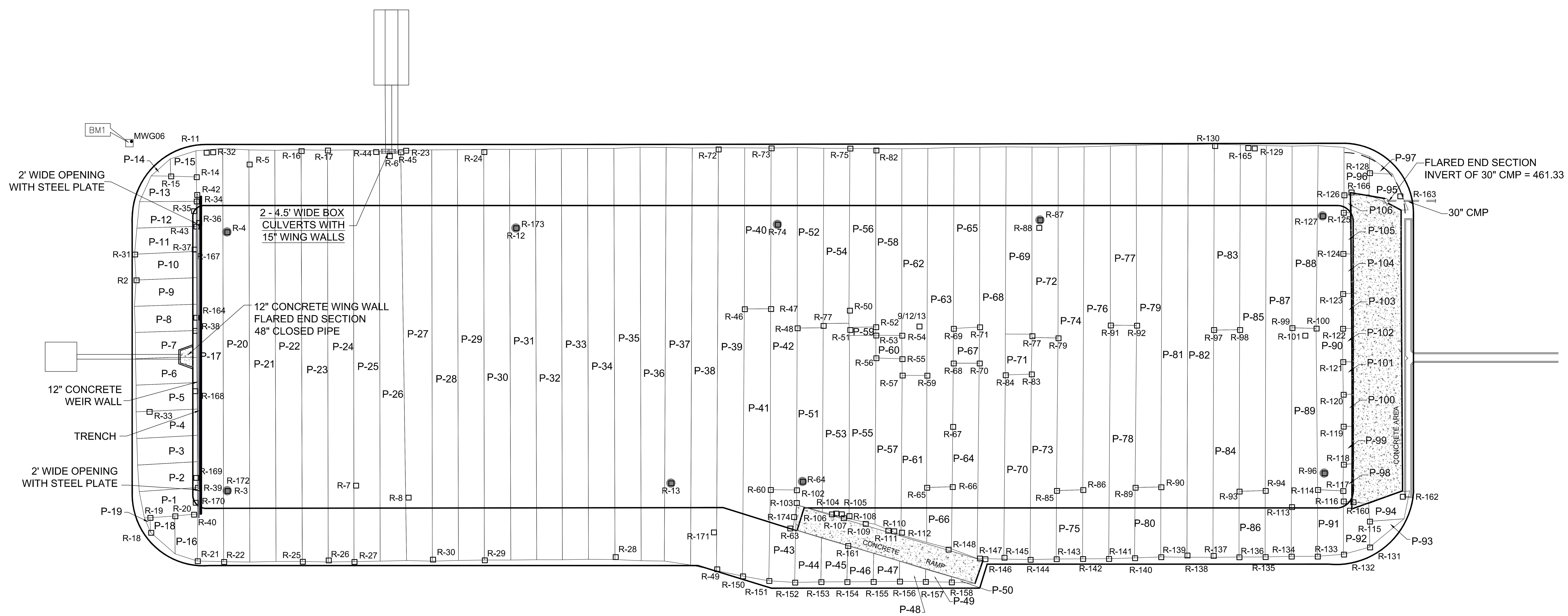

GEOMEMBRANE PANEL SEAM

P23 GEOMEMBRANE PANEL AND PANEL NUMBER

R87 GEOMEMBRANE REPAIR LOCATION (NOT TO SCALE)

BM2 BENCHMARK LOCATION

MARKER POST LOCATION

NOTES:
1. SITE BENCHMARK 1 (MWG06) - BRONZE DISK ON STEEL ROD W/ ACCESS COVER IS AT ELEVATION 466.79 FEET (NGVD 29).
2. BENCHMARK 2 - SE CORNER TOP CONCRETE WALL, ELEVATION 468.09 FEET (NGVD 29).

N

0 25 50 100

SCALE IN FEET

HORIZONTAL DATUM:
ILLINOIS STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD83 FEET.

VERTICAL DATUM:
PLANT DATUM

SOURCE NOTES:

1. THIS DRAWING WAS DEVELOPED FROM SURVEY DATA BY RIDGELINE CONSULTANTS, PROJECT NUMBER 2013-0340, DATED SEPTEMBER 3, 2013, PROVIDED BY TERRA CONTRACTING SERVICES.

REVISION		DATE:	APP'D BY:
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0.	ISSUED FOR RECORD DOCUMENTATION	07/17/14	EJT

NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 2113.2
DRAWN BY: RLH 03/06/14
CHECKED BY: JRR 03/06/14
APPROVED BY: EJT 07/17/14

GEOMEMBRANE PANEL LAYOUT

ASH SURGE BASIN LINER REPLACEMENT
POWERTON GENERATING STATION
MIDWEST GENERATION
PEKIN, ILLINOIS

DRAWING NO: D21132C021-00
REFERENCE: .
SHEET NO. C021

Jul 18, 2014 12:16pm PLOTTED BY: dduda SAVED BY: dduda C021
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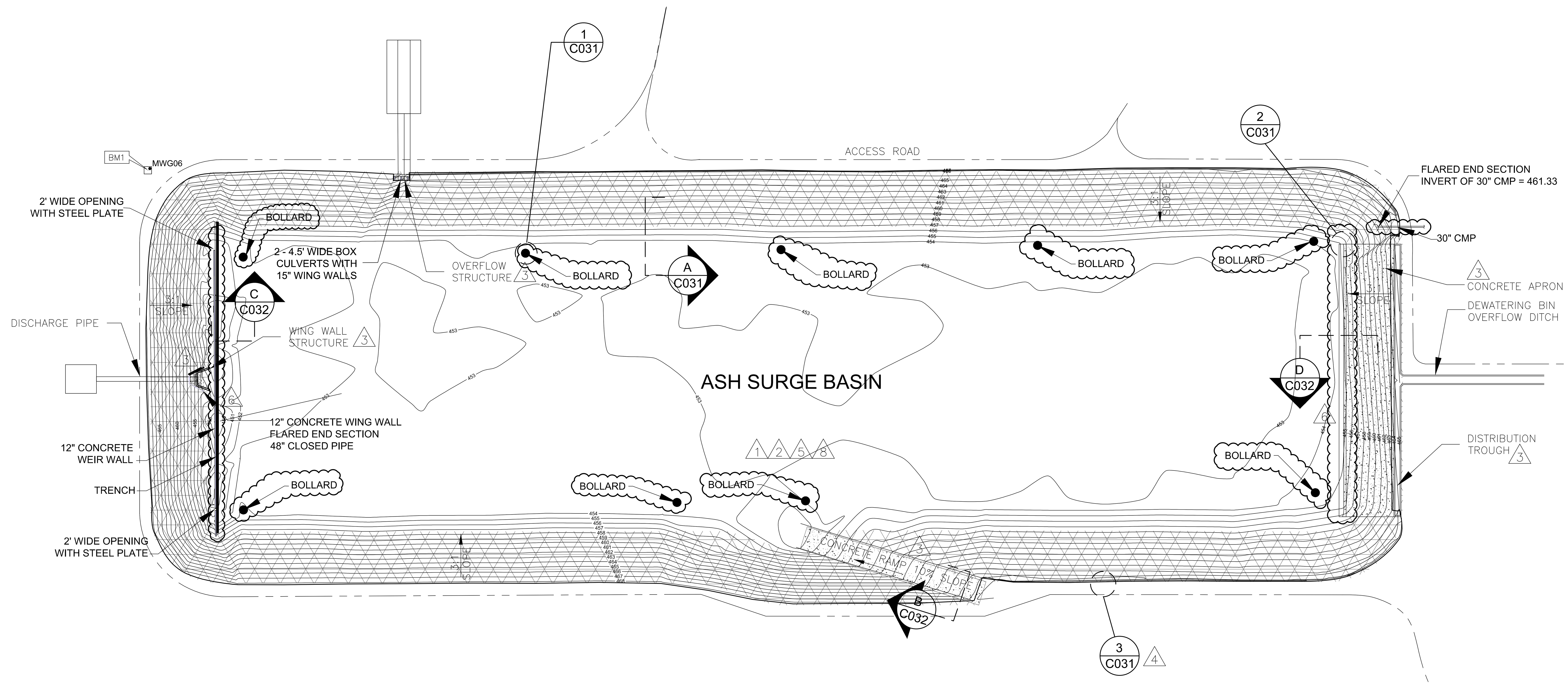

FINAL SURFACE CONTOUR (465)

LIGHT POLE

ACCESS ROAD

MARKER POST LOCATION

HDPE GEOMEMBRANE

CONCRETE

~~RIPRAP~~

BENCHMARK (BM1)

CONTRACTOR NOTES: △ COMPLETED DURING CONSTRUCTION

1. CONTRACTOR SHALL PLACE 16-OZ. NON-WOVEN GEOTEXTILE OVER THE SUBGRADE IN ACCORDANCE WITH THE TECHNICAL SPECIFICATIONS
2. CONTRACTOR SHALL INSTALL 60 MIL HDPE, WHITE, TEXTURED GEOMEMBRANE IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION PRIOR TO PLACEMENT OF THE WARNING LAYER. CONTRACTOR SHALL PROVIDE AND FOLLOW AN APPROVED GEOMEMBRANE LAYOUT PLAN.
3. CONTRACTOR SHALL ATTACH GEOMEMBRANE TO STRUCTURES, CONCRETE RAMP, AND APRON, IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION AND DETAILS ON SHEET C031 AND C032.
4. GEOMEMBRANE SHALL BE ANCHORED INTO 2.5 FEET DEEP TRENCHES ALONG TOP OF BANK, AS SHOWN IN DETAIL 3 ON SHEET C031. CONTRACTOR SHALL ADVISE OWNER AND/OR ENGINEER IF PROPOSED LOCATION FOR ANCHOR TRENCH IS NOT FEASIBLE.
5. CONTRACTOR SHALL PLACE 16-OZ. NON-WOVEN GEOTEXTILE, CUSHION MATERIAL AND WARNING LAYER MATERIAL OVER THE GEOMEMBRANE AT BASE AND 4 FEET ON SIDE SLOPES (SEE SECTION A, SHEET C031), FOLLOWING ENGINEER APPROVAL AND PASSING QUALITY CONTROL RESULTS IN ACCORDANCE WITH TECHNICAL SPECIFICATIONS.
6. CONTRACTOR SHALL PLACE AN 18-INCH LAYER OF ~~4 TO 12 INCH DIAMETER RIPRAP~~ WARNING LAYER MATERIAL BETWEEN WEIR AND WING WALL STRUCTURE ALONG THE NORTH TOE OF SLOPE AND AT TOE OF CONCRETE APRON AS DIRECTED BY ENGINEER. REFER TO DETAILS ON SHEET C032.
7. CONTRACTOR SHALL PROVIDE SURVEY DOCUMENTATION OF THE ITEMS LISTED IN THE TECHNICAL SPECIFICATIONS.
8. CONTRACTOR SHALL PERFORM A LEAK LOCATION SURVEY IN ACCORDANCE WITH TECHNICAL SPECIFICATIONS.
9. RESTORE AREAS DISTURBED BY EQUIPMENT AND MATERIAL LAYDOWN.

HORIZONTAL DATUM:
ILLINOIS STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD83 FEET.

VERTICAL DATUM:
PLANT DATUM

N

0 25 50 100
SCALE IN FEET

SOURCE NOTES:
1. TOPOGRAPHIC SURVEY BY AERO-METRIC, INC. DATED 6-19-2008, PROJECT NO. 1080611, PROVIDED BY MIDWEST GENERATION.
2. ASH SURGE BASIN FEATURES TAKEN FROM MIDWEST GENERATION DRAWING TITLED WASTE WATER TREATMENT FACILITY, DETAIL PLAN, ASH SURGE BASIN, NO. 3B-0-2071, DATED 5-12-78.
3. FINAL SURFACE CONTOURS AND FEATURE LOCATIONS FROM SURVEY BY RIDGELINE CONSULTANTS, PROJECT NUMBER 2013-0340, DATED OCTOBER 8, 2013, PROVIDED BY TERRA CONTRACTING SERVICES.

REVISION:		DATE:	APP'D BY:
6.			
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3.	ISSUED FOR RECORD DOCUMENTATION	07/18/14	EJT
2.	ISSUED FOR CONSTRUCTION	06/18/13	HMS
1.	ISSUED FOR BID	03/28/13	EJT
0.	ISSUED FOR PERMIT	01/15/13	HMS

NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 2113.2/POWER/CON
DRAWN BY: RLH 01/15/13
CHECKED BY: HMS 01/15/13
APPROVED BY: HMS 01/16/13

WARNING LAYER PLAN

ASH SURGE BASIN LINER REPLACEMENT
POWERTON GENERATING STATION
MIDWEST GENERATION
PEKIN, ILLINOIS

DRAWING NO: D21132C030-03
REFERENCE: .
SHEET NO. C030

Jul 18, 2014 12:25pm PLOTTED BY: dduda SAVED BY: dduda
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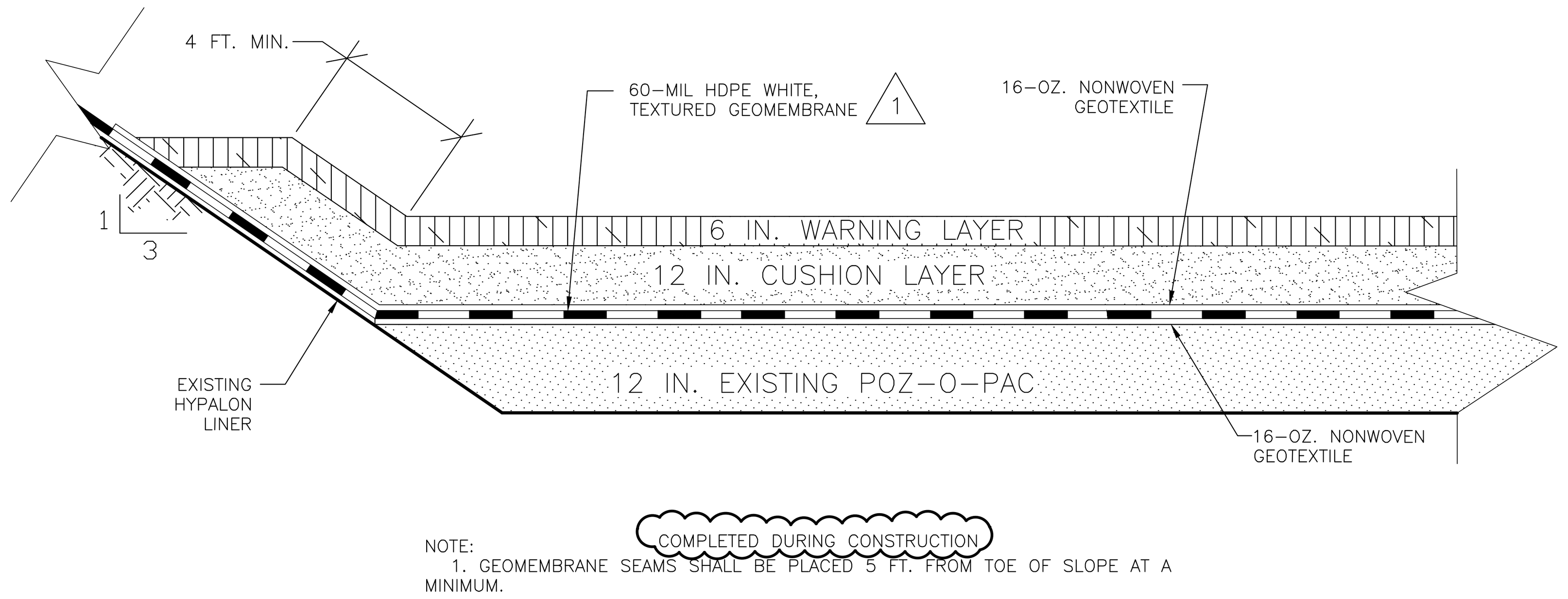
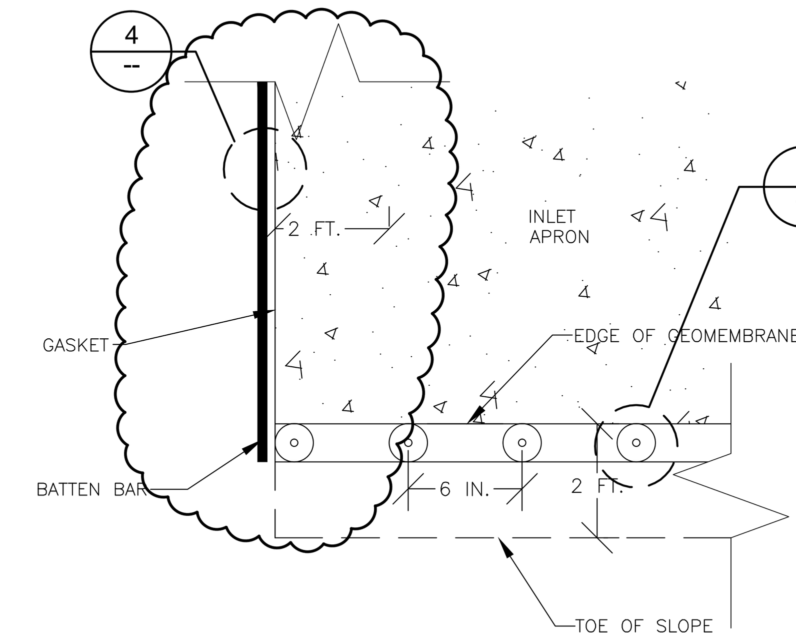
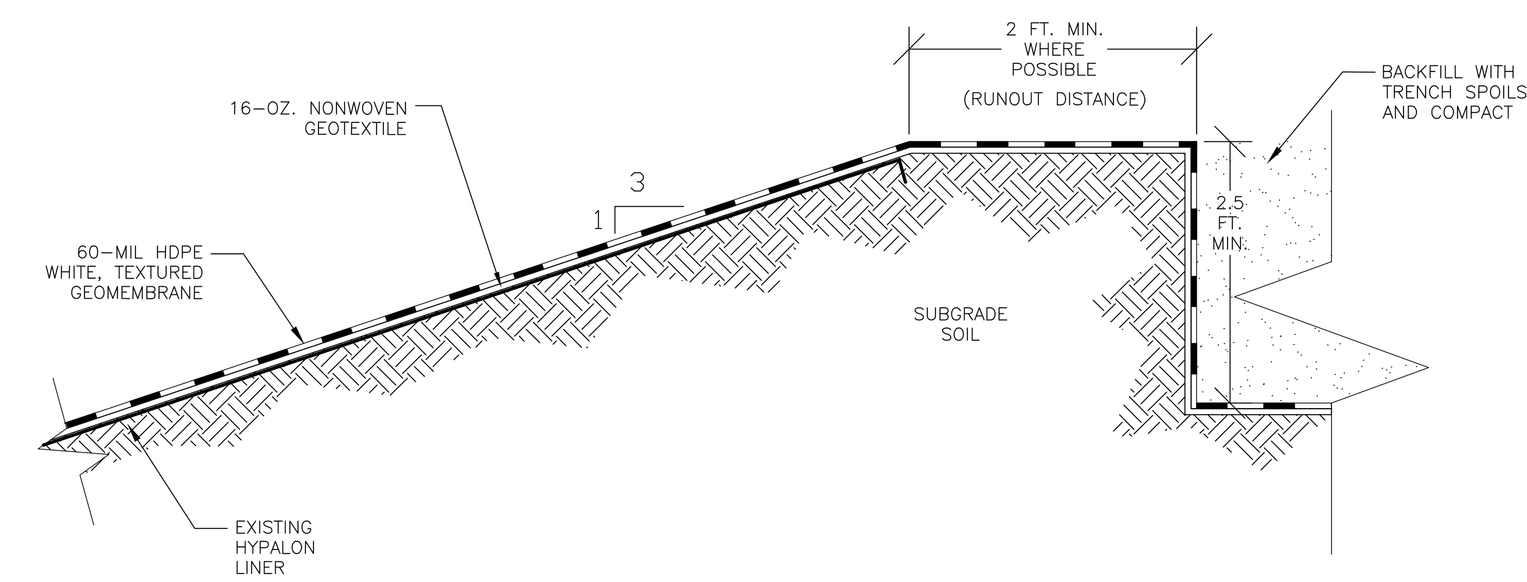


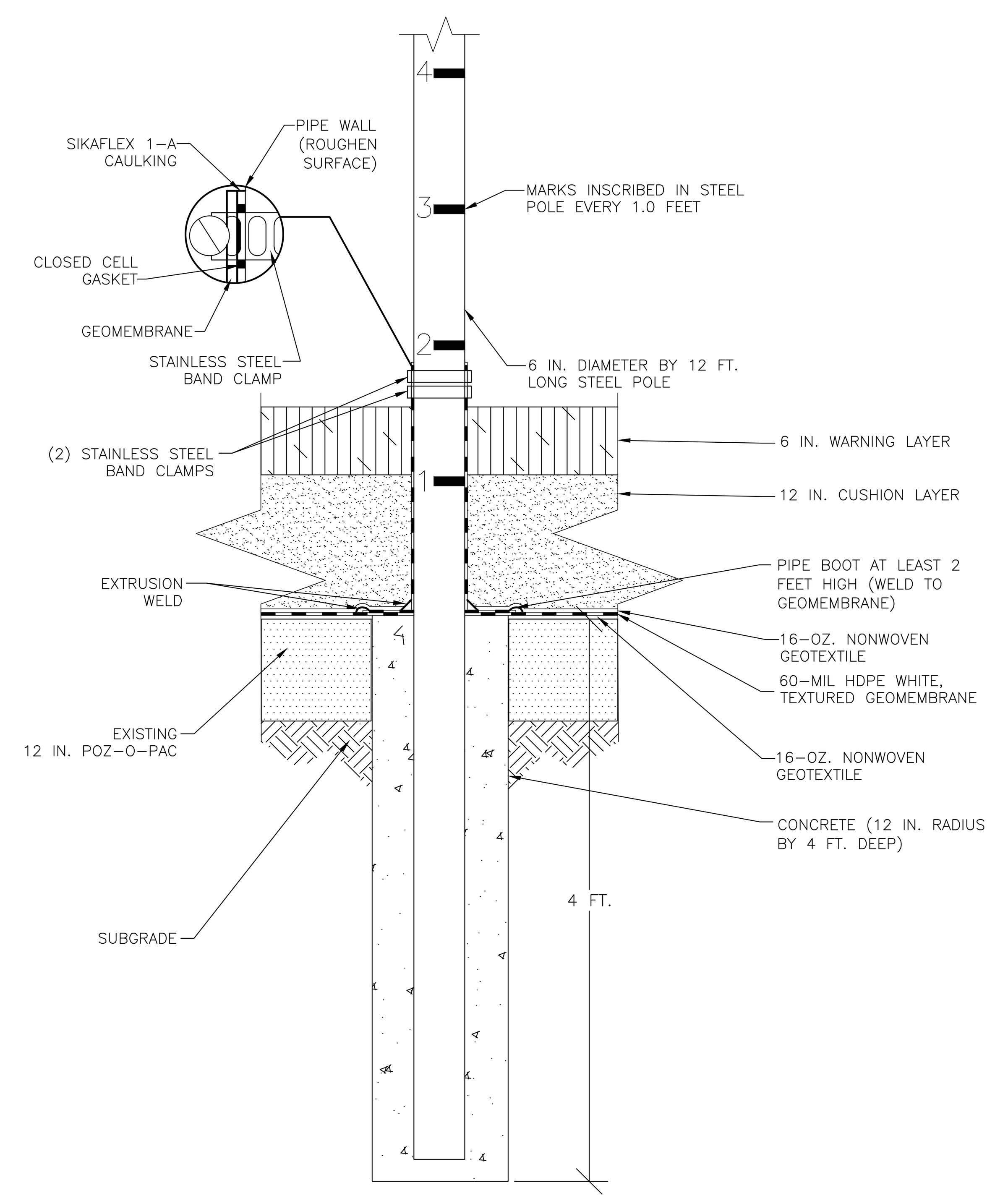
A / C030 SLOPE TRANSITION SECTION
NOT TO SCALE



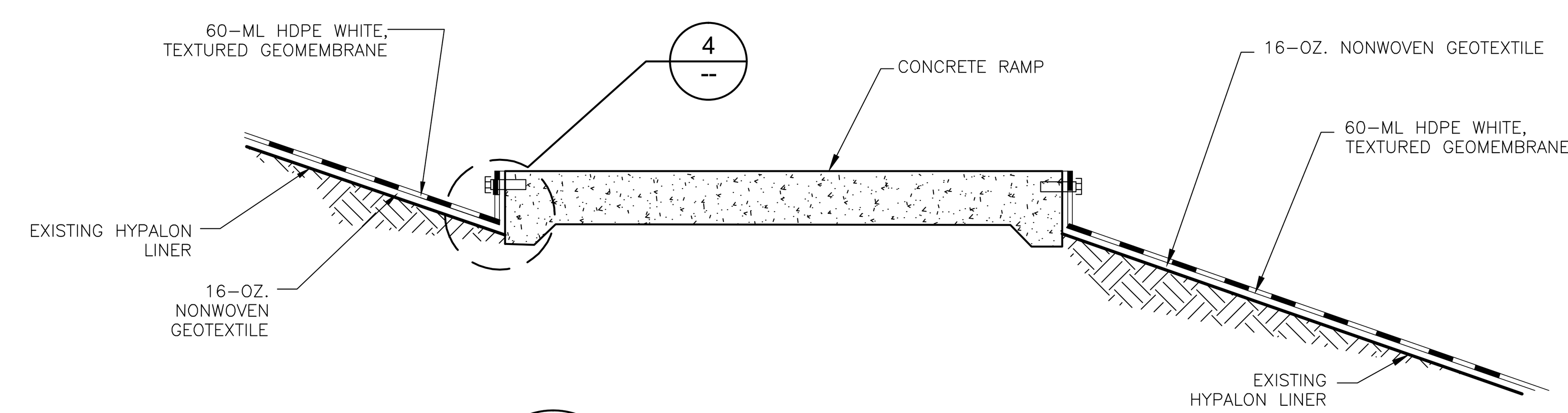
2 / C030 INLET APRON DETAIL PLAN
NOT TO SCALE



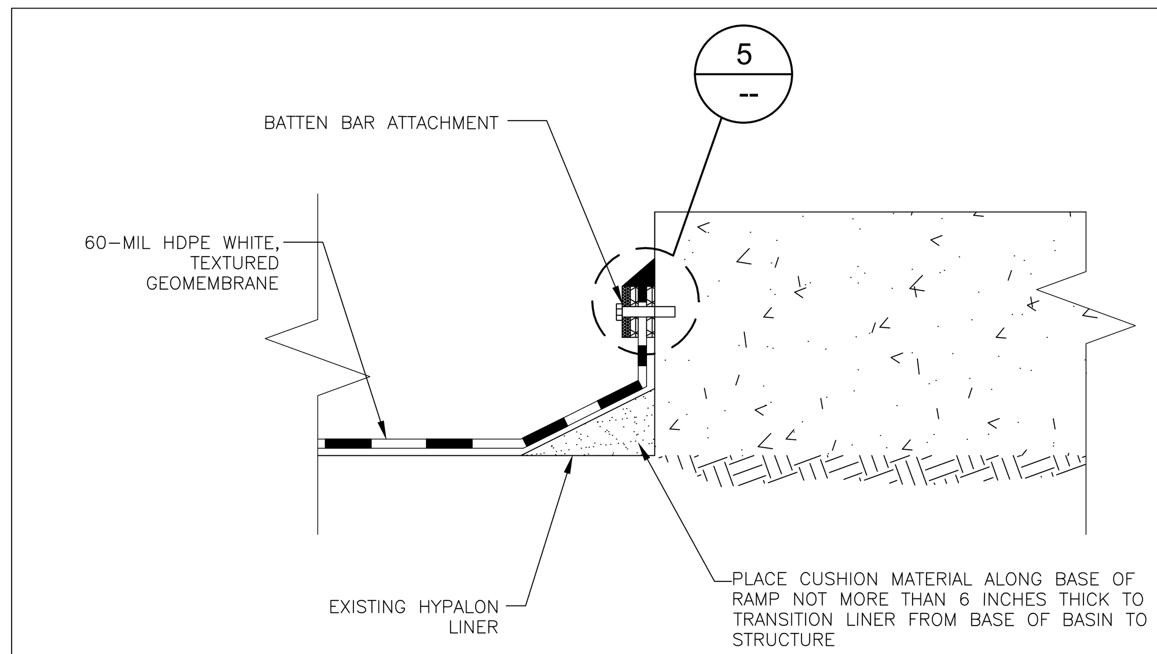
3 / C030 ANCHOR TRENCH DETAIL
NOT TO SCALE



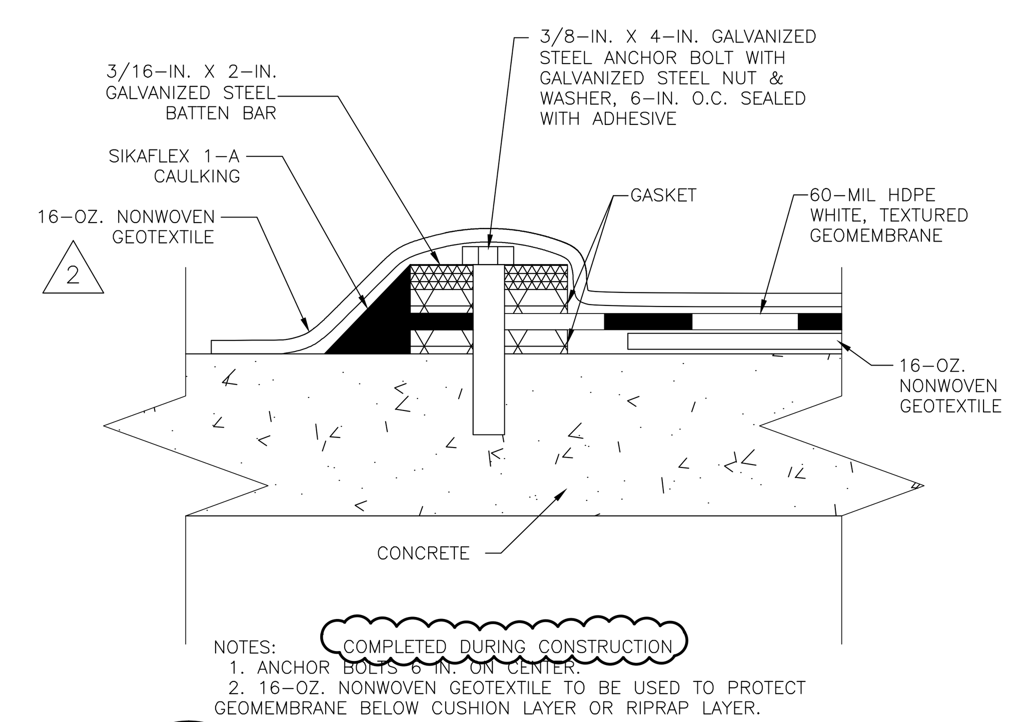
1 / C020 C030 MARKER POST DETAIL
NOT TO SCALE



B / C030 CONCRETE RAMP SECTION
NOT TO SCALE



4 / -- VERTICAL CONNECTION DETAIL
NOT TO SCALE



5 / -- BATTEN BAR ATTACHMENT
NOT TO SCALE

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3.	ISSUED FOR RECORD DOCUMENTATION	07/17/14	EJT
2.	ISSUED FOR CONSTRUCTION	06/25/13	HMS
1.	ISSUED FOR BID	03/28/13	EJT
0.	ISSUED FOR PERMIT	01/15/13	HMS
REVISION:		DATE:	APP'D BY:

NATURAL RESOURCE TECHNOLOGY

PROJECT NO.	2113.2/POWER/CON
DRAWN BY:	RLH 01/14/13
CHECKED BY:	HMS 01/14/13
APPROVED BY:	HMS 01/15/13

DETAILS AND SECTIONS

ASH SURGE BASIN LINER REPLACEMENT
POWERTON GENERATING STATION
MIDWEST GENERATION
PEKIN, ILLINOIS

DRAWING NO: D21132C031-03
REFERENCE: .
SHEET NO. C031

Jul 17, 2014 1:13pm PLOTTED BY: ddudo SAVED BY: ddudo
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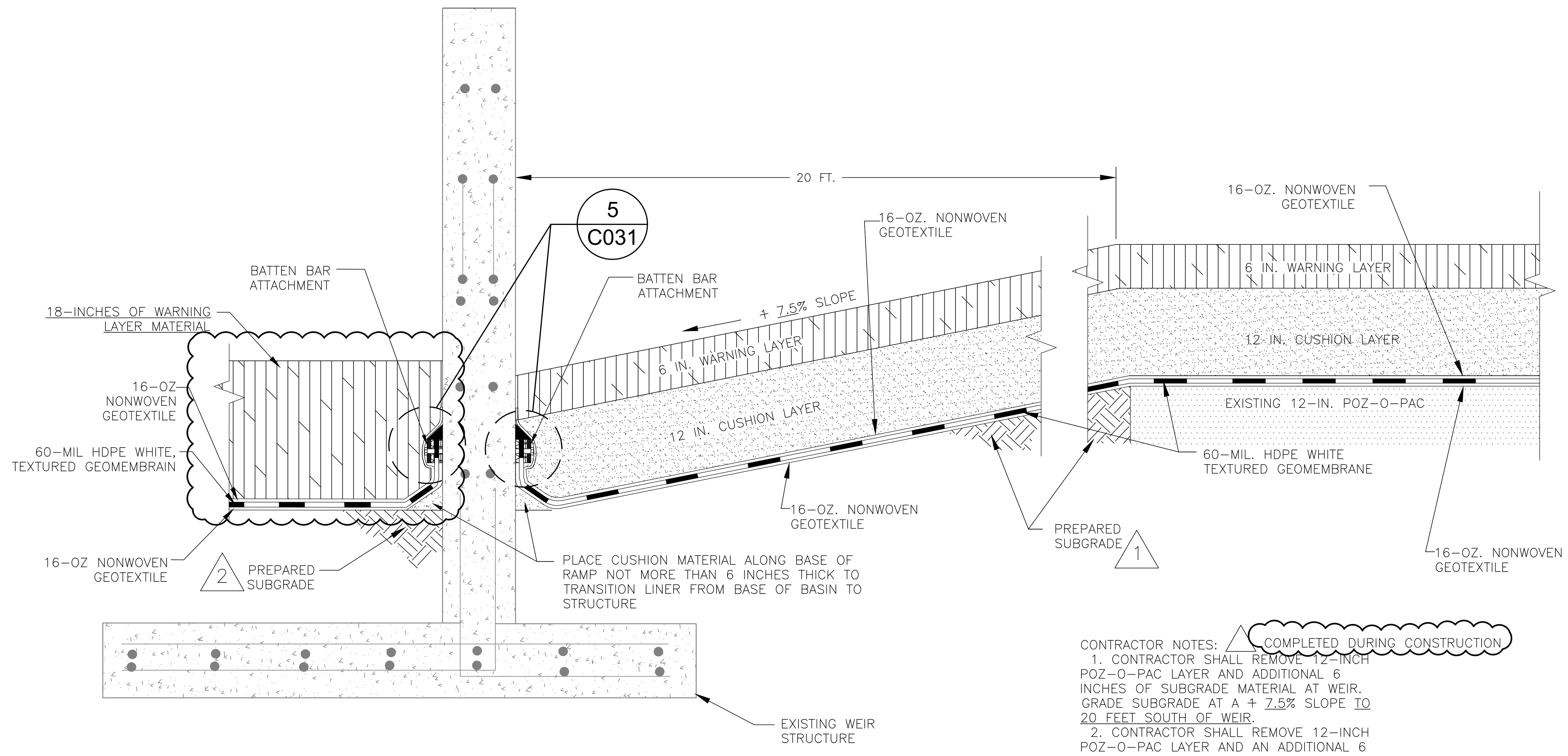
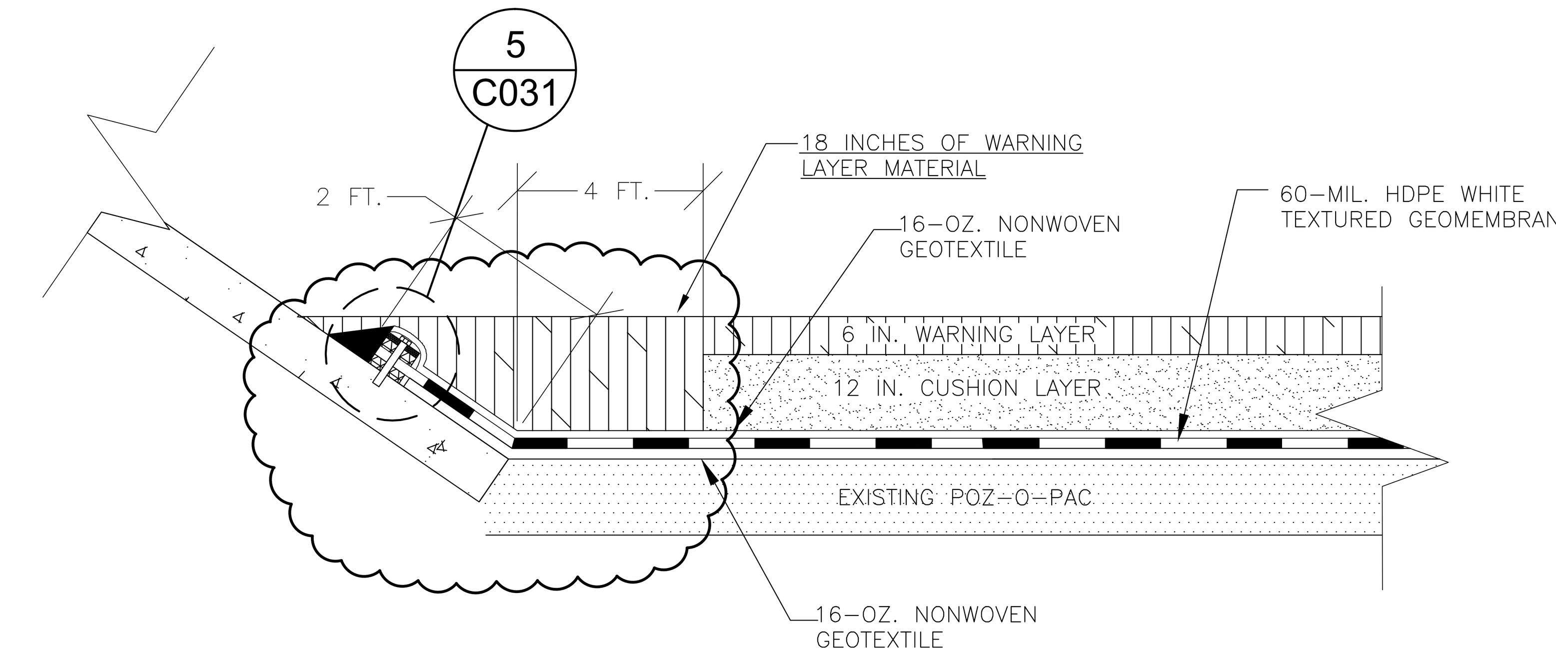


CONTRACTOR NOTES: 1 COMPLETED DURING CONSTRUCTION
1. CONTRACTOR SHALL REMOVE 12-INCH POZ-O-PAC LAYER AND ADDITIONAL 6 INCHES OF SUBGRADE MATERIAL AT WEIR. GRADE SUBGRADE AT A ± 7.5% SLOPE TO 20 FEET SOUTH OF WEIR.
2. CONTRACTOR SHALL REMOVE 12-INCH POZ-O-PAC LAYER AND AN ADDITIONAL 6 INCHES OF SUBGRADE MATERIAL LOCATED BETWEEN THE WEIR AND THE WING WALL STRUCTURE ALONG THE NORTH TOE OF SLOPE. INSTALL GEOMEMBRANE AND BACKFILL WITH ~~RIPRAP~~ WARNING LAYER MATERIAL.

C / C030 CONCRETE WEIR SECTION
NOT TO SCALE



D / C030 INLET APRON SECTION
NOT TO SCALE

REVISION:		DATE:	APP'D BY:
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4.			
3.	ISSUED FOR RECORD DOCUMENTATION	07/17/14	EJT
2.	ISSUED FOR CONSTRUCTION	06/25/13	HMS
1.	ISSUED FOR BID	03/28/13	EJT
0.	ISSUED FOR PERMIT	01/15/13	HMS

NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 2113.2/POWER/CON
DRAWN BY: RLH 01/14/13
CHECKED BY: HMS 01/14/13
APPROVED BY: HMS 01/15/13

DETAILS AND SECTIONS

ASH SURGE BASIN LINER REPLACEMENT
POWERTON GENERATING STATION
MIDWEST GENERATION
PEKIN, ILLINOIS

DRAWING NO: D21132C032-04
REFERENCE: .
SHEET NO. C032

EXHIBIT 16

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

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

PAT QUINN, GOVERNOR   JOHN J. KIM, INTERIM DIRECTOR

217-785-0561

October 24, 2012

CERTIFIED MAIL # 7011 1150 0001 0859 0119
RETURN RECEIPT REQUESTED

John Kennedy
Senior Vice President, Generation
235 Remington, Suite A
Bolingbrook, IL 60440

Re: Compliance Commitment Acceptance
Violation Notice: W-2012-00057
Midwest Generation, LLC, Powerton Generating Station; ID Number: 6282

Dear Mr. Kennedy:

The Illinois Environmental Protection Agency ("Illinois EPA") has approved the Compliance Commitment Agreement ("CCA") for Midwest Generation, LLC, Powerton Generating Station. Please find enclosed an executed copy of the CCA for your records.

Failure to fully comply with the CCA may, at the sole discretion of the Illinois EPA, result in referral of this matter to the Office of the Attorney General, the State's Attorney or the United States Environmental Protection Agency.

The CCA does not constitute a waiver or modification of the terms and conditions of any license or permit issued by the Illinois EPA or any other unit or department of local, state or federal government or of any local, state or federal statute or regulatory requirement.

Questions regarding this matter should be directed to Andrea Rhodes at 217/785-0561. Written communications should be directed to the Illinois Environmental Protection Agency, Bureau of Water, CAS #19, P.O. Box 19276, Springfield, IL 62794-9276, and all communications shall include reference to your Violation Notice Number W-2012-00057.

Sincerely,

Michael Crumly
Manager, Compliance Assurance Section
Division of Public Water Supplies
Bureau of Water

Attachments

cc: Basil G. Constantelos
Maria Race
Susan M. Franzetti

BOW ID: W1798010008 CASE ID: 2012-006

cc: Basil G. Constantelos
Midwest Generation EME, LLC
235 Remington Blvd, Suite A
Bolingbrook, IL 60440

Maria Race
Midwest Generation EME, LLC
2535 Remington Blvd, Suite A
Bolingbrook, IL 60440

Susan M. Franzetti
10 South LaSalle St.
Suite 3600
Chicago, IL 60603

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

IN THE MATTER OF:

MIDWEST GENERATION, LLC,
POWERTON GENERATING STATION
PEKIN, TAZEWELL COUNTY, IL
ID NUMBER: 6282

ILLINOIS EPA VN W-2012-00057
BUREAU OF WATER

COMPLIANCE COMMITMENT AGREEMENT

I. Jurisdiction

1. This Compliance Commitment Agreement ("CCA") is entered into voluntarily by the Illinois Environmental Protection Agency ("Illinois EPA") and Midwest Generation, LLC, Powerton Generating Station ("Respondent") (collectively, the "Parties") under the authority vested in the Illinois EPA pursuant to Section 31(a)(7)(i) of the Illinois Environmental Protection Act ("Act"), 415 ILCS 5/31(a)(7)(i).

II. Allegation of Violations

2. Respondent owns and operates Powerton Generating Station in Pekin, Tazewell County, Illinois ("Powerton").

3. Pursuant to Violation Notice ("VN") W-2012-00057 issued on June 11, 2012, the Illinois EPA contends that Respondent has violated the following provisions of the Act and Illinois Pollution Control Board ("Board") Regulations:

   a) Operations at ash impoundments have resulted in violations of the Groundwater Quality Standards at monitoring wells MW-1, MW-2, MW-4, MW-5, MW-6, MW-7, MW-8, MW-9, MW-10, MW-11, MW-12, MW-13, MW-14, and MW-15. Section 12 of the Act, 415 ILCS 5/12, 35 Ill. Adm. Code 620.115, 620.301, 620.401, 620.405, and 620.410.

III. Compliance Activities

4. On September 4, 2012, the Illinois EPA received Respondent's response to VN W-2012-00057, which included proposed terms for a CCA. The Illinois EPA has reviewed Respondent's proposed CCA terms, as well as considered whether any additional terms and conditions are necessary to attain compliance with the alleged violations cited in the VN.

5. Respondent agrees to undertake and complete the following actions, which the Illinois EPA has determined are necessary to attain compliance with the allegations contained in VN W-2012-00057:

   a) The ash ponds at Powerton shall not be used as permanent disposal sites and shall continue to function as treatment ponds to precipitate ash. Ash shall continue to be removed from the ponds on a periodic basis.

   b) The ash treatment ponds shall be maintained and operated in a manner which protects the integrity of the existing liners. During the removal of ash from the ponds, appropriate procedures shall be followed to protect the integrity of the existing liners, including operating the ash removal equipment in a manner which minimizes the risk of any damage to the liner.

   c) During the ash removal process, visual inspections of the ponds shall be conducted to identify any signs of a breach in the integrity of the pond liners. In the event that a breach of the pond liners is detected, Midwest Generation shall promptly notify the Illinois EPA and shall implement a corrective action plan for repair or replacement as necessary, of the liner. Upon the Illinois EPA's approval, and the issuance of any necessary construction permit, Midwest Generation will implement the corrective action plan.

   d) Midwest Generation shall monitor the new well as described in 5(f) below and the existing fifteen groundwater monitoring wells quarterly for constituents in 35 Ill. Adm. Code 620.410(a) and (d), with the exception of radium 226 and 228, and report its findings to the Illinois EPA within 30 days of the end of each quarter. In addition, Midwest Generation shall record and report groundwater elevation and submit a potentiometric surface map with the above quarterly groundwater monitoring report.

   e) Within 90 days of the effective date of the CCA, Midwest Generation shall submit an application for a construction permit to re-line the Ash Surge Basin and the Secondary Ash Settling Basin at Powerton with a 60 mil thickness high density polyethylene ("HDPE") liner or an Illinois EPA approved equivalent material.

   f) Midwest Generation shall install an additional groundwater monitoring well south of monitor well 9, in a location approved by the Illinois EPA, to better define up gradient groundwater quality, within 60 days of the effective date of the CCA.

g) Midwest Generation shall submit an application to establish a GMZ pursuant to 35 Ill. Adm. Code Part 620.250 within 90 days of the effective date of the CCA.

h) Midwest Generation shall enter into an Environmental Land Use Control (ELUC) to cover the area of the Powerton Station property which is contained within the GMZ. Midwest Generation shall submit a proposed draft ELUC to the Illinois EPA for review and comment within 90 days of the effective date of the CCA.

i) Midwest Generation shall record the ELUC within 30 days of approval of the ELUC by the Illinois EPA.

j) Midwest Generation shall establish a GMZ pursuant to 35 Ill. Adm. Code Part 620.250 within one year of the effective date of the CCA.

k) Once the Ash Surge Basin and the Secondary Ash Settling Basin have been lined and a GMZ and ELUC have been established at Powerton, Midwest Generation shall submit a certification (or a statement) of compliance. Midwest Generation may submit either the attached "Illinois EPA Compliance Statement" or another similar writing to satisfy the statement of compliance within one year of the effective date of the CCA.

l) Midwest Generation shall not allow the East Yard Run-off Basin to be part of the ash sluicing flow system. Further, Midwest Generation shall submit monitoring results from water contained in the East Yard Run-off Basin proximate to outfall monitoring point 003 within 60 days of the effective date of the CCA. Quarterly monitoring of the East Yard Run-off Basin shall be for the constituents listed in 35 Ill. Adm. Code 620.410(a) and (d) with the exception of radium 226 and radium 228. At the end of four (4) quarters of monitoring, Midwest Generation may request cessation of water monitoring from the East Yard Run-off Basin.

m) Midwest Generation shall not use any unlined areas for permanent or temporary ash storage or ash handling.

IV. Terms and Conditions

6. Respondent shall comply with all provisions of this CCA, including, but not limited to, any appendices to this CCA and all documents incorporated by reference into this CCA. Pursuant to Section 31(a)(10) of the Act, 415 ILCS 5/31(a)(10), if Respondent complies with the terms of this CCA, the Illinois EPA shall not refer the alleged violations that are the subject of this CCA, as described in Section II above, to the Office of the Illinois Attorney General or the State's Attorney of the county in which the alleged violations occurred. Successful completion of this CCA or an amended CCA shall be a factor to be weighed, in favor of the Respondent, by the Office of the Illinois Attorney General in determining whether to file a complaint on its own motion for the violations cited in VN W-2012-00057.

7. This CCA is solely intended to address the violations alleged in Illinois EPA VN W-2012-00057. The Illinois EPA reserves and this CCA is without prejudice to, all rights of the Illinois EPA against Respondent with respect to noncompliance with any term of this CCA, as well as to all other matters. Nothing in this CCA is intended as a waiver, discharge, release, or covenant not to sue for any claim or cause of action, administrative or judicial, civil or criminal, past or future, in law or in equity, which the Illinois EPA may have against Respondent, or any other person as defined by Section 3.315 of the Act, 415 ILCS 5/3.315. This CCA in no way affects the responsibilities of Respondent to comply with any other federal, state or local laws or regulations, including but not limited to the Act, and the Board Regulations [and Permit, if applicable].

8. Pursuant to Section 42(k) of the Act, 415 ILCS 5/42(k), in addition to any other remedy or penalty that may apply, whether civil or criminal, Respondent shall be liable for an additional civil penalty of $2,000 for violation of any of the terms or conditions of this CCA.

9. This CCA shall apply to and be binding upon the Illinois EPA, and on Respondent and Respondent's officers, directors, employees, agents, successors, assigns, heirs, trustees, receivers, and upon all persons, including but not limited to contractors and consultants, acting on behalf of Respondent, as well as upon subsequent purchasers of Respondent's Powerton in Pekin, Tazewell County, Illinois.

10. In any action by the Illinois EPA to enforce the terms of this CCA, Respondent consents to and agrees not to contest the authority or jurisdiction of the Illinois EPA to enter into or enforce this CCA, and agrees not to contest the validity of this CCA or its terms and conditions.

11. This CCA shall only become effective:

    a) If, within 30 days of receipt, Respondent executes this CCA and submits it, via certified mail, to Illinois EPA, Bureau of Water, Andrea Rhodes, MC #19, 1021 North Grand Ave East, Springfield, IL 62702. If Respondent fails to execute and submit this CCA within 30 days of receipt, via certified mail, this CCA shall be deemed rejected by operation of law; and

    b) Upon execution by all Parties.

12. Pursuant to Section 31(a)(7.5) of the Act, 415 ILCS 5/31(a)(7.5), this CCA shall not be amended or modified prior to execution by the Parties. Any amendment or modification to this CCA by Respondent prior to execution by all Parties shall be considered a rejection of the CCA by operation of law. This CCA may only be amended subsequent to its effective date, in writing, and by mutual agreement between the Illinois EPA and Respondent's signatory to this CCA, Respondent's legal representative, or Respondent's agent.

AGREED:
FOR THE ILLINOIS ENVIRONMENTAL PROTECTION AGENCY:

BY: [signature] DATE: 10/24/12

Michael Crumly
Manager, Compliance Assurance Section
Division of Public Water Supplies
Bureau of Water

FOR RESPONDENT:

BY: [signature] DATE: Oct 15, 2012

John Kennedy
Senior Vice President, Generation
Midwest Generation, LLC

Illinois EPA Compliance Statement

The owner of the facility must acknowledge that all compliance commitment agreement (CCA) measures have been successfully completed.

Please complete, sign, and return.

I ______________________________ *(print name)*, hereby certify that all violations addressed in Violation Notice (VN) number ____________________ have been addressed and that all CCA measures were completed on ______________________________ *(date)*.

____
Signature

____
Title

____
Telephone Number

____
Date

Be sure to retain copies of this document for your files. Should you need additional notification forms, please contact this office at (217)785-0561. Return this completed form to:

Illinois Environmental Protection Agency
Compliance Assurance Section #19
Bureau of Water
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9276

"Any person who knowingly makes a false, fictitious, or fraudulent material statement, orally or in writing, to the Agency,.....related to or required by this Act, a regulation adopted under this Act, any federal law or regulation for which the Agency has responsibility, or any permit, term, or condition thereof, commits a Class 4 felony..." (415 ILCS 5/44(h) (8))

EXHIBIT 17

KPRG

ENVIRONMENTAL CONSULTATION & REMEDIATION

KPRG and Associates, Inc.

ALTERNATE SOURCE DEMONSTRATION
CCR GROUNDWATER MONITORING
POWERTON GENERATING STATION

March 25, 2019

Ms. Sharene Shealey
Midwest Generation, LLC
529 E. Romeo Road
Romeoville, IL 60446

VIA E-MAIL

Re: Alternate Source Demonstration – Appendix IV Parameters
Powerton Generating Station – Ash By-pass Basin and Ash Surge Basin

Dear Ms. Shealey:

The Midwest Generation, LLC (Midwest Generation) Powerton Station is currently in assessment monitoring for the Ash By-pass Basin (ABB) and Ash Surge Basin (ASB) in accordance with the Federal Register, Environmental Protection Agency, 40 CFR Part 257.95, Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule dated April 17, 2015 (CCR Rule). The wells being sampled were selected to meet the monitoring requirements of the CCR Rule for the ABB and the ASB. The monitoring well network around these basins consists of nine monitoring wells (MW-01 [upgradient], MW-08, MW-09 [upgradient], MW-11, MW-12, MW-15, MW-17, MW-18 and MW-19 [upgradient]) as shown on Figure 1.

Pursuant to Part 257.95(h)(1-3) of the CCR Rule, the applicable site specific Groundwater Protection Standards (GWPSs) for the twelve detected Appendix IV parameters were established in accordance with procedures defined in CCR Compliance Statistical Approach for Groundwater Data Evaluation, Midwest Generation Powerton Generating Station. This evaluation was summarized in a letter report titled Statistical Evaluation Summary CCR Groundwater Assessment Monitoring Powerton Generating Station dated December 26, 2018. The evaluation identified arsenic, barium, molybdenum, selenium and thallium above established GWPSs at several well locations with none of the individual well locations having all five of the parameters at elevated levels. In accordance with the CCR Rule, Midwest Generation conducted an Alternate Source Demonstration (ASD) under provisions in Section 257.95(g)(ii) to determine whether these SSIs may be associated with an actual release from the regulated unit(s) or if another potential source in the vicinity of the basins may be affecting the local groundwater quality.

This report summarizes the results of the ASD completed in accordance with 40 CFR 257.95(g)(ii) for the Powerton Generating Station ABB and ASB. The report is structured to provide a documentation of field investigation activities, a presentation of Leaching Environmental Assessment Framework (LEAF) Test data, an alternate source evaluation of the potential SSI parameters, conclusions and recommendations. Each is discussed separately below. The statistical evaluation data tables from December 26, 2018 are provided in Attachment 1 for reference.

DOCUMENTATION OF FIELD ACTIVITIES

To assist in evaluating a potential alternate source(s), both basin water and ash samples were collected. One water sample was collected from the ASB and one water sample was collected from the ABB. The water samples were collected directly into laboratory prepared containers, transported on ice under a completed chain-of-custody to the analytical laboratory and analyzed for CCR Appendix IV assessment monitoring parameters. Analytical data package is provided in Attachment 2.

One composite ash sample was collected for each of the two basins (ASB and ABB). The composite samples consisted of a series of equivalent grab samples from across the length of each basin, from the inlet area to the outfall, to minimize potential skewing of the sample due to gradation changes (i.e., a larger coarse fraction near the inlet and larger fine fraction near outfall). The individual grab samples were thoroughly mixed to form a single composite sample for each basin. The composite samples were transferred directly into laboratory prepared containers, placed on ice and shipped to the analytical laboratory under a completed chain-of-custody. The ash sediment samples were analyzed using the LEAF test using Method 1313. Under this method, each ash sediment sample underwent leaching over a range of eight pH values plus under "Natural pH" conditions. The Natural pH condition is the actual pH of the ash itself measured in the laboratory prior to any pH modifications performed under the LEAF Test. The collected leachate from each pH value was analyzed for CCR Appendix IV assessment monitoring parameters. The analytical data package is provided in Attachment 2.

LEAF TEST DATA

The results of the basin water and the ash LEAF Test analyses are provided in Tables 1 and 2, respectively. A review of Table 2 indicates that the Natural pH of the leachate ranges from 9.0 in the ABB to 8.6 in the ASB. The basin water pH was at 8.2 and 7.3 for the ABB and ASB, respectively (Table 1).

The LEAF Test data for the five Appendix IV parameters that had detections above the GWPS are illustrated in graphical form on Figures 2 through 6 as a function of pH. On those figures are also plotted the results of the "Natural pH" test samples, upgradient monitoring wells MW-01, MW-09 and MW-19 and the monitoring well data from the affected wells which are the subject of this evaluation (MW-11, MW-12, MW-15 and MW-17) for the May and August 2018 sampling events (the assessment monitoring events which were compared to established GWPSs). For values reported as not-detected, one-half of the detection limit was used on the plots.

ALTERNATE SOURCE EVALUATION OF THE SSI PARAMETERS

Monitoring wells MW-11 and MW-12 are the immediate downgradient monitoring points for the ABB and wells MW-09 and MW-19 are considered local upgradient monitoring points. For statistical evaluation purposes, well MW-01 was also considered for representation of background. Downgradient monitoring well MW-11 is screened within a gravelly sand unit and indicated detections of arsenic and barium above the respective GWPSs. Downgradient well MW-12 is screened within a silty clay unit and indicated only detections of arsenic above the GWPS for that parameter.

Monitoring wells MW-15 and MW-17 are both immediately downgradient of the ASB and wells MW-11 and MW-12, discussed above to be downgradient relative to the ABB, may also be considered local upgradient of the ASB (they are downgradient wells for the ABB but upgradient of the ASB, located generally between the two basins; see Figure 1). Wells MW-15 and MW-17 are also both completed within areas of historical fill material placement which includes ash. Both are screened within a silty clay unit.

Arsenic

The established GWPS for arsenic is set at 0.011 mg/l. Arsenic detections in the May and August 2018 sampling events at well location MW-11 ranged from 0.089 mg/l to 0.68 mg/l, at well MW-12 0.09 mg/l to 0.12 mg/l and at well MW-17 0.087 mg/l to 0.42 mg/l.

A review of all available CCR monitoring data for the three noted upgradient/background wells shows arsenic concentrations to range from not detected to 0.0081 mg/l, however, in the May and August 2018 sampling events, arsenic was not detected in any of these three wells. LEAF Test data for arsenic in leachate under "Natural pH" conditions was 0.0048 mg/l and 0.0033 mg/l in the ABB and ASB, respectively. The basin water collected showed arsenic concentrations between 0.0019 mg/l (ABB) and 0.0032 mg/l (ASB). It is noted that these Natural pH and basin water concentrations are well below the established GWPS. If leachate was being released from the basins and mixing with background water quality, the resulting mixture would not exceed the established GWPS suggesting the elevated arsenic in wells MW-11, MW-12 and MW-17 is from a different source and not associated with a release from the regulated units.

Further review of the LEAF Test data indicates that the only conditions under which the leachate in either the ABB or the ASB show arsenic concentrations in excess of the GWPS is either under very basic conditions (pH greater than 10.5) or very acidic condition (pH less than 4). Basic conditions above pH 10.5 have not been documented at the site and are generally not associated with bottom ash. Similarly, acidic conditions are highly unlikely and are generally not associated with bottom ash. In addition, if the noted arsenic detections in wells MW-11, MW-12 and MW-17 were associated with some unexplained high or low swings in the pH within the basins, then the pH in the groundwater samples would also reflect an associated increase or decrease which would result in the elevated arsenic detections being correlated to pH. Figure 7 provides a plot of the arsenic and associated pH values for the three subject monitoring wells. Based on the LEAF Test data, the relationship between arsenic and pH to the basic side of neutral (pH>7) should be positive linear and to the acid side of neutral (pH<7) inverse linear (i.e., increasing arsenic with decreasing pH). No such correlations are seen on Figure 7 which again indicates a source of the arsenic other than the regulated units.

Barium

There was only one barium detection above the GWPS which was at well location MW-11 in the August 2018 sampling. Barium was detected at 3.0 mg/l and the GWPS is established at 2.0 mg/l. A review of the other historical data from well MW-11 indicates previous barium concentrations ranging from 0.30 mg/l to 1.4 mg/l.

A review of all available CCR monitoring data for the three noted upgradient/background wells shows barium concentrations to range from 0.027 mg/l to 0.089 mg/l. LEAF Test data for barium in leachate under "Natural pH" conditions was 0.35 mg/l and 0.15 mg/l in the ABB and ASB, respectively. The basin water collected showed barium concentrations between 0.056 mg/l (ABB) and 0.15 mg/l (ASB). It is noted that these Natural pH leachate and basin water concentrations are well below the established GWPS. If leachate was being released from the basins and mixing with background water quality, the resulting mixture would not exceed the established GWPS suggesting the elevated barium in well MW-11 is from a different localized source and not associated with a release from the regulated units.

Further reviewing the LEAF Test data indicates that the only conditions under which the leachate in either the ABB or the ASB show barium concentrations in excess of the GWPS is under acidic conditions (pH 5.5 or less). Acidic conditions are highly unlikely and generally not associated with bottom ash. However, if the noted elevated barium detection in well MW-11 is associated with some unexplained and unlikely downward shift in pH within the ABB, then the pH in the groundwater sample would also reflect an associated decrease which would result in the elevated barium detection being inversely correlated to pH (i.e., increasing barium with decreasing pH). Figure 8 provides a plot of the barium and associated pH values for MW-11 along with a linear regression analysis of the data. The regression analysis shows the R^2 value for the regression line to be approximately 0.002 which indicates no correlation between these two parameters. Looking at the data distribution, the highest detections are clearly not associated with the lowest pH values. Additional trend analysis using both Linear Regression and Sen's Slope estimator methods using the Sanitas™ statistical software for barium at MW-11 over time showed no statistically significant trends (see Attachment 3). These observations further indicate a localized barium source other than the regulated units.

Another factor to consider is that this is a single high detection above the GWPS. The most likely explanation is that this single high value is an unrepresentative outlier associated with either an analytical artifact or a higher suspended sediment load within the sample skewing the result upwards once preserved in the field with acid. If either of these two potential scenarios is the source of the elevated detection, the resultant data is not reflective of actual groundwater quality.

Molybdenum

There was only one molybdenum detection above the GWPS which was at well location MW-17 in the May 2018 sampling. Molybdenum was detected at 0.13 mg/l and the GWPS is established at 0.10 mg/l. A review of the other historical data from well MW-17 indicates previous molybdenum concentrations ranging from 0.019 mg/l to 0.12 mg/l.

A review of all available CCR monitoring data for the three noted upgradient/background wells shows molybdenum concentrations to range from not detected to 0.053 mg/l. The molybdenum concentrations at wells MW-11 and MW-12 ranged from not detected to 0.028 mg/l. LEAF Test data for molybdenum in leachate under "Natural pH" conditions was estimated at 0.0039 mg/l and 0.0029 mg/l in the ABB and ASB, respectively. The basin water collected showed molybdenum concentrations of 0.096 mg/l (ABB) and 0.01 mg/l (ASB). Well MW-17 is immediately downgradient of the ASB. It is noted that the Natural pH leachate concentrations and ASB basin water concentrations are well below the established GWPS. If leachate was being released from the basins and mixing with background water quality, the resulting mixture would not exceed the established GWPS. In fact, even the highest concentration of molybdenum generated in the LEAF Testing was only 0.0064 mg/l (over an order of magnitude lower than the GWPS) at a pH of 13 which is not a likely condition for bottom ash. The LEAF Test data basically document that the bottom ash within the subject basins is not a significant source of molybdenum, even under the most extreme conditions, indicating that the elevated molybdenum concentration in well MW-17 is from a different localized source and not associated with a release from the regulated units.

Selenium

Selenium was detected above the GWPS at only one downgradient monitoring well (MW-15). The concentration range was from 0.06 mg/l to 0.077 mg/l and the GWPS is established at 0.05 mg/l. A review of the other historical data from well

MW-15 indicates previous selenium concentrations ranging from 0.0032 mg/l to 0.045 mg/l.

A review of all available CCR monitoring data for the three noted upgradient/background wells shows selenium concentrations to range from not detected to 0.011 mg/l. The selenium concentrations at wells MW-11 and MW-12 were all non-detected. LEAF Test data for selenium in leachate under "Natural pH" conditions were not detected in both the ABB and ASB ash samples. The basin water collected showed a selenium concentration estimated at 0.002 mg/l in the ABB sample and was not detected in the ASB sample. It is noted that these Natural pH and basin water concentrations are well below the established GWPS. If leachate was being released from the basins and mixing with background water quality, the resulting mixture would not exceed the established GWPS. In fact, even the highest concentration of selenium generated in the LEAF Testing was only estimated at 0.041 mg/l at a pH of 2 which is not a likely condition for bottom ash. The LEAF Test data basically document that the bottom ash within the subject basins is not a significant source of selenium, even under the most extreme conditions, indicating that the elevated selenium concentration in well MW-15 is from a different localized source and not associated with a release from the regulated units.

Thallium

Thallium was detected above the GWPS at only one downgradient monitoring well (MW-17). The concentration range was from 0.0023 mg/l to 0.0068 mg/l and the GWPS is established at 0.002 mg/l. A review of the other historical data from well MW-17 indicates previous thallium concentrations ranging from not detected to 0.0075 mg/l.

A review of all available CCR monitoring data for the three noted upgradient/background wells shows thallium concentrations to be not detected. The thallium concentrations at wells MW-11 and MW-12 were all non-detected. LEAF Test data for thallium in leachate under "Natural pH" conditions were not detected in both the ABB and ASB ash samples. The basin water collected showed a thallium concentration estimated at 0.000091 mg/l in the ASB sample and was not detected in the ABB sample. It is noted that these Natural pH and basin water concentrations and/or detection limits are well below the established GWPS. If leachate was being released from the basins and mixing with background water quality, the resulting mixture would not exceed the established GWPS. Further evaluation of the LEAF Test data indicates that thallium is only detected in leachate on the acidic side of the pH scale and leachate concentrations only exceed the GWPS under conditions of a pH of approximately 4 or less. These acidic concentrations are not a likely condition for bottom ash. This would also indicate that the thallium concentration is an inverse function of pH (i.e., the lower the pH the higher the thallium concentration). Figure 9 provides a thallium versus pH plot for monitoring well MW-17 along with a linear regression analysis. The plot indicates poor correlation with an R^2 factor of 0.31 and that any such correlation is linear positive (i.e., increasing concentration with increasing pH) as opposed to inverse as seen in the LEAF Test data. Additional trend analysis using both Linear Regression and Sen's Slope estimator methods using the Sanitas™ statistical software for thallium at MW-17 over time showed no statistically significant trends (see Attachment 3). Combined, these observations indicate that the bottom ash within the subject basins is not a significant source of thallium under any expected site conditions and that the elevated thallium concentration in well MW-17 is from a different localized source and not associated with a release from the regulated units.

CONCLUSIONS/RECOMMENDATIONS

Based on the discussions provided above, the noted arsenic, barium, molybdenum, selenium and thallium concentrations detected above the GWPS at several well locations have been evaluated and determined to be associated with other potential alternate sources and not a release from the regulated units. It is recommended to continue with assessment monitoring on a semi-annual basis in accordance with Sections 257.95(d) and (e) of the CCR Rule.

If there are any questions, please contact me at 262-781-0475.

Sincerely,
KPRG and Associates, Inc.

Richard R. Gnat, P.G.
Principal

Timothy Stohner, P.E.
Project Manager/Sr. Engineer

cc: David Bacher, NRG
Joseph Kotas, Midwest Generation

CERTIFICATION

In accordance with Section 257.94(e)(2) of the CCR Rule, I hereby certify based on a review of the information contained within this CCR Alternate Source Demonstration dated March 25, 2019, that the information contained in this report is accurate to the best of my knowledge.

Certified by:
Date: March 25, 2019

TIMOTHY J. STOHNER
062-057635
REGISTERED
PROFESSIONAL
ENGINEER
OF
ILLINOIS

Timothy Stohner, P.E.
Illinois Professional Engineer Registration No.: 062.057635
KPRG and Associates, Inc.

FIGURES

ENVIRONMENTAL CONSULTATION & REMEDIATION

KPRG

KPRG and Associates, inc.

414 Plaza Drive, Suite 106 Westmont, Illinois 60559 Telephone 630-325-1300 Facsimile 630-325-1593

14665 West Lisbon Road, Suite 2B Brookfield, Wisconsin 53005 Telephone 262-781-0475 Facsimile 262-781-0478

ABB AND ASB CCR MONITORING WELL SITE MAP

POWERTON STATION
PEKIN, ILLINOIS

Scale: 1" = 350'	Date: March 13, 2019
KPRG Project No. 23517.3	FIGURE 1

W:\projects\midwest generation\attorney-client privilege\alt source\powerton map.dwg

Figure 2. Arsenic Concentration vs. pH Value - Powerton Station (May/August 2018 Data)

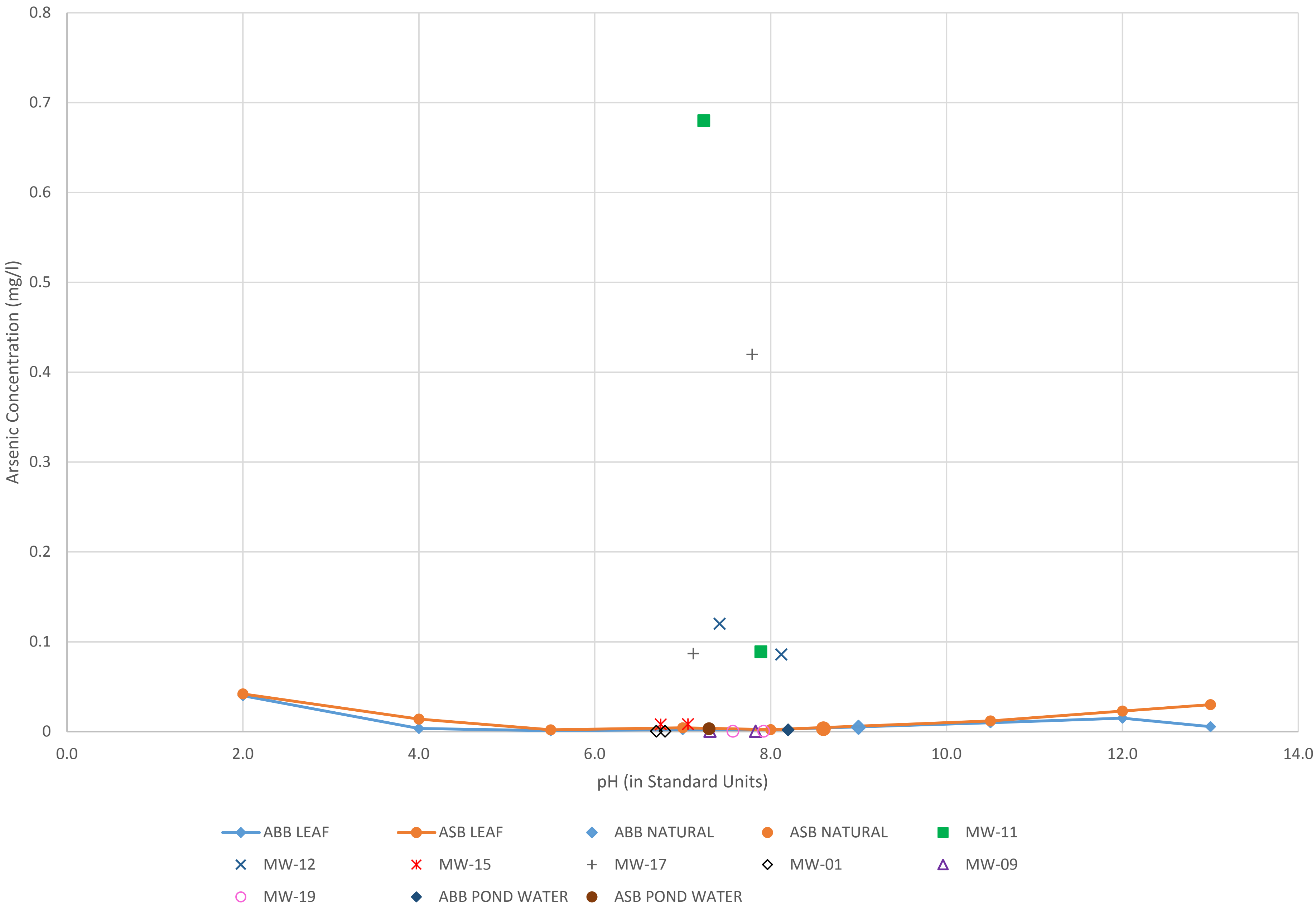
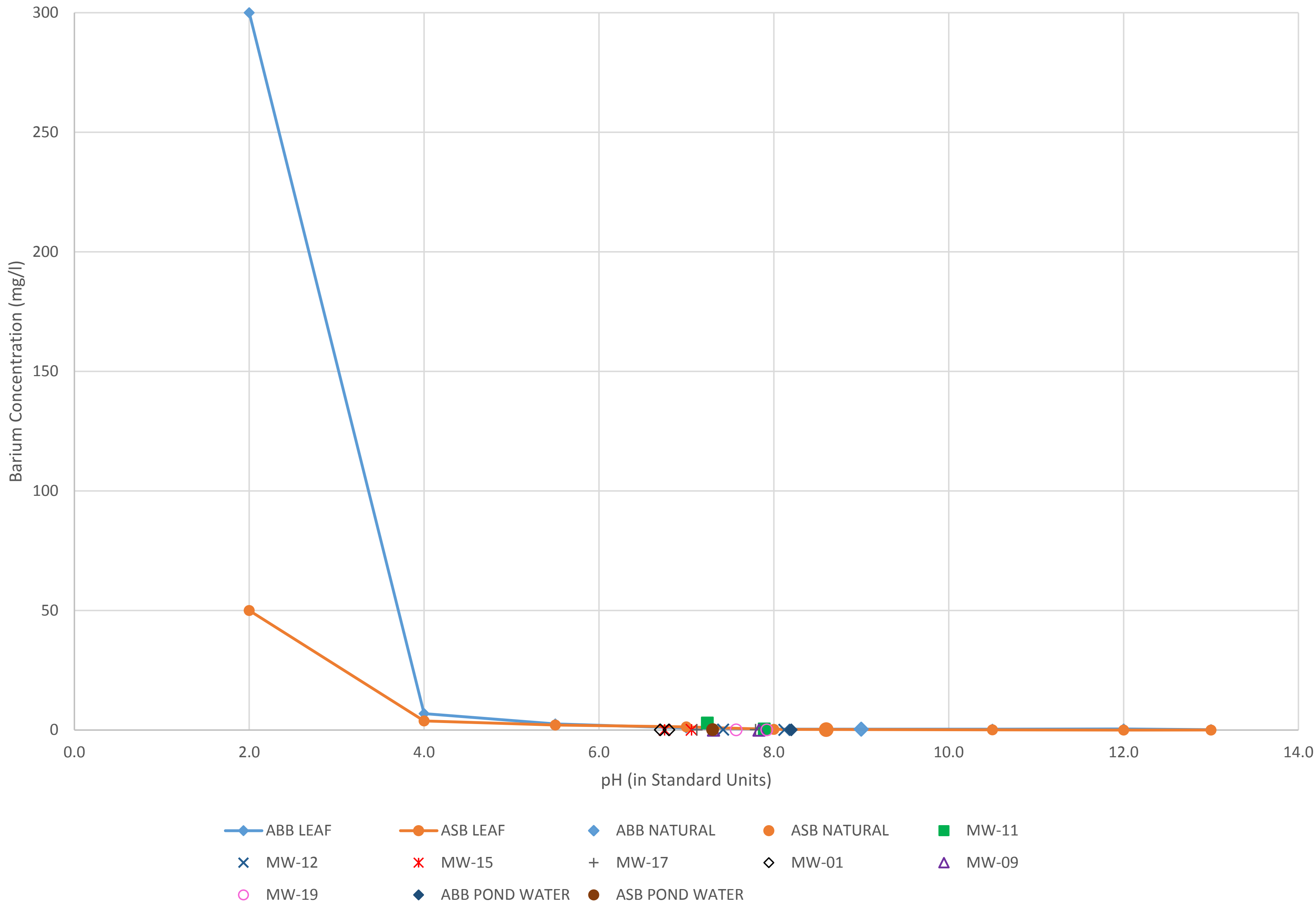


Figure 3. Barium Concentration vs. pH Value - Powerton Station (May/August 2018 Data)



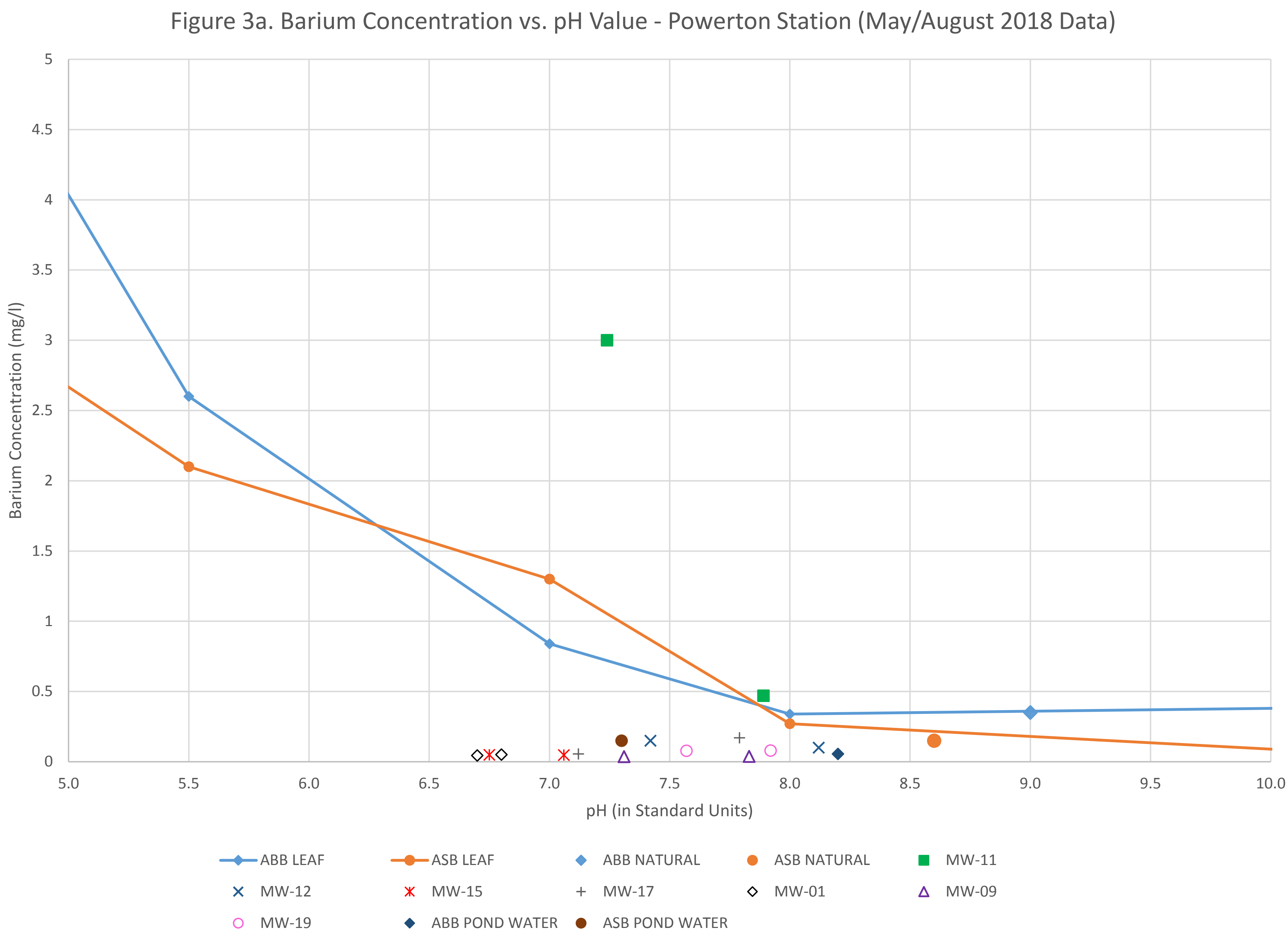
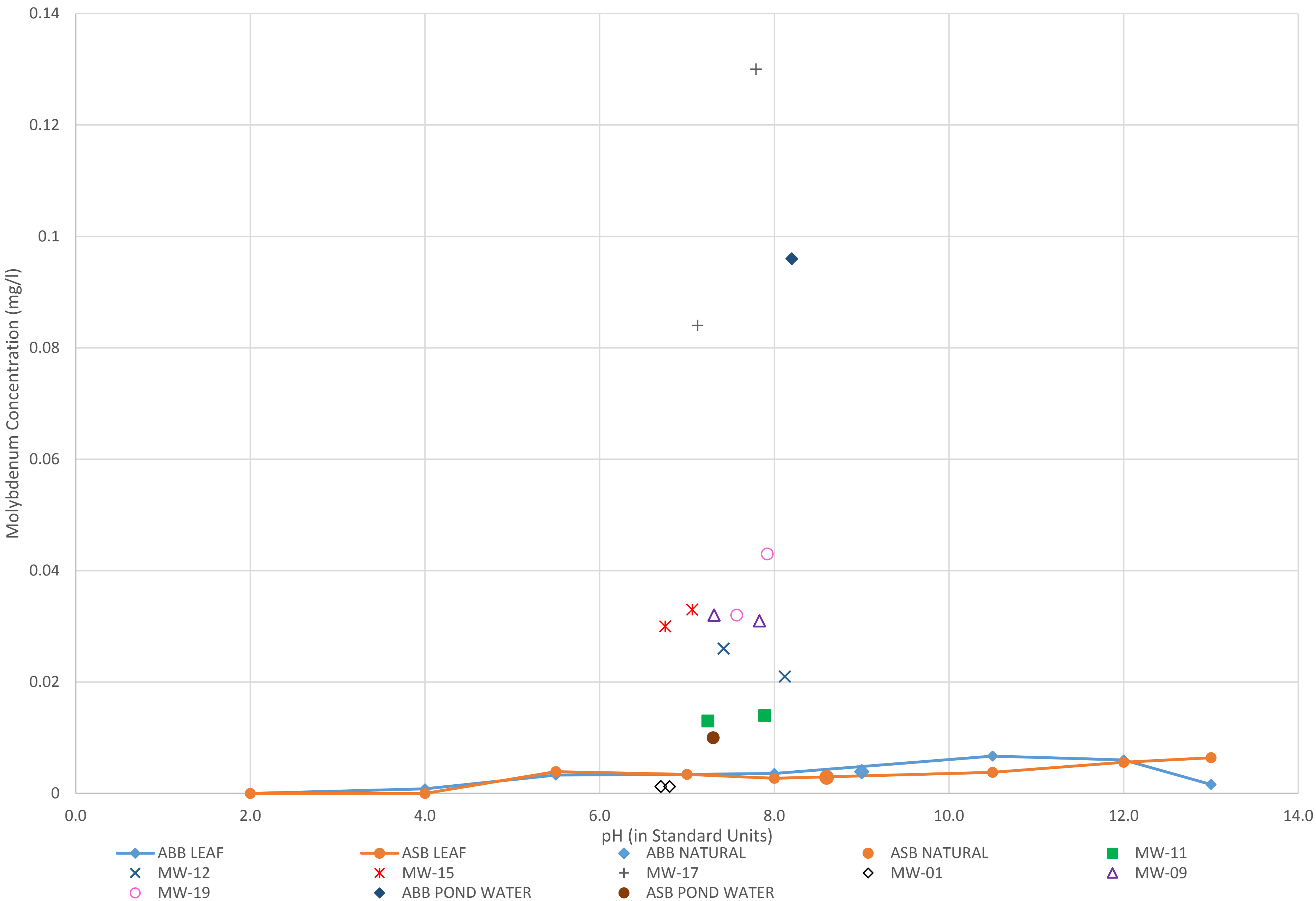


Figure 3a. Barium Concentration vs. pH Value - Powerton Station (May/August 2018 Data)
Barium Concentration (mg/l)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
pH (in Standard Units)
ABB LEAF
ASB LEAF
ABB NATURAL
ASB NATURAL
MW-11
MW-12
MW-15
MW-17
MW-01
MW-09
MW-19
ABB POND WATER
ASB POND WATER

Figure 4. Molybdenum Concentration vs. pH Value - Powerton Station (May/August 2018 Data)



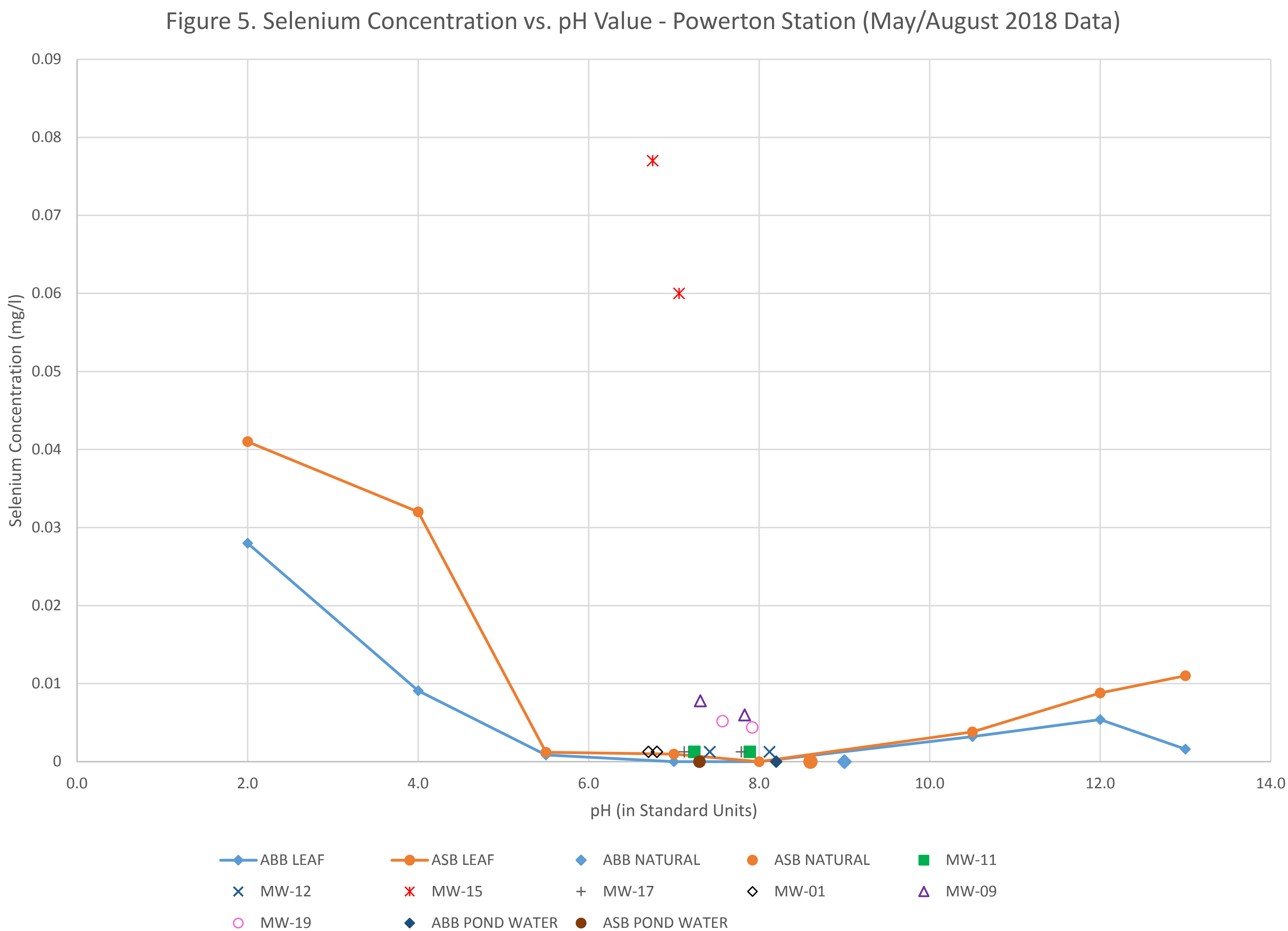
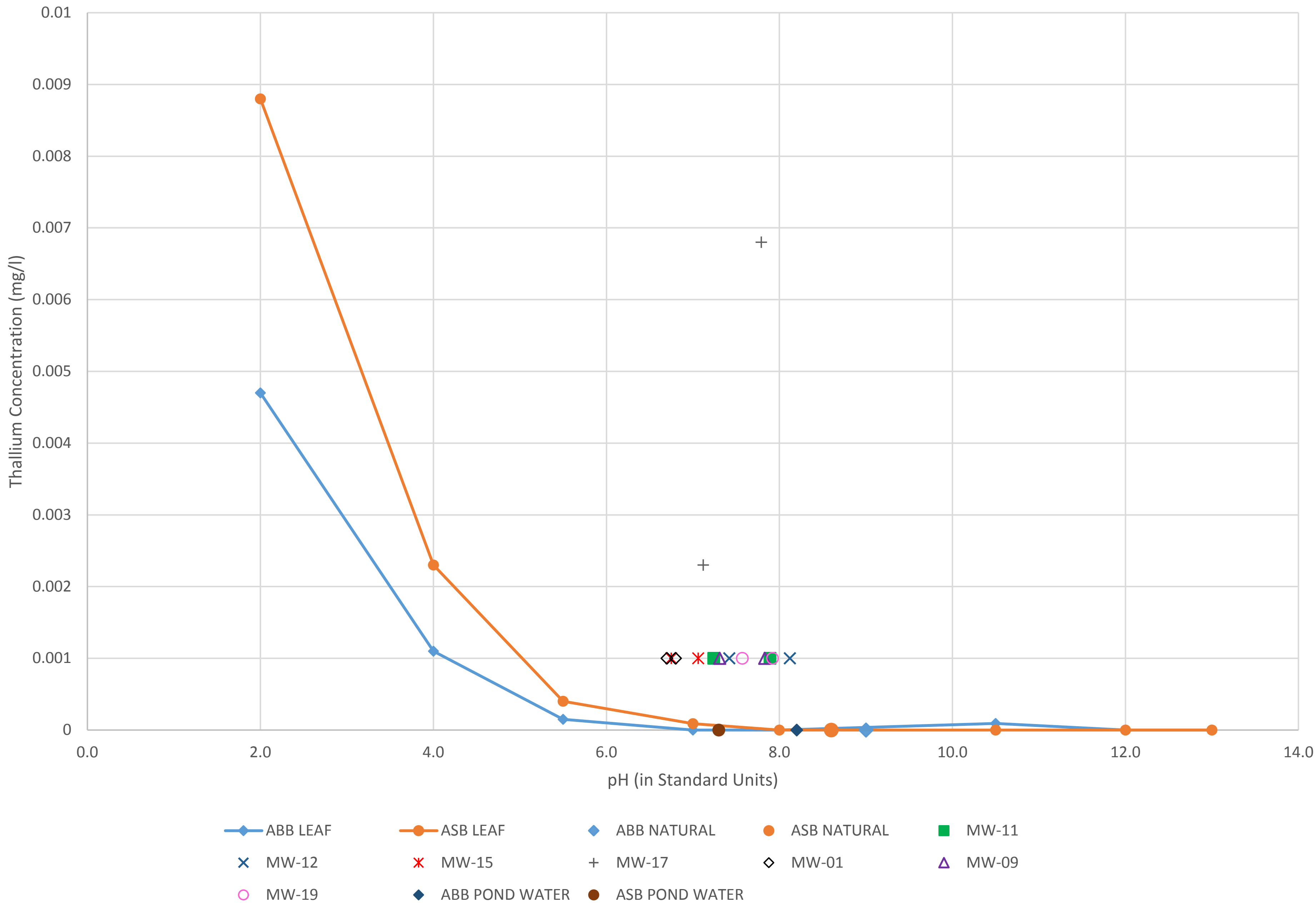


Figure 5. Selenium Concentration vs. pH Value - Powerton Station (May/August 2018 Data)
Selenium Concentration (mg/l)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
pH (in Standard Units)
ABB LEAF
ASB LEAF
ABB NATURAL
ASB NATURAL
MW-11
MW-12
MW-15
MW-17
MW-01
MW-09
MW-19
ABB POND WATER
ASB POND WATER

Figure 6. Thallium Concentration vs. pH Value - Powerton Station (May/August 2018 Data)



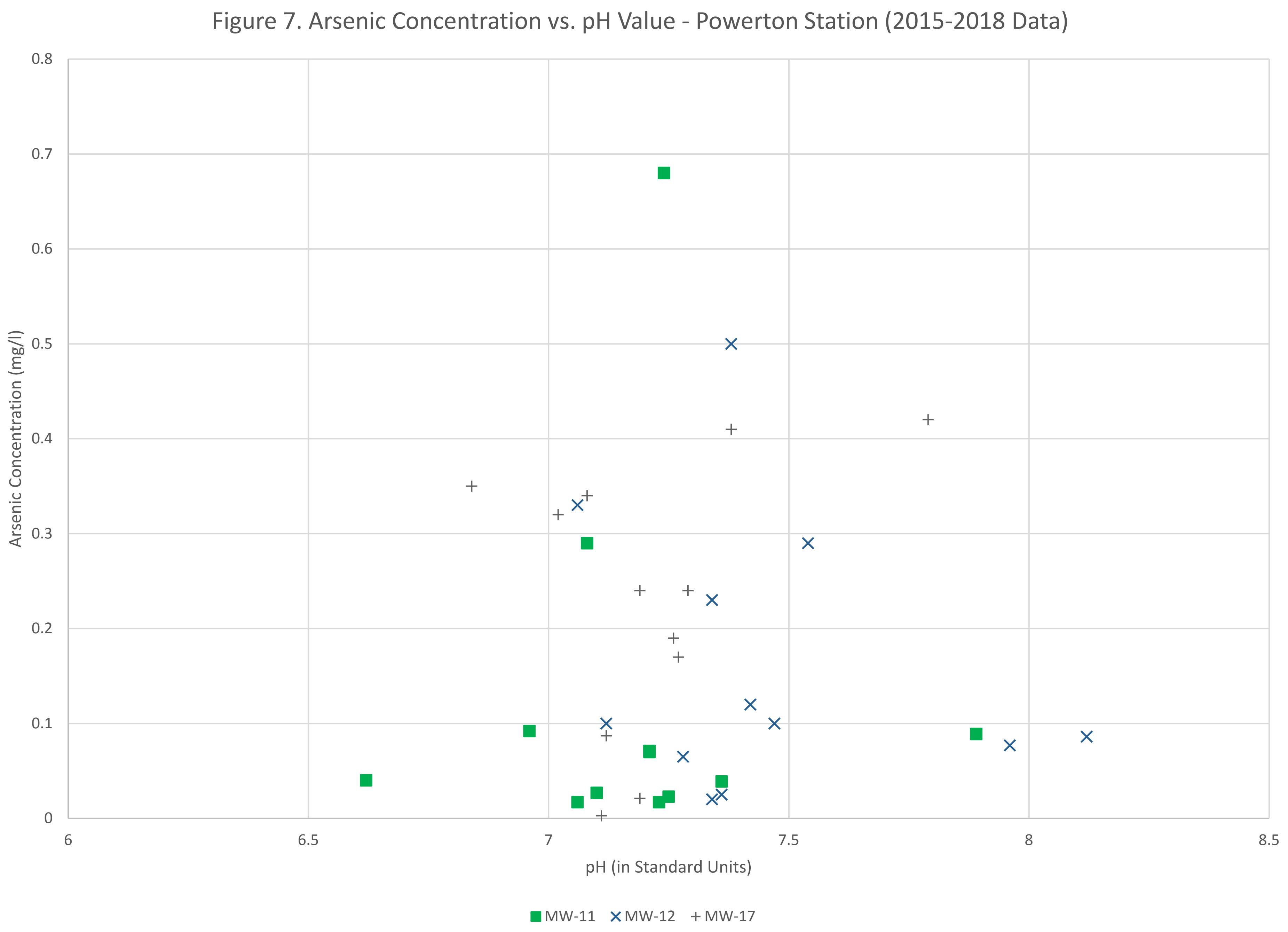


Figure 7. Arsenic Concentration vs. pH Value - Powerton Station (2015-2018 Data)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Arsenic Concentration (mg/l)
6
6.5
7
7.5
8
8.5
pH (in Standard Units)
MW-11
MW-12
MW-17

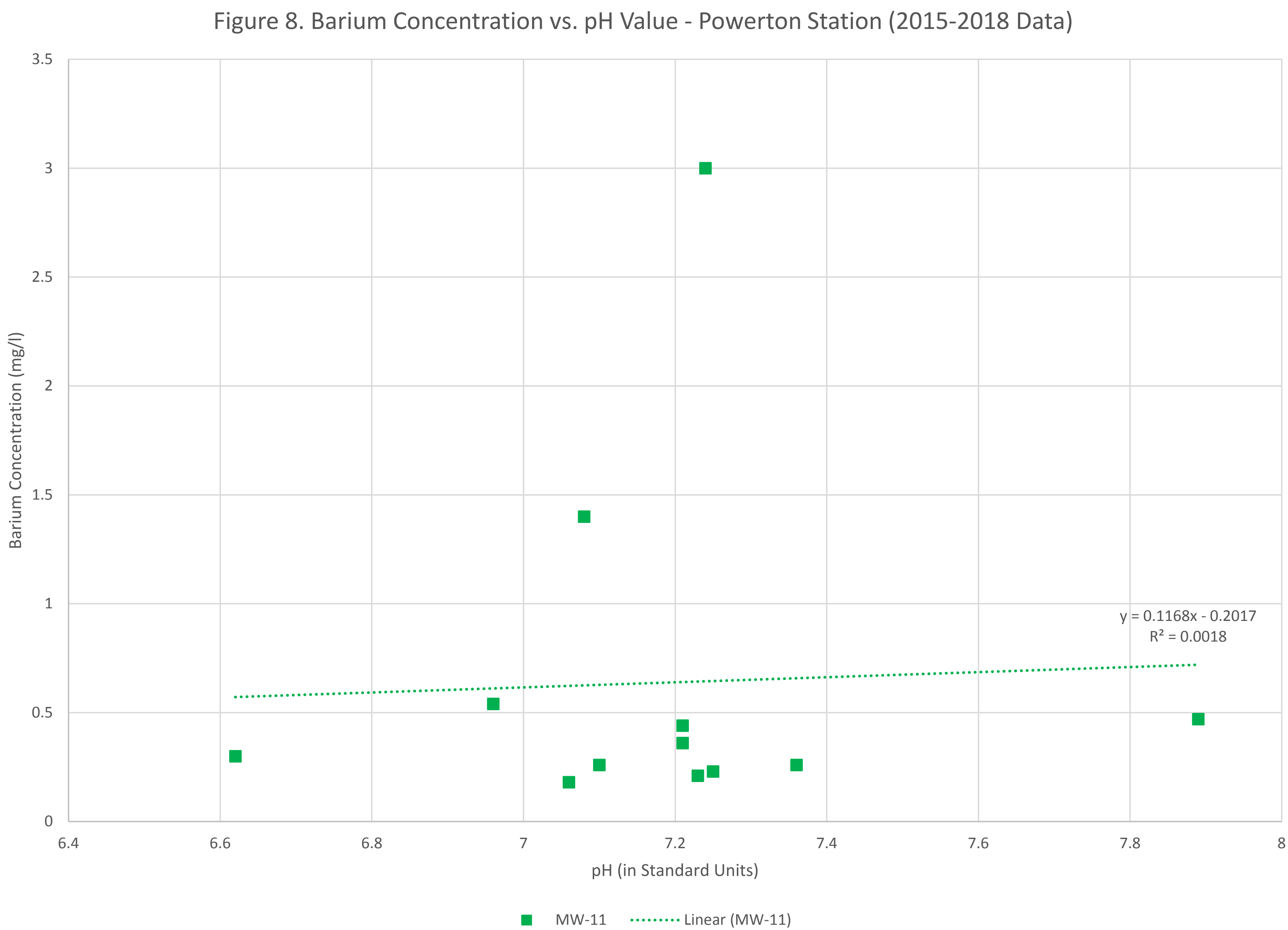


Figure 8. Barium Concentration vs. pH Value - Powerton Station (2015-2018 Data)
Barium Concentration (mg/l)
3.5
3
2.5
2
1.5
1
0.5
0
6.4
6.6
6.8
7
7.2
7.4
7.6
7.8
8
pH (in Standard Units)
y = 0.1168x - 0.2017
R² = 0.0018
MW-11
Linear (MW-11)

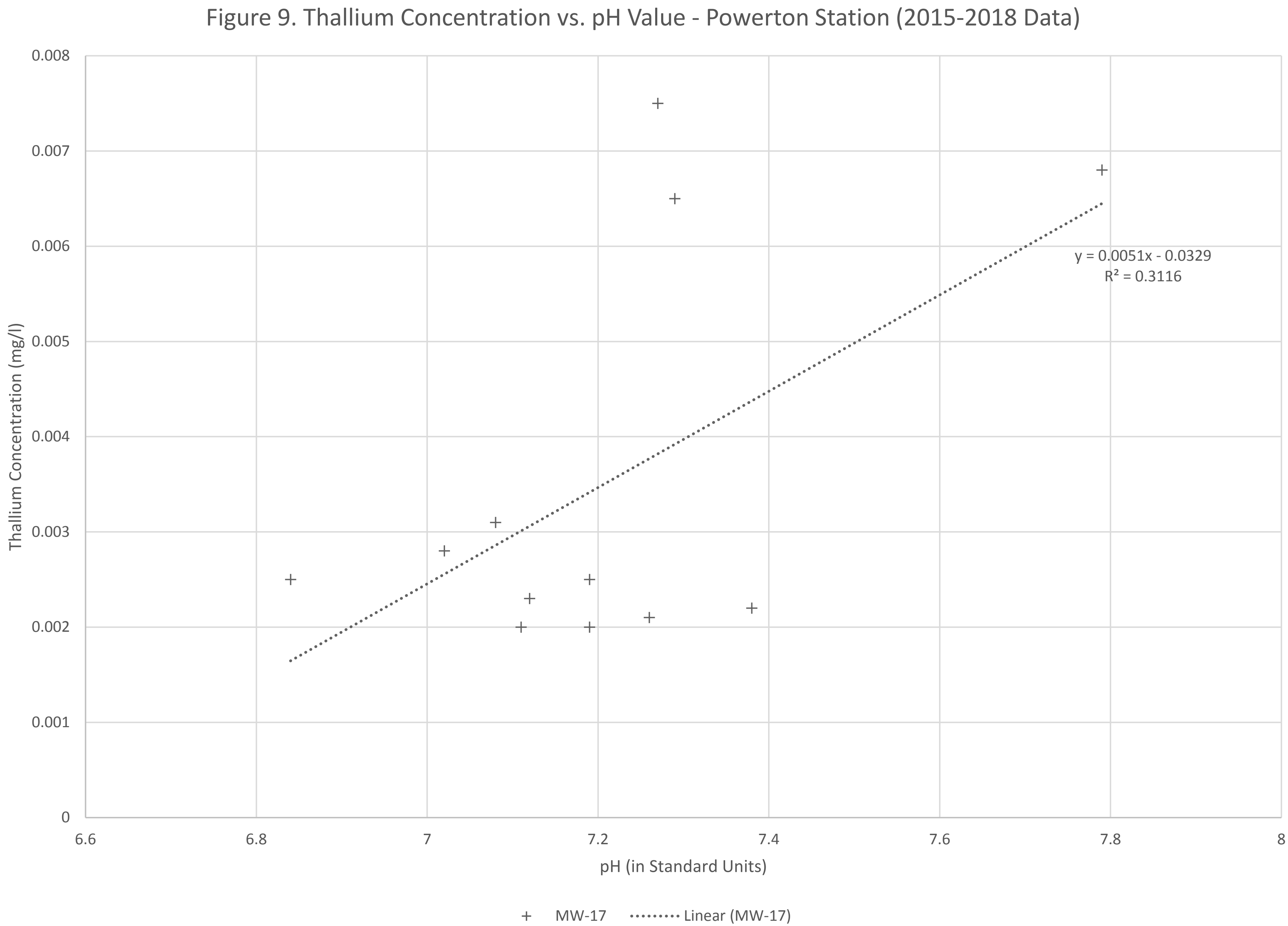


Figure 9. Thallium Concentration vs. pH Value - Powerton Station (2015-2018 Data)
Thallium Concentration (mg/l)
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
6.6
6.8
7
7.2
7.4
7.6
7.8
8
pH (in Standard Units)
y = 0.0051x - 0.0329
R² = 0.3116
MW-17
Linear (MW-17)

TABLES

Table 1. Basin Water Results - Midwest Generation Powerton Station, Pekin, Illinois

Sample:		Ash Bypass	Ash Surge
PARAMETER	UNITS	Basin (ABB) Water	Basin (ASB) Water
Antimony	mg/L	0.0014 J	0.0019 J
Arsenic	mg/L	0.0019	0.0032
Barium	mg/L	0.056	0.15
Beryllium	mg/L	<0.000057 ^	0.000069 J^
Cadmium	mg/L	<0.00013	<0.00013
Chromium	mg/L	0.0031	0.0036
Cobalt	mg/L	0.00014 J	0.00096
Fluoride	mg/L	1.8	0.46
Lead	mg/L	0.00028 J	0.00069 J
Lithium	mg/L	0.004 J	0.013
Mercury	mg/L	<0.000065	<0.000065
Molybdenum	mg/L	0.096	0.01
Combined Radium	pCi/L	<2.697	1.904
Selenium	mg/L	0.002 J	<0.00081
Thallium	mg/L	<0.000063	0.000091 J
pH	SU	8.2	7.3

Notes: Units are as noted.
J - Result is less than reporting limit but greater than or equal to method detection limit. Concentration is approximate value.
^ - Instrument related QC is outside acceptance limits

Table 2. LEAF Test Results from Ash Samples - Midwest Generation Powerton Station, Pekin, Illinois

Sample: ABB ASH		LEAF TEST TARGETED pH VALUES								
PARAMETER	UNITS	13.0	12.0	10.5	8.0	7.0	5.5	4.0	2.0	Natural*
Antimony	mg/L	<0.0011	0.0021	0.002	<0.0011	<0.0011	<0.0011	<0.0011	<0.011	<0.0011
Arsenic	mg/L	0.0055	0.015	0.01	0.0022	0.0023	0.0011	0.0035	0.04	0.0048
Barium	mg/L	0.15	0.44	0.39	0.34	0.84	2.6	6.9	300	0.35
Beryllium	mg/L	0.00014 J	0.00032 J	0.00018 J	<0.000057	<0.000057	<0.000057	0.016	0.16	0.00011 J
Cadmium	mg/L	0.0002 J	0.00037 J	0.00035 J	<0.00013	<0.00013	0.00055 J	0.012	0.017	0.00018 J
Chromium	mg/L	0.0047	0.017	0.013	0.0019 J	0.0017 J	0.0017 J	0.029	2.4	0.0085
Cobalt	mg/L	0.0016	0.0036	0.0029	0.000095 J	0.00023 J	0.0067	0.16	1.3	0.0014
Fluoride	mg/L	0.62	0.88	0.95 J	0.72	0.58	<0.13	3.4	<1.3	1.4
Lead	mg/L	0.0021 B	0.0058 B	0.0039	<0.000094	<0.000094	<0.000094	0.0045	0.18	0.0033 B
Lithium	mg/L	<0.0026	0.0038 J	0.003 J	0.005	0.0074	0.034	0.31	2.8	0.0034 J
Mercury	mg/L	<0.000065	0.000082 J	<0.000065	<0.000065	<0.000065	<0.000065	<0.000065	0.00097	<0.000065
Molybdenum	mg/L	0.0016 J	0.006	0.0067	0.0036 J	0.0034 J	0.0033 J	0.00083 J	<0.0047	0.0039 J
ORP	millivolts	-166	-25	96	170	210	240	350	590	310
pH	SU	12.7	11.5	10.8	7.9	7.2	5.9	3.8	2.2	9.0
Combined Radium	pCi/L	2.424 UG	2.334 UG	2.078 UG	0.906 U	0.86 U	0.911	1.828	224.1	0.911 U
Selenium	mg/L	0.0016 J	0.0054	0.0032 J	<0.00081	<0.00081	0.00085 J	0.0091	0.028 J	<0.00081
Specific Conductance	umhos/cm	20000	1200	590	650	1300	4400	14000	78000	210
Thallium	mg/L	<0.000063	<0.000063	0.000091 J	<0.000063	<0.000063	0.00015 J	0.0011	0.0047 J	<0.000063

Sample: ASB ASH		LEAF TEST TARGETED pH VALUES								
PARAMETER	UNITS	13.0	12.0	10.5	8.0	7.0	5.5	4.0	2.0	Natural*
Antimony	mg/L	0.0041	0.0032	0.0022	0.0011 J	0.0011 J	<0.0011	<0.011	<0.011	0.0013 J
Arsenic	mg/L	0.03	0.023	0.012	0.0023	0.0042	0.0021	0.014	0.042	0.0033
Barium	mg/L	0.029	0.03	0.044	0.27	1.3	2.1	3.8	50	0.15
Beryllium	mg/L	<0.000057	<0.000057	<0.000057	<0.000057	<0.000057	<0.000057	0.022	0.15	<0.000057
Cadmium	mg/L	<0.00013	<0.00013	<0.00013	<0.00013	<0.00013	0.0016	0.029	0.037	<0.00013
Chromium	mg/L	0.0032	0.0039	0.0041	0.0018 J	0.0016 J	0.0017 J	0.021 B	0.7	0.002
Cobalt	mg/L	0.00097	0.00039 J	0.00021 J	0.000081 J	0.00059	0.033	0.36	1.2	<0.000075
Fluoride	mg/L	0.62	2.0	1.2	0.41	0.29	<0.26	7.9	1.9 J	0.45
Lead	mg/L	0.00043 JB	0.00024 JB	0.00019 JB	<0.000094	<0.000094	<0.000094	0.0059 J	0.2	<0.000094
Lithium	mg/L	<0.0026	<0.0026	<0.0026	0.014	0.035	0.14	0.52	2.4	0.0097
Mercury	mg/L	<0.000065	<0.000065	<0.000065	<0.000065	<0.000065	<0.000065	<0.000065	<0.000065	<0.000065
Molybdenum	mg/L	0.0064	0.0056	0.0038 J	0.0027 J	0.0034 J	0.0039 J	<0.0047	<0.0047	0.0029 J
ORP	millivolts	-86	-24	45	160	210	240	360	550	180
pH	SU	12.7	12.4	10.8	8.3	7.4	5.7	4.1	2.4	8.6
Combined Radium	pCi/L	1.05	0.913 U	0.894 U	0.784 U	0.943	1.334 G	NR	NR	0.874 U
Selenium	mg/L	0.011	0.0088	0.0038 J	<0.00081	0.00096 J	0.0012 J	0.032 J	0.041 J	<0.00081
Specific Conductance	umhos/cm	16000	6200	760	720	4200	15000	26000	77000	300
Thallium	mg/L	<0.000063	<0.000063	<0.000063	<0.000063	0.000088 J	0.0004 J	0.0023 J	0.0088 J	<0.000063

Notes: Units are as noted.
ORP - Oxidation Reduction Potential
ABB - Ash By-pass Basin
ASB - Ash Surge Basin
G - The sample MDC is greater than the requested RL
U - Undetected.
NR - Lab unable to obtain result due to matrix interference.
MDC - Minimum Detectable Concentration (radiochemistry)

Natural - pH of ash as measured in the laboratory prior to any pH test modifications.
J - Result is less than reporting limit but greater than or equal to method detection limit. Concentration is approximate value.
^ - Instrument related QC is outside acceptance limits

ATTACHMENT 1

Statistical Data Evaluation Tables – December 26, 2018

Table 4. ASB/ABB Assessment Monitoring - Appendix III Groundwater Analytical Results through 2018 - Midwest Generation, LLC, Powerton Station, Pekin, IL.

Well	Date	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
MW-01 (S) up-gradient	11/16/2015	1.0	98	44	0.17	7.07	93	530
	2/25/2016	0.2	110	42	0.16	7.23	54	460
	5/20/2016	0.34	100	44	0.17	6.95	65	430
	8/17/2016	0.27	78	39	0.25	7.16	50	530
	11/16/2016	0.18	97	39	0.21	7.22	32	500
	2/14/2017	0.18	120	55	0.17	7.30	60	550
	5/3/2017	0.19	86	66	0.16	7.41	45	460
	6/21/2017	0.18	85	58	0.18	7.60	47	540
	Pred. Limit*	**1.0**	**142**	**81**	**0.25**	**7.90-6.58**	**115**	**648**
	8/25/2017	0.56	86	41	0.18	7.41	63	490
	11/8/2017	0.57	130	38	0.12	6.69	61	640
	5/17/2018	0.15	88	50	0.12	6.7	48	540
	8/8/2018	0.14	86	48	0.13	6.80	43	430
MW-09 (S) up-gradient	11/18/2015	2.0	63	H 31	H 0.19	7.15	H 110	H 440
	2/25/2016	2.3	77	36	0.19	7.34	120	500
	5/19/2016	2.0	73	38	0.17	7.30	100	520
	8/17/2016	2.7	74	39	0.15	7.32	120	750
	11/17/2016	4.5	85	38	0.13	7.37	110	630
	2/15/2017	4.1	84	38	0.13	6.94	160	620
	5/3/2017	3.5	85	38	0.17	7.48	170	680
	6/21/2017	3.3	82	38	0.14	7.63	180	760
	Pred. Limit*	**6.19**	**103**	**39**	**0.24**	**7.99-6.64**	**236**	**1000**
	8/25/2017	3.8	85	36	0.14	7.30	150	630
	11/8/2017	4	89	37	0.13	6.92	190	650
	5/16/2018	4.1	89	36	0.15	7.83	180	550
	8/8/2018	4.3	86	39	0.14	7.31	180	690
MW-19^ (S) up-gradient	11/18/2016	3.8	89	38	0.13	7.34	120	670
	2/15/2017	4.7	88	37	0.13	7.50	180	630
	5/5/2017	3.3	88	38	0.14	7.51	160	640
	6/21/2017	2.3	110	35	0.12	7.30	170	690
	8/28/2017	3.5	97	36	0.16	7.20	160	700
	11/6/2017	4.5	86	35	0.17	7.26	190	640
	5/14/2018	4.1	96	35	0.16	7.92	180	820
	8/6/2018	3.8	100	37	0.13	7.57	170	720
	Pred. Limit*	**6.20**	**121**	**41**	**0.20**	**8.20-6.70**	**236**	**890**
MW-08 (CL) down-gradient	11/18/2015	1.5	160	H 170	H 0.44	7.61	H 470	H 1300
	2/25/2016	1.7	160	200	0.30	7.00	280	1100
	5/18/2016	1.7	160	140	0.34	7.67	300	1200
	8/17/2016	1.0	150	230	0.35	7.33	360	1400
	11/15/2016	1.2	140	290	0.33	6.90	230	1300
	2/16/2017	1.5	150	460	0.28	7.00	230	1500
	5/2/2017	0.55	140	300	0.33	7.30	320	1300
	6/21/2017	1.2	160	490	0.30	7.27	350	1700
	Pred. Limit	**1.0**	**136**	**77**	**0.24****	**7.73-6.83****	**107**	**788****
	8/29/2017	**1.2**	**150**	**360**	**0.47**	7.29	**300**	**1500**
	11/8/2017	**0.68**	130	**260**	**0.45**	7.27	**270**	**1200**
	5/17/2018	**1.2**	130	**200**	**0.37**	6.79	**170**	**1000**
	8/8/2018	**1.1**	**140**	**270**	**0.32**	6.93	**190**	**1200**

Notes: All units are in mg/l except pH is in standard units.
Pred. Limit - Prediction Limit
(S) - Sandy Unit
(CL) - Silty Clay Unit
* - Intrawell Prediction Limit. All others are interwell comparisons.
** - Based on pooled background from MW-01/MW-09. All others based on MW-01 as background.
^ - Recently installed upgradient well. Insufficient rounds of sampling for statistical evaluation at this time.
Italics Date - First round of Detection Monitoring and resample after statistical background establishment.

Bold - Potential statistically significant increase.
F1 - MS and/or MSD Recovery outside of limits.
H - Sample was prepped or analyzed beyond the specified holding time.
V- Serial dilution exceeds control limits.

Table 4. ASB/ABB Assessment Monitoring - Appendix III Groundwater Analytical Results through 2018 - Midwest Generation, LLC, Powerton Station, Pekin, IL.

Well	Date	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
MW-11 (S) down-gradient	11/18/2015	1.7	110	H 54	H 0.55	7.06	H 160	H 670
	2/26/2016	1.5	140	120	0.55	7.25	220	850
	5/20/2016	1.6	140	120	0.56	7.10	210	920
	8/17/2016	1.0	130	93	0.67	7.08	180	910
	11/17/2016	1.2	140	130	0.44	7.21	240	1100
	2/16/2017	1.6	140	110	0.40	6.62	260	910
	5/3/2017	1.3	160	160	0.42	7.36	440	1300
	6/22/2017	1.2	140	120	0.60	7.21	260	1000
	Pred. Limit	**1.0**	**136**	**77**	**0.24****	**7.73-6.83****	**107**	**788****
	8/29/2017	**2.2**	130	**83**	**0.52**	7.23	**310**	**1100**
	11/9/2017	**1.5**	**140**	**100**	**0.59**	6.96	**230**	**970**
	5/16/2018	**2.0**	**140**	**88**	**0.61**	**7.89**	**270**	**1000**
	8/9/2018	**1.4**	**160**	**120**	**0.65**	7.24	**220**	**1000**
MW-12 (CL) down-gradient	11/19/2015	0.94	160	H 220	H 0.57	7.12	H 650	H 1400
	2/26/2016	0.42	130	200	0.40	7.96	530	1200
	5/20/2016	0.65	150	200	0.49	7.28	550	1400
	8/18/2016	0.69	170	200	0.49	7.06	620	1600
	11/18/2016	0.83	140	180	0.46	7.34	340	1300
	2/16/2017	0.48	140	190	0.37	7.54	630	1300
	5/3/2017	0.49	120	190	0.37	7.47	500	1200
	6/22/2017	0.50	130	190	0.48	7.36	580	1400
	Pred. Limit	**1.0**	**136**	**77**	**0.24****	**7.73-6.83****	**107**	**788****
	8/29/2017	0.78	**140**	**180**	**0.52**	7.34	**520**	**1400**
	11/10/2017	0.94	**130**	**170**	**0.48**	7.38	**370**	**1200**
	5/16/2018	0.46	**100**	**180**	**0.47**	**8.12**	**720**	**1500**
	8/9/2018	0.61	120	**190**	**0.44**	7.42	**480**	**1300**
MW-15 (CL) down-gradient	11/18/2015	1.5	270	H 210	H 0.53	6.55	H 1400	H 2400
	2/25/2016	2.0	240	110	0.61	6.84	640	1700
	5/19/2016	2.7	320	240	0.53	6.83	1200	2800
	8/18/2016	1.5	200	F1 170	0.54	6.96	660	1900
	11/17/2016	1.3	120	180	0.47	6.91	560	1900
	2/17/2017	1.9	200	190	0.43	7.24	670	1700
	5/4/2017	1.5	180	190	0.57	7.35	670	1700
	6/21/2017	1.6	180	200	0.56	7.30	530	1600
	Pred. Limit	**1.0**	**136**	**77**	**0.24****	**7.73-6.83****	**107**	**788****
	8/29/2017	**2.2**	**190**	**200**	**0.53**	6.87	**540**	**1800**
	11/10/2017	**1.6**	**170**	**180**	**0.63**	7.09	**530**	**1500**
	5/17/2018	**2.3**	**200**	**160**	**0.5**	**6.75**	**680**	**1800**
	8/9/2018	**2.3**	**200**	**200**	**0.48**	7.06	**520**	**1700**
MW-17 (CL) down-gradient	11/19/2015	1.6	210	H 230	H 0.43	7.11	H 850	H 1800
	2/22/2016	1.8	290	280	0.55	7.19	960	2100
	5/18/2016	1.4	200	230	0.64	7.02	700	1800
	8/15/2016	1.1	220	220	0.60	7.08	860	2100
	11/14/2016	1.5	200	210	0.56	7.26	560	2000
	2/13/2017	1.6	190	230	0.56	6.84	770	1600
	5/4/2017	1.2	170	210	0.61	7.29	720	1500
	6/22/2017	0.95	150	230	0.72	7.38	580	1600
	Pred. Limit	**1.0**	**136**	**77**	**0.24****	**7.73-6.83****	**107**	**788****
	8/29/2017	**1.4**	**190**	**230**	**0.64**	7.19	**640**	**1900**
	11/6/2017	**1.7**	**190**	**240**	**0.62**	7.27	**840**	**1800**
	5/14/2018	**1.6**	**170**	**220**	**0.6**	**7.79**	**800**	**1700**
	8/6/2018	**1.3**	**170**	**230**	**0.6**	7.12	**620**	**1600**
MW-18 (S) down-gradient	11/19/2015	0.80	140	H 220	H 0.66	7.62	H 310	H 1200
	2/22/2016	0.76	150	220	0.68	7.06	310	1200
	5/18/2016	0.72	120	230	0.71	7.68	230	1200
	8/15/2016	0.67	130	210	0.64	7.52	330	1300
	11/18/2016	0.94	130	200	0.58	7.69	250	1300
	2/15/2017	0.56	140	190	0.50	7.81	340	1200
	5/5/2017	0.46	130	180	0.52	8.12	360	1100
	6/21/2017	0.53	120	190	0.51	8.10	320	1200
	Pred. Limit	**1.00**	**136**	**77**	**0.24****	**7.73-6.83****	**107**	**788****
	8/28/2017	0.65	120	**200**	**0.53**	**7.81**	**310**	**1200**
	11/6/2017	0.67	120	**190**	**0.57**	**7.74**	**400**	**1200**
	5/14/2018	0.57	130	**180**	**0.59**	**8.27**	**440**	**1200**
	8/6/2018	0.58	120	**230**	**0.57**	**7.88**	**270**	**1100**

Notes: All units are in mg/l except pH is in standard units.
Pred. Limit - Prediction Limit
(S) - Sandy Unit
(CL) - Silty Clay Unit
* - Intrawell Prediction Limit. All others are interwell comparisons.
** - Based on pooled background from MW-01/MW-09. All others based on MW-01 as background.
^ - Recently installed upgradient well. Insufficient rounds of sampling for statistical evaluation at this time.
Italics Date - First round of Detection Monitoring and resample after statistical background establishment.

Bold - Potential statistically significant increase.
F1 - MS and/or MSD Recovery outside of limits.
H - Sample was prepped or analyzed beyond the specified holding time.
V- Serial dilution exceeds control limits.

Table 5. ASB/ABB Assessment Monitoring - Detected Appendix IV Groundwater Analytical Results through 2018 - Midwest Generation, LLC, Powerton Station, Pekin, IL.

Well	Date	Arsenic	Barium	Cadmium	Cobalt	Fluoride	Lead	Lithium	Mercury	Molybdenum	Radium 226 + 228 Combined	Selenium	Thallium
MW-01 up-gradient	11/16/2015	< 0.001	0.057	< 0.0005	< 0.001	0.17	* < 0.0005	< 0.01	< 0.0002	< 0.0050	0.744	< 0.0025	* < 0.002
	2/25/2016	0.0025	0.053	< 0.0005	0.0014	0.16	0.0019	< 0.01	< 0.0002	< 0.005	< 0.722	0.0029	< 0.002
	5/20/2016	0.0081	0.062	< 0.0005	0.0053	0.17	0.011	< 0.01	< 0.0002	< 0.005	< 0.953	< 0.0025	< 0.002
	8/17/2016	0.0014	0.048	< 0.0005	< 0.001	0.25	0.0014	< 0.010	< 0.0002	0.0057	< 0.491	< 0.0025	< 0.002
	11/16/2016	0.0051	0.056	< 0.0005	0.0044	0.21	0.0082	< 0.01	< 0.0002	0.0059	< 0.618	< 0.0025	< 0.002
	2/14/2017	0.0041	0.056	< 0.0005	0.0045	0.17	0.0076	< 0.01	< 0.0002	0.0056	< 0.837	< 0.0025	< 0.002
	5/3/2017	0.0015	0.045	< 0.0005	0.0033	0.16	0.0067	< 0.01	< 0.0002	< 0.005	0.574	< 0.0025	< 0.002
	6/21/2017	< 0.001	0.04	< 0.0005	< 0.001	0.18	< 0.0005	< 0.01	< 0.0002	0.0061	< 0.418	< 0.0025	< 0.002
	8/25/2017	< 0.001	0.049	< 0.0005	< 0.001	0.18	< 0.0005	< 0.01	< 0.0002	0.0059	0.775	< 0.0025	< 0.002
	11/8/2017	< 0.001	0.083	< 0.0005	< 0.001	0.12	< 0.0005	< 0.01	< 0.0002	< 0.005	0.343	< 0.0025	< 0.002
	GWPS	**0.011**	**2.0**	**0.005**	**0.009**	**4.0**	**0.018**	**0.04**	**0.002**	**0.10**	**5.0**	**0.05**	**0.002**
	5/17/2018	< 0.001	0.045	< 0.0005	< 0.001	0.12	0.00068	< 0.01	< 0.0002	< 0.005	< 0.396	< 0.0025	< 0.002
	8/8/2018	< 0.001	0.051	< 0.0005	< 0.001	0.13	< 0.0005	< 0.01	< 0.0002	< 0.005	0.579	< 0.0025	< 0.002
MW-09 up-gradient	11/18/2015	< 0.001	0.027	< 0.0005	< 0.001	H 0.19	< 0.0005	< 0.01	H < 0.0002	0.043	< 0.655	< 0.0025	< 0.002
	2/25/2016	0.0042	0.036	< 0.0005	0.0011	0.19	< 0.0005	< 0.01	< 0.0002	0.053	< 0.361	< 0.0025	< 0.002
	5/19/2016	< 0.001	0.029	< 0.0005	< 0.001	0.17	< 0.0005	< 0.01	< 0.0002	0.042	< 0.394	0.0032	< 0.002
	8/17/2016	< 0.001	0.031	< 0.0005	< 0.001	0.15	< 0.0005	< 0.01	< 0.0002	0.036	< 0.498	< 0.0025	< 0.002
	11/17/2016	0.0038	0.039	< 0.0005	< 0.001	0.13	< 0.0005	< 0.010	< 0.0002	0.036	0.646	0.0025	< 0.002
	2/15/2017	0.0032	0.043	< 0.0005	< 0.001	0.13	< 0.0005	< 0.010	< 0.0002	0.035	< 0.377	0.0062	< 0.002
	5/3/2017	0.0012	0.034	< 0.0005	< 0.001	0.17	< 0.0005	< 0.010	< 0.0002	0.034	< 0.445	0.011	< 0.002
	6/21/2017	< 0.001	0.037	< 0.0005	< 0.001	0.14	< 0.0005	< 0.010	< 0.0002	0.033	< 0.380	0.0072	< 0.002
	8/25/2017	< 0.001	0.044	< 0.0005	< 0.001	0.14	< 0.0005	< 0.010	< 0.0002	0.028	< 0.160	0.0043	< 0.002
	11/8/2017	0.0012	0.048	< 0.0005	< 0.001	0.13	< 0.0005	< 0.010	< 0.0002	0.026	0.344	< 0.0025	< 0.002
	GWPS	**0.011**	**2.0**	**0.005**	**0.009**	**4.0**	**0.018**	**0.04**	**0.002**	**0.10**	**5.0**	**0.05**	**0.002**
	5/16/2018	< 0.001	0.038	< 0.0005	< 0.001	0.15	< 0.0005	< 0.010	0.00029	0.031	< 0.424	0.006	< 0.002
	8/8/2018	< 0.001	0.037	< 0.0005	< 0.001	0.14	< 0.0005	< 0.010	< 0.0002	0.032	0.440	0.0078	< 0.002
MW-19 up-gradient	11/18/2016	< 0.001	0.084	< 0.0005	0.001	0.13	0.00068	< 0.01	< 0.0002	0.035	< 0.476	0.0043	< 0.002
	2/15/2017	< 0.001	0.088	< 0.0005	< 0.001	0.13	0.00061	< 0.01	< 0.0002	0.046	< 0.482	0.0063	< 0.002
	5/5/2017	< 0.001	0.076	< 0.0005	0.0013	0.14	0.0012	< 0.01	< 0.0002	0.035	0.923	0.0068	< 0.002
	6/21/2017	< 0.001	0.089	< 0.0005	< 0.001	0.12	< 0.0005	< 0.01	< 0.0002	0.024	< 0.334	0.0028	< 0.002
	8/28/2017	< 0.001	0.073	< 0.0005	< 0.001	0.16	< 0.0005	< 0.01	< 0.0002	0.041	0.370	0.0035	< 0.002
	11/6/2017	< 0.001	0.071	< 0.0005	< 0.001	0.17	< 0.0005	< 0.01	< 0.0002	0.042	0.360	< 0.0025	< 0.002
	5/14/2018	< 0.001	0.079	< 0.0005	< 0.001	0.16	< 0.0005	< 0.01	< 0.0002	0.043	0.562	0.0044	< 0.002
	8/7/2018	< 0.001	0.078	< 0.0005	< 0.001	0.13	< 0.0005	< 0.01	< 0.0002	0.032	0.835	0.0052	< 0.002
	GWPS	**0.011**	**2.0**	**0.005**	**0.009**	**4.0**	**0.018**	**0.04**	**0.002**	**0.10**	**5.0**	**0.05**	**0.002**
MW-08 down-gradient	11/18/2015	0.0029	0.15	< 0.0005	< 0.001	H 0.44	< 0.0005	0.028	H < 0.0002	0.01	< 0.559	< 0.0025	< 0.002
	2/25/2016	0.0018	0.11	0.00052	< 0.001	0.30	0.00072	0.015	< 0.0002	0.02	0.535	< 0.0025	< 0.002
	5/18/2016	0.0029	0.16	< 0.0005	< 0.001	0.34	< 0.0005	0.036	< 0.0002	0.0069	0.417	< 0.0025	< 0.002
	8/17/2016	0.0032	0.15	< 0.0005	< 0.001	0.35	< 0.0005	0.023	< 0.0002	0.013	< 0.519	< 0.0025	< 0.002
	11/15/2016	0.0012	0.076	< 0.0005	< 0.001	0.33	< 0.0005	0.017	< 0.0002	0.016	0.583	< 0.0025	< 0.002
	2/16/2017	0.003	0.086	< 0.0005	< 0.001	0.28	0.00087	< 0.01	< 0.0002	0.026	< 0.375	< 0.0025	< 0.002
	5/2/2017	0.0029	0.13	< 0.0005	< 0.001	0.33	< 0.0005	0.022	< 0.0002	0.0083	< 0.480	< 0.0025	< 0.002
	6/21/2017	0.0045	0.14	< 0.0005	< 0.001	0.30	< 0.0005	0.017	< 0.0002	0.031	< 0.439	< 0.0025	< 0.002
	8/29/2017	0.0011	0.062	< 0.0005	< 0.001	0.47	< 0.0005	< 0.01	< 0.0002	0.034	0.699	< 0.0025	< 0.002
	11/8/2017	0.0027	0.10	< 0.0005	< 0.001	0.45	< 0.0005	0.019	< 0.0002	0.014	0.806	< 0.0025	< 0.002
	GWPS	**0.011**	**2.0**	**0.005**	**0.009**	**4.0**	**0.018**	**0.04**	**0.002**	**0.10**	**5.0**	**0.05**	**0.002**
	5/17/2018	0.003	0.07	< 0.0005	< 0.001	0.37	< 0.0005	< 0.01	< 0.0002	0.024	0.655	< 0.0025	< 0.002
	8/8/2018	0.0055	0.071	< 0.0005	< 0.001	0.32	< 0.0005	< 0.01	< 0.0002	0.019	< 0.410	< 0.0025	< 0.002

Notes:

All units are in mg/l except Radium is in pCi/L as noted.

Italics - Assessment Monitoring Conducted After Identification of Detected Appendix IV Compounds.

GWPS - Groundwater Protection Standard based on Table 2 and discussion in text

BOLD - Above established GWPS.

F1 - MS and/or MSD Recovery outside of limits.

H - Sample was prepped or analyzed beyond the specified holding time.

* - LCS or LCSD is outside acceptance limits.

^ - Denotes instrument related QC exceeds the control limits

Table 5. ASB/ABB Assessment Monitoring - Detected Appendix IV Groundwater Analytical Results through 2018 - Midwest Generation, LLC, Powerton Station, Pekin, IL.

Well	Date	Arsenic	Barium	Cadmium	Cobalt	Fluoride	Lead	Lithium	Mercury	Molybdenum	Radium 226 + 228 Combined	Selenium	Thallium
MW-11 down-gradient	11/18/2015	0.017	0.18	< 0.0005	0.002	H 0.55	< 0.0005	< 0.01	H < 0.0002	0.0120	0.788	< 0.0025	< 0.002
	2/26/2016	0.023	0.23	< 0.0005	0.0023	0.55	< 0.0005	< 0.01	< 0.0002	0.013	0.562	< 0.0025	< 0.002
	5/20/2016	0.027	0.26	< 0.0005	0.0024	0.56	0.00076	< 0.01	< 0.0002	0.014	0.524	< 0.0025	< 0.002
	8/17/2016	F1 0.29	1.4	< 0.0005	0.0034	0.67	0.001	< 0.010	< 0.0002	0.011	1.130	< 0.0025	< 0.002
	11/17/2016	0.071	0.44	< 0.0005	0.0037	0.44	0.0013	< 0.01	< 0.0002	0.0088	0.734	< 0.0025	< 0.002
	2/16/2017	0.04	0.3	< 0.0005	0.003	0.40	0.00094	< 0.01	< 0.0002	0.013	0.341	< 0.0025	< 0.002
	5/3/2017	0.039	0.26	< 0.0005	0.0035	0.42	0.00093	< 0.01	< 0.0002	0.015	0.662	< 0.0025	< 0.002
	6/22/2017	0.07	0.36	< 0.0005	0.0025	0.60	< 0.0005	< 0.01	< 0.0002	0.014	< 0.418	< 0.0025	< 0.002
	8/29/2017	0.017	0.21	< 0.0005	0.0026	0.52	< 0.0005	< 0.01	< 0.0002	0.016	< 0.313	< 0.0025	< 0.002
	11/9/2017	0.092	0.54	< 0.0005	0.0034	0.59	< 0.0005	< 0.01	< 0.0002	0.014	1.24	< 0.0025	< 0.002
	GWPS	**0.011**	**2.0**	**0.005**	**0.009**	**4.0**	**0.018**	**0.04**	**0.002**	**0.10**	**5.0**	**0.05**	**0.002**
	5/16/2018	**0.089**	0.47	< 0.0005	0.0041	0.61	< 0.0005	< 0.01	< 0.0002	0.014	1.12	< 0.0025	< 0.002
	8/9/2018	**0.68**	**3.0**	0.00082	0.0053	0.65	0.0012	< 0.01	< 0.0002	0.013	1.48	< 0.0025	< 0.002
MW-12 down-gradient	11/19/2015	0.10	0.180	0.00068	< 0.001	H 0.57	0.00063	0.023	H < 0.0002	0.0280	< 0.685	< 0.0025	< 0.002
	2/26/2016	0.077	0.130	0.0016	< 0.001	0.40	0.0014	0.014	< 0.0002	0.0150	1.11	< 0.0025	< 0.002
	5/20/2016	0.065	0.16	0.00077	< 0.001	0.49	0.0016	0.013	< 0.0002	0.028	0.576	< 0.0025	< 0.002
	8/18/2016	0.33	0.88	0.007	0.001	0.49	0.0011	0.015	< 0.0002	0.011	3.68	< 0.0025	< 0.002
	11/18/2016	0.23	0.67	0.0028	< 0.001	0.46	< 0.0005	0.017	< 0.0002	< 0.01	1.86	< 0.0025	< 0.002
	2/16/2017	0.29	0.26	0.0057	0.0013	0.37	0.0042	0.010	< 0.0002	0.015	1.15	< 0.0025	< 0.002
	5/3/2017	0.10	0.17	0.0022	< 0.001	0.37	0.0038	0.011	< 0.0002	0.017	0.518	< 0.0025	< 0.002
	6/22/2017	0.025	0.11	< 0.0005	< 0.001	0.48	0.00096	< 0.010	< 0.0002	0.028	0.376	< 0.0025	< 0.002
	8/29/2017	0.02	0.095	< 0.0005	< 0.001	0.52	< 0.0005	0.014	< 0.0002	0.024	0.529	< 0.0025	< 0.002
	11/10/2017	0.50	0.45	0.0015	< 0.001	0.48	0.00097	0.018	< 0.0002	0.023	1.67	< 0.0025	< 0.002
	GWPS	**0.011**	**2.0**	**0.005**	**0.009**	**4.0**	**0.018**	**0.04**	**0.002**	**0.10**	**5.0**	**0.05**	**0.002**
	5/16/2018	**0.09**	0.1	0.00052	< 0.001	0.47	0.00067	0.012	< 0.0002	0.021	0.741	< 0.0025	< 0.002
	8/9/2018	**0.12**	0.15	0.00084	< 0.001	0.44	0.00072	< 0.010	< 0.0002	0.026	0.735	< 0.0025	< 0.002
MW-15 down-gradient	11/18/2015	0.03	0.096	0.00061	< 0.001	H 0.53	< 0.0005	0.042	H < 0.0002	0.023	< 0.599	0.0065	< 0.002
	2/25/2016	0.025	0.083	< 0.0005	< 0.001	0.61	< 0.0005	0.041	< 0.0002	0.035	0.870	0.045	< 0.002
	5/19/2016	0.04	0.097	0.00098	< 0.001	0.53	< 0.0005	0.044	< 0.0002	0.041	< 0.420	0.0067	< 0.002
	8/18/2016	0.13	0.11	0.0041	< 0.001	0.54	< 0.0005	0.028	< 0.0002	0.027	< 0.672	0.0061	< 0.002
	11/17/2016	0.0033	0.031	< 0.0005	< 0.0010	0.47	< 0.0005	0.016	< 0.0002	0.018	< 0.570	0.0078	< 0.002
	2/17/2017	0.02	0.056	< 0.0005	< 0.0010	0.43	< 0.0005	0.025	< 0.0002	0.027	< 0.392	0.0032	< 0.002
	5/4/2017	0.011	0.049	< 0.0005	< 0.0010	0.57	< 0.0005	0.023	< 0.0002	0.023	< 0.456	0.0034	< 0.002
	6/21/2017	0.0093	0.054	< 0.0005	< 0.0010	0.56	< 0.0005	0.027	< 0.0002	0.03	< 0.347	0.019	< 0.002
	8/29/2017	0.0018	0.044	< 0.0005	< 0.0010	0.53	< 0.0005	0.023	< 0.0002	0.032	0.377	0.0092	< 0.002
	11/10/2017	0.0063	0.046	< 0.0005	< 0.0010	0.63	< 0.0005	0.025	< 0.0002	0.02	< 0.313	0.016	< 0.002
	GWPS	**0.011**	**2.0**	**0.005**	**0.009**	**4.0**	**0.018**	**0.04**	**0.002**	**0.10**	**5.0**	**0.05**	**0.002**
	5/17/2018	0.0081	0.05	< 0.0005	< 0.0010	0.5	< 0.0005	0.029	< 0.0002	0.03	0.397	**0.077**	< 0.002
	8/9/2018	0.0083	0.048	< 0.0005	< 0.0010	0.48	< 0.0005	0.026	< 0.0002	0.033	0.566	**0.06**	< 0.002
MW-17 down-gradient	11/19/2015	0.0028	0.14	< 0.0005	0.0012	H 0.43	0.0012	0.019	H < 0.0002	0.035	< 0.790	< 0.0025	< 0.002
	2/22/2016	0.021	0.051	< 0.0005	0.0012	0.55	< 0.0005	0.038	< 0.0002	0.093	1.07	< 0.0025	< 0.002
	5/18/2016	0.32	0.12	0.0011	0.0015	0.64	< 0.0005	0.026	< 0.0002	0.12	8.27	< 0.0025	0.0028
	8/15/2016	0.34	0.12	0.001	0.0016	0.6	< 0.0005	0.022	< 0.0002	0.1	0.606	< 0.0025	0.0031
	11/14/2016	0.19	0.073	0.00051	0.0012	0.56	< 0.0005	0.022	< 0.0002	0.042	3.76	< 0.0025	0.0021
	2/13/2017	0.35	0.16	0.00093	0.0014	0.56	0.00079	0.019	< 0.0002	0.088	2.08	< 0.0025	0.0025
	5/4/2017	0.24	0.39	0.0023	0.0023	0.61	0.00066	0.016	< 0.0002	0.036	1.91	< 0.0025	0.0065
	6/22/2017	0.41	0.13	0.0007	0.0012	0.72	0.0011	0.022	< 0.0002	0.11	1.21	< 0.0025	0.0022
	8/29/2017	0.24	0.092	< 0.0005	< 0.001	0.64	0.00058	0.021	< 0.0002	0.13	3.32	< 0.0025	0.0025
	11/6/2017	0.17	0.38	0.0022	0.0015	0.62	< 0.0005	< 0.01	< 0.0002	0.019	2.54	< 0.0025	0.0075
	GWPS	**0.011**	**2.0**	**0.005**	**0.009**	**4.0**	**0.018**	**0.04**	**0.002**	**0.10**	**5.0**	**0.05**	**0.002**
	5/14/2018	**0.42**	0.17	0.002	0.0029	0.6	0.0021	0.015	< 0.0002	**0.13**	2.03	< 0.0025	**0.0068**
	8/6/2018	**0.087**	0.055	0.00094	0.0015	0.60	< 0.0005	0.019	< 0.0002	0.084	1.34	< 0.0025	**0.0023**
MW-18 down-gradient	11/19/2015	0.0014	0.14	< 0.0005	< 0.001	H 0.66	< 0.0005	0.017	H < 0.0002	0.0051	< 0.845	< 0.0025	< 0.002
	2/22/2016	0.0012	0.15	< 0.0005	< 0.001	0.68	< 0.0005	0.022	< 0.0002	0.0055	1.88	< 0.0025	< 0.002
	5/18/2016	< 0.001	0.13	< 0.0005	< 0.001	0.71	< 0.0005	0.014	< 0.0002	0.0052	< 0.493	< 0.0025	< 0.002
	8/15/2016	< 0.001	0.14	< 0.0005	< 0.001	0.64	< 0.0005	0.012	< 0.0002	0.0059	0.836	< 0.0025	< 0.002
	11/18/2016	< 0.001	0.14	< 0.0005	< 0.001	0.58	< 0.0005	0.013	< 0.0002	0.0053	0.488	< 0.0025	< 0.002
	2/15/2017	< 0.001	0.14	< 0.0005	< 0.001	0.5	< 0.0005	0.014	< 0.0002	0.0058	< 0.347	< 0.0025	< 0.002
	5/5/2017	0.0032	0.12	< 0.0005	< 0.001	0.52	0.00057	0.01	< 0.0002	< 0.005	0.612	< 0.0025	< 0.002
	6/21/2017	< 0.001	0.12	< 0.0005	< 0.001	0.51	< 0.0005	0.014	< 0.0002	0.0051	0.629	< 0.0025	< 0.002
	8/28/2017	< 0.001	0.12	< 0.0005	< 0.001	0.53	< 0.0005	0.012	< 0.0002	0.005	0.498	< 0.0025	< 0.002
	11/6/2017	< 0.001	0.12	< 0.0005	< 0.001	0.57	< 0.0005	0.011	< 0.0002	0.0057	0.755	< 0.0025	< 0.002
	GWPS	**0.011**	**2.0**	**0.005**	**0.009**	**4.0**	**0.018**	**0.04**	**0.002**	**0.10**	**5.0**	**0.05**	**0.002**
	5/14/2018	< 0.001	0.13	< 0.0005	< 0.001	0.59	< 0.0005	0.013	< 0.0002	0.0052	0.641	< 0.0025	< 0.002
	8/6/2018	< 0.001	0.12	< 0.0005	< 0.001	0.57	< 0.0005	0.013	< 0.0002	0.0052	1.02	< 0.0025	< 0.002

Notes:

All units are in mg/l except Radium is in pCi/L as noted.

Italics - Assessment Monitoring Conducted After Identification of Detected Appendix IV Compounds.

GWPS - Groundwater Protection Standard based on Table 2 and discussion in text

BOLD - Above established GWPS.

F1 - MS and/or MSD Recovery outside of limits.

H - Sample was prepped or analyzed beyond the specified holding time.

* - LCS or LCSD is outside acceptance limits.

^ - Denotes instrument related QC exceeds the control limits

ATTACHMENT 2

Analytical Data Packages

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica Pittsburgh
301 Alpha Drive
RIDC Park
Pittsburgh, PA 15238
Tel: (412)963-7058

TestAmerica Job ID: 180-85446-1
Client Project/Site: Midwest Generation

For:
KPRG and Associates, Inc.
14665 West Lisbon Road,
Suite 1A
Brookfield, Wisconsin 53005

Attn: Richard Gnat

Authorized for release by:
1/18/2019 1:57:25 PM

Carrie Gamber, Senior Project Manager
(412)963-2428
carrie.gamber@testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

PA Lab ID: 02-00416

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Job ID: 180-85446-1

Laboratory: TestAmerica Pittsburgh

Narrative

CASE NARRATIVE

Client: KPRG and Associates, Inc.

Project: Midwest Generation

Report Number: 180-85446-1

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

RECEIPT
The samples were received on 01/05/2019; the samples arrived in good condition, properly preserved and on ice. The temperature of the coolers at receipt was 1.9 C.

The Field Sampler was not listed on the Chain of Custody.

IC
No analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

METALS
Molybdenum was detected in method blank MB 180-267216/1-A at a level that was above the method detection limit but below the reporting limit. The value should be considered an estimate, and has been flagged. If the associated sample reported a result above the MDL and/or RL, the result has been flagged.

The continuing calibration verification (CCV) recovered above the upper control limit for beryllium. The samples associated with this CCV were less than the reporting limit for the affected analytes; therefore, the data have been reported. The following samples were impacted: ABB (180-85446-1), ASB (180-85446-2), (180-85446-H-2-C MS), (180-85446-H-2-D MSD), (180-85446-H-2-B PDS) and (180-85446-H-2-B SD ^5).

Definitions/Glossary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85446-1

Qualifiers

Metals

Qualifier	Qualifier Description
J	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.
^	ICV,CCV,ICB,CCB, ISA, ISB, CRI, CRA, DLCK or MRL standard: Instrument related QC is outside acceptance limits.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Accreditation/Certification Summary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85446-1

Laboratory: TestAmerica Pittsburgh

Unless otherwise noted, all analytes for this laboratory were covered under each accreditation/certification below.

Authority	Program	EPA Region	Identification Number	Expiration Date
Illinois	NELAP	5	200005	06-30-19

The following analytes are included in this report, but the laboratory is not certified by the governing authority. This list may include analytes for which the agency does not offer certification.

Analysis Method	Prep Method	Matrix	Analyte
EPA 6020A	3005A	Water	Lithium

Sample Summary

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
180-85446-1	ABB	Water	01/04/19 11:00	01/05/19 09:30
180-85446-2	ASB	Water	01/04/19 12:00	01/05/19 09:30

Method Summary

Method	Method Description	Protocol	Laboratory
EPA 9056A	Anions, Ion Chromatography	SW846	TAL PIT
EPA 6020A	Metals (ICP/MS)	SW846	TAL PIT
EPA 7470A	Mercury (CVAA)	SW846	TAL PIT
3005A	Preparation, Total Recoverable or Dissolved Metals	SW846	TAL PIT
7470A	Preparation, Mercury	SW846	TAL PIT

Protocol References:

SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.

Laboratory References:

TAL PIT = TestAmerica Pittsburgh, 301 Alpha Drive, RIDC Park, Pittsburgh, PA 15238, TEL (412)963-7058

Lab Chronicle

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85446-1

Client Sample ID: ABB

Lab Sample ID: 180-85446-1

Date Collected: 01/04/19 11:00
Date Received: 01/05/19 09:30

Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	EPA 9056A		1			267731	01/13/19 07:44	CMR	TAL PIT
	Instrument ID: CHICS2100B									
Total Recoverable	Prep	3005A			50 mL	50 mL	267216	01/07/19 11:48	NAM	TAL PIT
Total Recoverable	Analysis	EPA 6020A		1			267457	01/08/19 20:24	WTR	TAL PIT
	Instrument ID: A									
Total/NA	Prep	7470A			50 mL	50 mL	267213	01/07/19 11:26	KA	TAL PIT
Total/NA	Analysis	EPA 7470A		1			267249	01/07/19 18:31	KA	TAL PIT
	Instrument ID: HGY									

Client Sample ID: ASB

Lab Sample ID: 180-85446-2

Date Collected: 01/04/19 12:00
Date Received: 01/05/19 09:30

Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	EPA 9056A		1			267731	01/13/19 08:15	CMR	TAL PIT
	Instrument ID: CHICS2100B									
Total Recoverable	Prep	3005A			50 mL	50 mL	267216	01/07/19 11:48	NAM	TAL PIT
Total Recoverable	Analysis	EPA 6020A		1			267457	01/08/19 20:28	WTR	TAL PIT
	Instrument ID: A									
Total/NA	Prep	7470A			50 mL	50 mL	267213	01/07/19 11:26	KA	TAL PIT
Total/NA	Analysis	EPA 7470A		1			267249	01/07/19 18:32	KA	TAL PIT
	Instrument ID: HGY									

Laboratory References:

TAL PIT = TestAmerica Pittsburgh, 301 Alpha Drive, RIDC Park, Pittsburgh, PA 15238, TEL (412)963-7058

Analyst References:

Lab: TAL PIT

Batch Type: Prep

KA = Kayla Kalamasz

NAM = Nicole Marfisi

Batch Type: Analysis

CMR = Carl Reagle

KA = Kayla Kalamasz

WTR = Bill Reinheimer

Client Sample Results

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85446-1

Client Sample ID: ABB

Lab Sample ID: 180-85446-1

Date Collected: 01/04/19 11:00
Matrix: Water
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	**1.8**		0.10	0.026	mg/L			01/13/19 07:44	1

Method: EPA 6020A - Metals (ICP/MS) - Total Recoverable

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	**1.9**		1.0	0.32	ug/L		01/07/19 11:48	01/08/19 20:24	1
Barium	**56**		10	0.37	ug/L		01/07/19 11:48	01/08/19 20:24	1
Cadmium	ND		1.0	0.13	ug/L		01/07/19 11:48	01/08/19 20:24	1
Beryllium	ND	^	1.0	0.057	ug/L		01/07/19 11:48	01/08/19 20:24	1
Chromium	**3.4**		2.0	0.63	ug/L		01/07/19 11:48	01/08/19 20:24	1
Lead	**0.28**	**J**	1.0	0.094	ug/L		01/07/19 11:48	01/08/19 20:24	1
Selenium	**2.0**	**J**	5.0	0.81	ug/L		01/07/19 11:48	01/08/19 20:24	1
Cobalt	**0.14**	**J**	0.50	0.075	ug/L		01/07/19 11:48	01/08/19 20:24	1
Molybdenum	**96**		5.0	0.47	ug/L		01/07/19 11:48	01/08/19 20:24	1
Antimony	**1.4**	**J**	2.0	1.1	ug/L		01/07/19 11:48	01/08/19 20:24	1
Thallium	ND		1.0	0.063	ug/L		01/07/19 11:48	01/08/19 20:24	1
Lithium	**4.0**	**J**	5.0	2.6	ug/L		01/07/19 11:48	01/08/19 20:24	1

Method: EPA 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/07/19 11:26	01/07/19 18:31	1

Client Sample ID: ASB

Lab Sample ID: 180-85446-2

Date Collected: 01/04/19 12:00
Matrix: Water
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	**0.46**		0.10	0.026	mg/L			01/13/19 08:15	1

Method: EPA 6020A - Metals (ICP/MS) - Total Recoverable

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	**3.2**		1.0	0.32	ug/L		01/07/19 11:48	01/08/19 20:28	1
Barium	**150**		10	0.37	ug/L		01/07/19 11:48	01/08/19 20:28	1
Cadmium	ND		1.0	0.13	ug/L		01/07/19 11:48	01/08/19 20:28	1
Beryllium	**0.069**	**J ^**	1.0	0.057	ug/L		01/07/19 11:48	01/08/19 20:28	1
Chromium	**3.6**		2.0	0.63	ug/L		01/07/19 11:48	01/08/19 20:28	1
Lead	**0.69**	**J**	1.0	0.094	ug/L		01/07/19 11:48	01/08/19 20:28	1
Selenium	ND		5.0	0.81	ug/L		01/07/19 11:48	01/08/19 20:28	1
Cobalt	**0.96**		0.50	0.075	ug/L		01/07/19 11:48	01/08/19 20:28	1
Molybdenum	**10**		5.0	0.47	ug/L		01/07/19 11:48	01/08/19 20:28	1
Antimony	**1.9**	**J**	2.0	1.1	ug/L		01/07/19 11:48	01/08/19 20:28	1
Thallium	**0.091**	**J**	1.0	0.063	ug/L		01/07/19 11:48	01/08/19 20:28	1
Lithium	**13**		5.0	2.6	ug/L		01/07/19 11:48	01/08/19 20:28	1

Method: EPA 7470A - Mercury (CVAA)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/07/19 11:26	01/07/19 18:32	1

Client: KPRG and Associates, Inc. TestAmerica Job ID: 180-85446-1
Project/Site: Midwest Generation

Method: EPA 9056A - Anions, Ion Chromatography

Lab Sample ID: MB 180-267731/6 **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 267731

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		0.10	0.026	mg/L			01/13/19 06:56	1

Lab Sample ID: LCS 180-267731/5 **Client Sample ID: Lab Control Sample**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 267731

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Fluoride	1.25	1.32		mg/L		105	80 - 120

Lab Sample ID: 180-85446-2 MS **Client Sample ID: ASB**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 267731

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Fluoride	0.51		6.25	7.35		mg/L		109	80 - 120

Lab Sample ID: 180-85446-2 MSD **Client Sample ID: ASB**
Matrix: Water **Prep Type: Total/NA**
Analysis Batch: 267731

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Fluoride	0.51		6.25	7.28		mg/L		108	80 - 120	1	15

Method: EPA 6020A - Metals (ICP/MS)

Lab Sample ID: MB 180-267216/1-A **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total Recoverable**
Analysis Batch: 267457 **Prep Batch: 267216**

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	ND		1.0	0.32	ug/L		01/07/19 11:48	01/08/19 19:14	1
Barium	ND		10	0.37	ug/L		01/07/19 11:48	01/08/19 19:14	1
Cadmium	ND		1.0	0.13	ug/L		01/07/19 11:48	01/08/19 19:14	1
Beryllium	ND		1.0	0.057	ug/L		01/07/19 11:48	01/08/19 19:14	1
Chromium	ND		2.0	0.63	ug/L		01/07/19 11:48	01/08/19 19:14	1
Lead	ND		1.0	0.094	ug/L		01/07/19 11:48	01/08/19 19:14	1
Selenium	ND		5.0	0.81	ug/L		01/07/19 11:48	01/08/19 19:14	1
Cobalt	ND		0.50	0.075	ug/L		01/07/19 11:48	01/08/19 19:14	1
Molybdenum	ND		5.0	0.47	ug/L		01/07/19 11:48	01/08/19 19:14	1
Antimony	ND		2.0	1.1	ug/L		01/07/19 11:48	01/08/19 19:14	1
Thallium	ND		1.0	0.063	ug/L		01/07/19 11:48	01/08/19 19:14	1
Lithium	ND		5.0	2.6	ug/L		01/07/19 11:48	01/08/19 19:14	1

Lab Sample ID: MB 180-267216/1-A **Client Sample ID: Method Blank**
Matrix: Water **Prep Type: Total Recoverable**
Analysis Batch: 267572 **Prep Batch: 267216**

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	ND		1.0	0.32	ug/L		01/07/19 11:48	01/09/19 20:11	1

Method: EPA 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: MB 180-267216/1-A
Matrix: Water
Analysis Batch: 267572

Client Sample ID: Method Blank
Prep Type: Total Recoverable
Prep Batch: 267216

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Barium	ND		10	0.37	ug/L		01/07/19 11:48	01/09/19 20:11	1
Cadmium	ND		1.0	0.13	ug/L		01/07/19 11:48	01/09/19 20:11	1
Beryllium	ND		1.0	0.057	ug/L		01/07/19 11:48	01/09/19 20:11	1
Chromium	ND		2.0	0.63	ug/L		01/07/19 11:48	01/09/19 20:11	1
Lead	ND		1.0	0.094	ug/L		01/07/19 11:48	01/09/19 20:11	1
Selenium	ND		5.0	0.81	ug/L		01/07/19 11:48	01/09/19 20:11	1
Cobalt	ND		0.50	0.075	ug/L		01/07/19 11:48	01/09/19 20:11	1
Molybdenum	0.664	J	5.0	0.47	ug/L		01/07/19 11:48	01/09/19 20:11	1
Antimony	ND		2.0	1.1	ug/L		01/07/19 11:48	01/09/19 20:11	1
Thallium	ND		1.0	0.063	ug/L		01/07/19 11:48	01/09/19 20:11	1
Lithium	ND		5.0	2.6	ug/L		01/07/19 11:48	01/09/19 20:11	1

Lab Sample ID: LCS 180-267216/2-A
Matrix: Water
Analysis Batch: 267457

Client Sample ID: Lab Control Sample
Prep Type: Total Recoverable
Prep Batch: 267216

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Arsenic	40.0	40.5		ug/L		101	80 - 120
Barium	2000	2040		ug/L		102	80 - 120
Cadmium	50.0	53.0		ug/L		106	80 - 120
Beryllium	50.0	56.7		ug/L		113	80 - 120
Chromium	200	209		ug/L		105	80 - 120
Lead	20.0	21.3		ug/L		106	80 - 120
Selenium	10.0	9.95		ug/L		99	80 - 120
Cobalt	500	515		ug/L		103	80 - 120
Molybdenum	1000	1070		ug/L		107	80 - 120
Antimony	500	517		ug/L		103	80 - 120
Thallium	50.0	53.2		ug/L		106	80 - 120
Lithium	50.0	46.7		ug/L		93	80 - 120

Lab Sample ID: LCS 180-267216/2-A
Matrix: Water
Analysis Batch: 267572

Client Sample ID: Lab Control Sample
Prep Type: Total Recoverable
Prep Batch: 267216

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Arsenic	40.0	39.4		ug/L		98	80 - 120
Barium	2000	1820		ug/L		91	80 - 120
Cadmium	50.0	56.5		ug/L		113	80 - 120
Beryllium	50.0	50.2		ug/L		100	80 - 120
Chromium	200	192		ug/L		96	80 - 120
Lead	20.0	20.8		ug/L		104	80 - 120
Selenium	10.0	8.24		ug/L		82	80 - 120
Cobalt	500	452		ug/L		90	80 - 120
Molybdenum	1000	1090		ug/L		109	80 - 120
Antimony	500	467		ug/L		93	80 - 120
Thallium	50.0	51.0		ug/L		102	80 - 120
Lithium	50.0	54.4		ug/L		109	80 - 120

Method: EPA 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: 180-85446-2 MS
Matrix: Water
Analysis Batch: 267572
Client Sample ID: ASB
Prep Type: Total Recoverable
Prep Batch: 267216

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Arsenic	3.2		40.0	43.3		ug/L		100	75 - 125
Barium	150		2000	1970		ug/L		91	75 - 125
Cadmium	ND		50.0	57.7		ug/L		115	75 - 125
Beryllium	0.069	J ^	50.0	49.2		ug/L		98	75 - 125
Chromium	3.6		200	189		ug/L		93	75 - 125
Lead	0.69	J	20.0	22.1		ug/L		107	75 - 125
Selenium	ND		10.0	9.53		ug/L		95	75 - 125
Cobalt	0.96		500	440		ug/L		88	75 - 125
Molybdenum	10		1000	1150		ug/L		114	75 - 125
Antimony	1.9	J	500	483		ug/L		96	75 - 125
Thallium	0.091	J	50.0	50.8		ug/L		101	75 - 125
Lithium	13		50.0	67.9		ug/L		110	75 - 125

Lab Sample ID: 180-85446-2 MSD
Matrix: Water
Analysis Batch: 267457
Client Sample ID: ASB
Prep Type: Total Recoverable
Prep Batch: 267216

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Arsenic	3.2		40.0	42.7		ug/L		99	75 - 125	172	20
Barium	150		2000	2280		ug/L		106	75 - 125	175	20
Cadmium	ND		50.0	55.9		ug/L		112	75 - 125	NC	20
Beryllium	0.069	J ^	50.0	57.6	^	ug/L		115	75 - 125	NC	20
Chromium	3.6		200	226		ug/L		111	75 - 125	194	20
Lead	0.69	J	20.0	22.5		ug/L		109	75 - 125	189	20
Selenium	ND		10.0	9.14		ug/L		91	75 - 125	NC	20
Cobalt	0.96		500	489		ug/L		98	75 - 125	200	20
Molybdenum	10		1000	1110		ug/L		110	75 - 125	197	20
Antimony	1.9	J	500	545		ug/L		109	75 - 125	199	20
Thallium	0.091	J	50.0	53.6		ug/L		107	75 - 125	NC	20
Lithium	13		50.0	62.3		ug/L		99	75 - 125	132	20

Method: EPA 7470A - Mercury (CVAA)

Lab Sample ID: MB 180-267213/1-A
Matrix: Water
Analysis Batch: 267249
Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 267213

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/07/19 11:26	01/07/19 18:19	1

Lab Sample ID: LCS 180-267213/2-A
Matrix: Water
Analysis Batch: 267249
Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 267213

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Mercury	2.50	2.66		ug/L		106	80 - 120

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85446-1

HPLC/IC

Analysis Batch: 267731

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85446-1	ABB	Total/NA	Water	EPA 9056A	
180-85446-2	ASB	Total/NA	Water	EPA 9056A	
MB 180-267731/6	Method Blank	Total/NA	Water	EPA 9056A	
LCS 180-267731/5	Lab Control Sample	Total/NA	Water	EPA 9056A	
180-85446-2 MS	ASB	Total/NA	Water	EPA 9056A	
180-85446-2 MSD	ASB	Total/NA	Water	EPA 9056A	

Metals

Prep Batch: 267213

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85446-1	ABB	Total/NA	Water	7470A	
180-85446-2	ASB	Total/NA	Water	7470A	
MB 180-267213/1-A	Method Blank	Total/NA	Water	7470A	
LCS 180-267213/2-A	Lab Control Sample	Total/NA	Water	7470A	

Prep Batch: 267216

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85446-1	ABB	Total Recoverable	Water	3005A	
180-85446-2	ASB	Total Recoverable	Water	3005A	
MB 180-267216/1-A	Method Blank	Total Recoverable	Water	3005A	
LCS 180-267216/2-A	Lab Control Sample	Total Recoverable	Water	3005A	
180-85446-2 MS	ASB	Total Recoverable	Water	3005A	
180-85446-2 MSD	ASB	Total Recoverable	Water	3005A	

Analysis Batch: 267249

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85446-1	ABB	Total/NA	Water	EPA 7470A	267213
180-85446-2	ASB	Total/NA	Water	EPA 7470A	267213
MB 180-267213/1-A	Method Blank	Total/NA	Water	EPA 7470A	267213
LCS 180-267213/2-A	Lab Control Sample	Total/NA	Water	EPA 7470A	267213

Analysis Batch: 267457

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85446-1	ABB	Total Recoverable	Water	EPA 6020A	267216
180-85446-2	ASB	Total Recoverable	Water	EPA 6020A	267216
MB 180-267216/1-A	Method Blank	Total Recoverable	Water	EPA 6020A	267216
LCS 180-267216/2-A	Lab Control Sample	Total Recoverable	Water	EPA 6020A	267216
180-85446-2 MSD	ASB	Total Recoverable	Water	EPA 6020A	267216

Analysis Batch: 267572

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
MB 180-267216/1-A	Method Blank	Total Recoverable	Water	EPA 6020A	267216
LCS 180-267216/2-A	Lab Control Sample	Total Recoverable	Water	EPA 6020A	267216
180-85446-2 MS	ASB	Total Recoverable	Water	EPA 6020A	267216

1 2 3 4 5 6 7 8 9 10 11 12 13

Chain of Custody Record

273172

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING
TestAmerica Laboratories, Inc.
TAL-8210 (0713)

Regulatory Program: ☐ DW ☐ NPDES ☐ RCRA ☐ Other:

Client Contact	Project Manager:	Site Contact:	Date:	COC No:
Company Name: KPRG and Associates	Tel/Fax:	Lab Contact:	Carrier:	___ of ___ COCs
Address: 14665 W Lisbon Rd Ste 1A	Analysis Turnaround Time			Sampler:
City/State/Zip: Brookfield / WI 53005	☐ CALENDAR DAYS ☐ WORKING DAYS			For Lab Use Only:
Phone: 262-781-0475	TAT if different from Below ___			Walk-in Client:
Fax:	☐ 2 weeks			Lab Sampling:
Project Name: NRG	☐ 1 week			
Site: Powerton	☐ 2 days			Job / SDG No.:
PO# 23517.0	☐ 1 day			

Sample Identification	Sample Date	Sample Time	Sample Type (C=Comp, G=Grab)	Matrix	# of Cont.	Filtered Sample (Y/N)	Perform MS / MSD (Y/N)	Fluoride	Metals	Rad 226/228	Sample Specific Notes:
ABB	1-4-19	1100	G	W	4	N	N	X	X	X	
ASB	1-4-19	1200	G	W	4	N	N	X	X	X	

180-85446 Chain of Custody

Preservation Used: 1= Ice, 2= HCl; 3= H2SO4; 4=HNO3; 5=NaOH; 6= Other ___ | 1 | 4 | 4

Possible Hazard Identification:
Are any samples from a listed EPA Hazardous Waste? Please List any EPA Waste Codes for the sample in the Comments Section if the lab is to dispose of the sample.
☐ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ Return to Client ☐ Disposal by Lab ☐ Archive for ___ Months

Special Instructions/QC Requirements & Comments:
CCR Appedix 4 metals → As, Ba, Cd, Co, Pb, Li, Hg, Mo, Se, Tl / Date for all samples is 1-4-19

Custody Seals Intact: ☐ Yes ☐ No | Custody Seal No.: | Cooler Temp. (°C): Obs'd: ___ Corr'd: ___ Therm ID No.: ___

Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Mitchel Dolan	KPRG	1-4-19/1400	FEDEX		1-4-19 / 1400
Relinquished by:	Company:	Date/Time:	Received by: Julie Watson	Company: TAPH	Date/Time: 1-5-19 - 9:30
Relinquished by:	Company:	Date/Time:	Received in Laboratory by:	Company:	Date/Time:

FedEx®

180-85446 Waybill

Do Not Lift Usin

erica

ST 3 9 1 12:00 A 0897 01.05

ORIGIN ID:PIAA (000) 000-0000
KPRG ASSOCIATES
414 PLAZA DR STE 106
WESTMONT, IL 60559
UNITED STATES US

SHIP DATE: 04JAN19
ACTWGT: 50.00 LB
CAD: 006994779/SSFE1922
DIMS: 22x12x12 IN
BILL THIRD PARTY

TO ATTN CARRIE GAMBER
TEST AMERICA
301 ALPHA DR RIDC PARK

PITTSBURGH PA 15238
(412) 963-7058 REF:
INV:
PO: DEPT:

FedEx Express E

SATURDAY 12:00P
PRIORITY OVERNIGHT

TRK# 0201 7848 0408 0897

XO AGCA

15238
US PIT

Uncorrected temp 1.9 °C
Thermometer ID 10
CF 0 Initials TS
PT-WI-SR-001 effective 11/6/18

FedEx Express

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc. Job Number: 180-85446-1

Login Number: 85446 **List Source: TestAmerica Pittsburgh**
List Number: 1
Creator: Watson, Debbie

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	False	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

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ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica Pittsburgh
301 Alpha Drive
RIDC Park
Pittsburgh, PA 15238
Tel: (412)963-7058

TestAmerica Job ID: 180-85446-2
Client Project/Site: Midwest Generation

For:
KPRG and Associates, Inc.
14665 West Lisbon Road,
Suite 2B
Brookfield, Wisconsin 53005

Attn: Richard Gnat

Authorized for release by:
2/7/2019 4:39:54 PM

Carrie Gamber, Senior Project Manager
(412)963-2428
carrie.gamber@testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

PA Lab ID: 02-00416

Table of Contents

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Receipt Checklists 16

Job ID: 180-85446-2

Laboratory: TestAmerica Pittsburgh

Narrative

CASE NARRATIVE

Client: KPRG and Associates, Inc.

Project: Midwest Generation

Report Number: 180-85446-2

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

RECEIPT
The samples were received on 01/05/2019; the samples arrived in good condition, properly preserved and on ice. The temperature of the coolers at receipt was 1.9 C.

The Field Sampler was not listed on the Chain of Custody.

903.0
The following samples were prepared at a reduced aliquot: ABB (180-85446-1) and ASB (180-85446-2). Sample 180-85446-1 was reduced due to yellow discoloration. Sample 180-85446-2 was reduced due to sediment.

904.0
The following samples were prepared at a reduced aliquot due to limited sample volume due to re-extract: ABB (180-85446-1) and ASB (180-85446-2).

Method(s) PrecSep_0: Radium 228 Prep Batch 160-410725: The following samples were prepared at a reduced aliquot: ABB (180-85446-1) and ASB (180-85446-2). Sample 180-85446-1 was reduced due to yellow discoloration. Sample 180-85446-2 was reduced due to sediment.

Definitions/Glossary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85446-2

Qualifiers

Rad

Qualifier	Qualifier Description
G	The Sample MDC is greater than the requested RL.
U	Result is less than the sample detection limit.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Accreditation/Certification Summary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85446-2

Laboratory: TestAmerica Pittsburgh

The accreditations/certifications listed below are applicable to this report.

Authority	Program	EPA Region	Identification Number	Expiration Date
Illinois	NELAP	5	200005	06-30-19

Laboratory: TestAmerica St. Louis

All accreditations/certifications held by this laboratory are listed. Not all accreditations/certifications are applicable to this report.

Authority	Program	EPA Region	Identification Number	Expiration Date
Alaska	State Program	10	MO00054	06-30-19
ANAB	DoD ELAP		L2305	04-06-19
Arizona	State Program	9	AZ0813	12-08-19
California	State Program	9	2886	06-30-19
Connecticut	State Program	1	PH-0241	03-31-19
Florida	NELAP	4	E87689	06-30-19
Illinois	NELAP	5	200023	11-30-19
Iowa	State Program	7	373	12-01-20
Kansas	NELAP	7	E-10236	10-31-19
Kentucky (DW)	State Program	4	90125	12-31-18 *
Louisiana	NELAP	6	04080	06-30-19
Louisiana (DW)	NELAP	6	LA011	12-31-19
Maryland	State Program	3	310	09-30-19
Michigan	State Program	5	9005	06-30-19
Missouri	State Program	7	780	06-30-19
Nevada	State Program	9	MO000542018-1	07-31-19
New Jersey	NELAP	2	MO002	06-30-19
New York	NELAP	2	11616	03-31-19
North Dakota	State Program	8	R207	06-30-19
NRC	NRC		24-24817-01	12-31-22
Oklahoma	State Program	6	9997	08-31-19
Pennsylvania	NELAP	3	68-00540	02-28-19 *
South Carolina	State Program	4	85002001	06-30-19
Texas	NELAP	6	T104704193-18-12	07-31-19
US Fish & Wildlife	Federal		058448	07-31-19
USDA	Federal		P330-17-0028	02-02-20
Utah	NELAP	8	MO000542018-10	07-31-19
Virginia	NELAP	3	460230	06-14-19
Washington	State Program	10	C592	08-30-19
West Virginia DEP	State Program	3	381	08-31-19

* Accreditation/Certification renewal pending - accreditation/certification considered valid.

Sample Summary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85446-2

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
180-85446-1	ABB	Water	01/04/19 11:00	01/05/19 09:30
180-85446-2	ASB	Water	01/04/19 12:00	01/05/19 09:30

Method Summary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85446-2

Method	Method Description	Protocol	Laboratory
903.0	Radium-226 (GFPC)	EPA	TAL SL
904.0	Radium-228 (GFPC)	EPA	TAL SL
PrecSep_0	Preparation, Precipitate Separation	None	TAL SL
PrecSep-21	Preparation, Precipitate Separation (21-Day In-Growth)	None	TAL SL

Protocol References:

EPA = US Environmental Protection Agency

None = None

Laboratory References:

TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Lab Chronicle

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85446-2

Client Sample ID: ABB

Date Collected: 01/04/19 11:00
Date Received: 01/05/19 09:30

Lab Sample ID: 180-85446-1
Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			750.59 mL	1.0 g	409814	01/09/19 09:10	SJC	TAL SL
Total/NA	Analysis	903.0		1			413802	02/06/19 08:40	KLS	TAL SL
	Instrument ID: GFPCPURPLE									
Total/NA	Prep	PrecSep_0			196.71 mL	1.0 g	412615	01/28/19 08:01	JLC	TAL SL
Total/NA	Analysis	904.0		1			413086	01/31/19 09:19	KLS	TAL SL
	Instrument ID: GFPCORANGE									

Client Sample ID: ASB

Date Collected: 01/04/19 12:00
Date Received: 01/05/19 09:30

Lab Sample ID: 180-85446-2
Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			750.46 mL	1.0 g	409814	01/09/19 09:10	SJC	TAL SL
Total/NA	Analysis	903.0		1			413802	02/06/19 08:40	KLS	TAL SL
	Instrument ID: GFPCPURPLE									
Total/NA	Prep	PrecSep_0			264.91 mL	1.0 g	412615	01/28/19 08:01	JLC	TAL SL
Total/NA	Analysis	904.0		1			413086	01/31/19 09:19	KLS	TAL SL
	Instrument ID: GFPCORANGE									

Laboratory References:

TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Analyst References:

Lab: TAL SL

Batch Type: Prep

JLC = Jessica Chapman

SJC = Sarah Cooper

Batch Type: Analysis

KLS = Kody Saulters

Client Sample Results

Client Sample ID: ABB

Lab Sample ID: 180-85446-1
Date Collected: 01/04/19 11:00
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0261	U	0.0578	0.0578	1.00	0.107	pCi/L	01/09/19 09:10	02/06/19 08:40	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*96.2*		*40 - 110*	*01/09/19 09:10*	*02/06/19 08:40*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	1.85	U G	1.61	1.62	1.00	2.59	pCi/L	01/28/19 08:01	01/31/19 09:19	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*92.3*		*40 - 110*	*01/28/19 08:01*	*01/31/19 09:19*	*1*
Y Carrier	*75.5*		*40 - 110*	*01/28/19 08:01*	*01/31/19 09:19*	*1*

Client Sample ID: ASB

Lab Sample ID: 180-85446-2
Date Collected: 01/04/19 12:00
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.144**		0.0952	0.0961	1.00	0.125	pCi/L	01/09/19 09:10	02/06/19 08:40	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*79.6*		*40 - 110*	*01/09/19 09:10*	*02/06/19 08:40*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	1.02	U G	1.08	1.08	1.00	1.76	pCi/L	01/28/19 08:01	01/31/19 09:19	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*89.7*		*40 - 110*	*01/28/19 08:01*	*01/31/19 09:19*	*1*
Y Carrier	*74.4*		*40 - 110*	*01/28/19 08:01*	*01/31/19 09:19*	*1*

QC Sample Results

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85446-2

Method: 903.0 - Radium-226 (GFPC)

Lab Sample ID: MB 160-409814/22-A
Matrix: Water
Analysis Batch: 413803

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 409814

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	-0.01039	U	0.0415	0.0415	1.00	0.0985	pCi/L	01/09/19 09:10	02/06/19 08:42	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*103*		*40 - 110*	*01/09/19 09:10*	*02/06/19 08:42*	*1*

Lab Sample ID: LCS 160-409814/1-A
Matrix: Water
Analysis Batch: 413801

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 409814

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-226	15.1	14.10		1.44	1.00	0.116	pCi/L	93	68 - 137

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*97.9*		*40 - 110*

Method: 904.0 - Radium-228 (GFPC)

Lab Sample ID: MB 160-412615/22-A
Matrix: Water
Analysis Batch: 413086

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 412615

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	1.743	U G	1.16	1.18	1.00	1.79	pCi/L	01/28/19 08:01	01/31/19 09:20	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*108*		*40 - 110*	*01/28/19 08:01*	*01/31/19 09:20*	*1*
Y Carrier	*74.8*		*40 - 110*	*01/28/19 08:01*	*01/31/19 09:20*	*1*

Lab Sample ID: LCS 160-412615/1-A
Matrix: Water
Analysis Batch: 413086

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 412615

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-228	47.6	41.82		4.97	1.00	1.83	pCi/L	88	56 - 140

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*99.4*		*40 - 110*
Y Carrier	*79.3*		*40 - 110*

Method: 904.0 - Radium-228 (GFPC) (Continued)

Lab Sample ID: LCSD 160-412615/2-A
Matrix: Water
Analysis Batch: 413086

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 412615

Analyte			Spike Added	LCSD Result	LCSD Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits	RER	RER Limit
Radium-228			47.6	41.03		4.84	1.00	1.63	pCi/L	86	56 - 140	0.08	1

Carrier	*LCSD %Yield*	*LCSD Qualifier*	*Limits*
Ba Carrier	*104*		*40 - 110*
Y Carrier	*79.6*		*40 - 110*

QC Association Summary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85446-2

Rad

Prep Batch: 409814

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85446-1	ABB	Total/NA	Water	PrecSep-21	
180-85446-2	ASB	Total/NA	Water	PrecSep-21	
MB 160-409814/22-A	Method Blank	Total/NA	Water	PrecSep-21	
LCS 160-409814/1-A	Lab Control Sample	Total/NA	Water	PrecSep-21	

Prep Batch: 412615

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85446-1	ABB	Total/NA	Water	PrecSep_0	
180-85446-2	ASB	Total/NA	Water	PrecSep_0	
MB 160-412615/22-A	Method Blank	Total/NA	Water	PrecSep_0	
LCS 160-412615/1-A	Lab Control Sample	Total/NA	Water	PrecSep_0	
LCSD 160-412615/2-A	Lab Control Sample Dup	Total/NA	Water	PrecSep_0	

Chain of Custody Record

273172

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING
TestAmerica Laboratories, Inc.
TAL-8210 (0713)

Regulatory Program: ☐ DW ☐ NPDES ☐ RCRA ☐ Other:

Client Contact	Project Manager:	Site Contact:	Date:	COC No:
Company Name: KPRG and Associates	Tel/Fax:	Lab Contact:	Carrier:	___ of ___ COCs
Address: 14665 W Lisbon Rd Ste 1A	Analysis Turnaround Time			Sampler:
City/State/Zip: Brookfield / WI 53005	☐ CALENDAR DAYS ☐ WORKING DAYS			For Lab Use Only:
Phone: 262-781-0475	TAT if different from Below ___			Walk-in Client:
Fax:	☐ 2 weeks			Lab Sampling:
Project Name: NRG	☐ 1 week			
Site: Powerton	☐ 2 days			Job / SDG No.:
PO# 23517.0	☐ 1 day			

Sample Identification	Sample Date	Sample Time	Sample Type (C=Comp, G=Grab)	Matrix	# of Cont.	Filtered Sample (Y / N)	Perform MS / MSD (Y / N)	Fluoride	Metals	Rad 226/228	Sample Specific Notes:
ABB	1-4-19	1100	G	W	4	N	N	X	X	X	
ASB	1-4-19	1200	G	W	4	N	N	X	X	X	

180-85446 Chain of Custody

Preservation Used: 1= Ice, 2= HCl; 3= H2SO4; 4=HNO3; 5=NaOH; 6= Other ___ 1 4 4

Possible Hazard Identification:
Are any samples from a listed EPA Hazardous Waste? Please List any EPA Waste Codes for the sample in the Comments Section if the lab is to dispose of the sample.
☐ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ Return to Client ☐ Disposal by Lab ☐ Archive for ___ Months

Special Instructions/QC Requirements & Comments:
CCR Appedix 4 metals → As, Ba, Cd, Co, Pb, Li, Hg, Mo, Se, Tl / Date for all samples is 1-4-19

Custody Seals Intact: ☐ Yes ☐ No | Custody Seal No.: | Cooler Temp. (°C): Obs'd: ___ Corr'd: ___ | Therm ID No.: ___

Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Mitchel Dolan	KPRG	1-4-19/1400	FEDEX		1-4-19 / 1400
Relinquished by:	Company:	Date/Time:	Received by: Julie Watson	Company: TA Ptt	Date/Time: 1-5-19 - 9:30
Relinquished by:	Company:	Date/Time:	Received in Laboratory by:	Company:	Date/Time:

FedEx®

180-85446 Waybill

Do Not Lift Usin

erica

ST 3 9 1 12:00 A 0897 01.05

ORIGIN ID:PIAA (000) 000-0000
KPRG ASSOCIATES
414 PLAZA DR STE 106
WESTMONT, IL 60559
UNITED STATES US

SHIP DATE: 04JAN19
ACTWGT: 50.00 LB
CAD: 006994779/SSFE1922
DIMS: 22x12x12 IN
BILL THIRD PARTY

TO ATTN CARRIE GAMBER
TEST AMERICA
301 ALPHA DR RIDC PARK

PITTSBURGH PA 15238
(412) 963-7058 REF:
INV:
PO: DEPT:

FedEx Express

E

SATURDAY 12:00P
PRIORITY OVERNIGHT

TRK# 0201 7848 0408 0897

XO AGCA

15238
US PIT

Uncorrected temp 1.9 °C
Thermometer ID 10
CF 0 Initials TS
PT-WI-SR-001 effective 11/6/18

FedEx Express

TestAmerica Pittsburgh
301 Alpha Drive RIDC Park
Pittsburgh, PA 15238
Phone (412) 963-7058 Fax (412) 963-2468

Chain of Custody Record

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Client Information (Sub Contract Lab)	Sampler:	Lab PM: Gamber, Carrie L	Carrier Tracking No(s):	COC No: 180-351860.1
Client Contact: Shipping/Receiving	Phone:	E-Mail: carrie.gamber@testamericainc.com	State of Origin: Illinois	Page: Page 1 of 1
Company: TestAmerica Laboratories, Inc.		Accreditations Required (See note): NELAP - Illinois		Job #: 180-85446-2
Address: 13715 Rider Trail North,	Due Date Requested: 1/17/2019	**Analysis Requested**		**Preservation Codes:**
City: Earth City	TAT Requested (days):			A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA; M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
State, Zip: MO, 63045				
Phone: 314-298-8566(Tel) 314-298-8757(Fax)	PO #:			
Email:	WO #:			
Project Name: Midwest Generation	Project #: 18018377			Other:
Site:	SSOW#:			

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	903.0/PrecSep_21 Standard Target List	904.0/PrecSep_0 Standard Target List	Total Number of containers	Special Instructions/Note:
			Preservation Code:							
ABB (180-85446-1)	1/4/19	11:00 Central		Water			X	X	2	
ASB (180-85446-2)	1/4/19	12:00 Central		Water			X	X	2	

Note: Since laboratory accreditations are subject to change, TestAmerica Laboratories, Inc. places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody. If the laboratory does not currently maintain accreditation in the State of Origin listed above for analysis/tests/matrix being analyzed, the samples must be shipped back to the TestAmerica laboratory or other instructions will be provided. Any changes to accreditation status should be brought to TestAmerica Laboratories, Inc. attention immediately. If all requested accreditations are current to date, return the signed Chain of Custody attesting to said complicance to TestAmerica Laboratories, Inc.

Possible Hazard Identification Unconfirmed		*Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)* ☐ Return To Client ☐ Disposal By Lab ☐ Archive For ____ Months
Deliverable Requested: I, II, III, IV, Other (specify)	Primary Deliverable Rank: 2	Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:		Time:	Method of Shipment:	
Relinquished by: [signature]	Date/Time: 1/7/19 1700	Company: MA Pitt	Received by: [signature]	Date/Time: 1-8-19/0855	Company: TASK
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Custody Seals Intact: Δ Yes Δ No	Custody Seal No.:		Cooler Temperature(s) °C and Other Remarks:		

Ver: 09/20/2016

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc. | Job Number: 180-85446-2

Login Number: 85446 | **List Source: TestAmerica Pittsburgh**
List Number: 1
Creator: Watson, Debbie

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	False	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc.

Job Number: 180-85446-2

Login Number: 85446
List Number: 2
Creator: Press, Nicholas B

List Source: TestAmerica St. Louis
List Creation: 01/08/19 02:44 PM

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	19.0
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica Pittsburgh
301 Alpha Drive
RIDC Park
Pittsburgh, PA 15238
Tel: (412)963-7058

TestAmerica Job ID: 180-85447-1
Client Project/Site: Midwest Generation

For:
KPRG and Associates, Inc.
14665 West Lisbon Road,
Suite 2B
Brookfield, Wisconsin 53005

Attn: Richard Gnat

Authorized for release by:
2/21/2019 3:09:58 PM

Carrie Gamber, Senior Project Manager
(412)963-2428
carrie.gamber@testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

PA Lab ID: 02-00416

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Job ID: 180-85447-1

Laboratory: TestAmerica Pittsburgh

Narrative

CASE NARRATIVE

Client: KPRG and Associates, Inc.

Project: Midwest Generation

Report Number: 180-85447-1

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

RECEIPT
The samples were received on 01/05/2019; the samples arrived in good condition, properly preserved and on ice. The temperature of the coolers at receipt was 1.9 C.

The Field Sampler was not listed on the Chain of Custody.

One out of two containers for the following sample did not match the information listed on the Chain-of-Custody (COC): ABB PRETEST (180-85447-1). The container label lists a sample collection time of 11:00, while the COC lists 11:10. The time on the COC was used.

METALS
A couple samples were diluted due to the high concentration of non-target metals or due to the sample matrix. Elevated reporting limits (RLs) are provided.

Lead was detected in method blank MB 180-268107/1-A at a level that was above the method detection limit but below the reporting limit. The value should be considered an estimate, and has been flagged. If the associated sample reported a result above the MDL and/or RL, the result has been flagged.

Chromium and Cobalt were detected in method blank MB 180-268586/1-A at levels that were above the method detection limit but below the reporting limit. The values should be considered estimates, and have been flagged. If the associated sample reported a result above the MDL and/or RL, the result has been flagged.

GENERAL CHEMSITRY
Several samples were diluted due to the nature of the sample matrix or due to the detection of non-target analytes for IC (Nitrate). Nitric Acid is used to adjust the pH of the sample per the leach method. Elevated reporting limits (RLs) are provided.

The continuing calibration verification (CCV) associated with batch 180-269858 recovered outside acceptance criteria, biased low, for Fluoride. A reporting limit (RL) standard was analyzed, and the target analyte was detected. Since the associated samples were non-detect or at an estimated level for this analyte, the data have been reported. The samples contained high concentrations of Nitric Acid which caused the CCV after it to fail low for this analyte.

Qualifiers

HPLC/IC

Qualifier	Qualifier Description
J	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

Metals

Qualifier	Qualifier Description
J	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.
B	Compound was found in the blank and sample.

General Chemistry

Qualifier	Qualifier Description
E	Result exceeded calibration range.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Accreditation/Certification Summary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-1

Laboratory: TestAmerica Pittsburgh

Unless otherwise noted, all analytes for this laboratory were covered under each accreditation/certification below.

Authority	Program	EPA Region	Identification Number	Expiration Date
Illinois	NELAP	5	200005	06-30-19

The following analytes are included in this report, but the laboratory is not certified by the governing authority. This list may include analytes for which the agency does not offer certification.

Analysis Method	Prep Method	Matrix	Analyte
2540G		Solid	Percent Moisture
2540G		Solid	Percent Solids
EPA 6020A	3010A	Solid	Lithium
SM 2510B		Solid	Specific Conductance
SM 2580B		Solid	Oxidation Reduction Potential

Sample Summary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-1

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
180-85447-1	ABB PRETEST	Solid	01/04/19 11:10	01/05/19 09:30
180-85447-2	ABB pH 13.0	Solid	01/04/19 11:10	01/05/19 09:30
180-85447-3	ABB pH 12.0	Solid	01/04/19 11:10	01/05/19 09:30
180-85447-4	ABB pH 10.5	Solid	01/04/19 11:10	01/05/19 09:30
180-85447-6	ABB pH 8.0	Solid	01/04/19 11:10	01/05/19 09:30
180-85447-7	ABB pH 7.0	Solid	01/04/19 11:10	01/05/19 09:30
180-85447-8	ABB pH 5.5	Solid	01/04/19 11:10	01/05/19 09:30
180-85447-9	ABB pH 4.0	Solid	01/04/19 11:10	01/05/19 09:30
180-85447-10	ABB pH 2.0	Solid	01/04/19 11:10	01/05/19 09:30
180-85447-11	ABB pH NATURAL	Solid	01/04/19 11:10	01/05/19 09:30
180-85447-12	ASB PRETEST	Solid	01/04/19 11:45	01/05/19 09:30
180-85447-13	ASB pH 13.0	Solid	01/04/19 11:45	01/05/19 09:30
180-85447-14	ASB pH 12.0	Solid	01/04/19 11:45	01/05/19 09:30
180-85447-15	ASB pH 10.5	Solid	01/04/19 11:45	01/05/19 09:30
180-85447-17	ASB pH 8.0	Solid	01/04/19 11:45	01/05/19 09:30
180-85447-18	ASB pH 7.0	Solid	01/04/19 11:45	01/05/19 09:30
180-85447-19	ASB pH 5.5	Solid	01/04/19 11:45	01/05/19 09:30
180-85447-20	ASB pH 4.0	Solid	01/04/19 11:45	01/05/19 09:30
180-85447-21	ASB pH 2.0	Solid	01/04/19 11:45	01/05/19 09:30
180-85447-22	ASB pH NATURAL	Solid	01/04/19 11:45	01/05/19 09:30
180-85447-23	MB LOW	Solid	01/04/19 00:00	01/05/19 09:30
180-85447-24	MB NATURAL	Solid	01/04/19 00:00	01/05/19 09:30
180-85447-25	MB HIGH	Solid	01/04/19 00:00	01/05/19 09:30
180-85447-49	MB LOW 1	Solid	01/21/19 00:00	01/05/19 09:30
180-85447-51	MB LOW 2	Solid	01/31/19 00:00	01/05/19 09:30

Method Summary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-1

Method	Method Description	Protocol	Laboratory
EPA 9056A	Anions, Ion Chromatography	SW846	TAL PIT
EPA 6020A	Metals (ICP/MS)	SW846	TAL PIT
EPA 7470A	Mercury (CVAA)	SW846	TAL PIT
2540G	SM 2540G	SM22	TAL PIT
EPA 9040C	pH	SW846	TAL PIT
SM 2510B	Conductivity, Specific Conductance	SM	TAL PIT
SM 2580B	Reduction-Oxidation (REDOX) Potential	SM	TAL PIT
1313	Liquid-Solid Partitioning as a Function of pH via Parallel Batch	SW846	TAL PIT
3010A	Preparation, Total Metals	SW846	TAL PIT
7470A	Preparation, Mercury	SW846	TAL PIT

Protocol References:

SM = "Standard Methods For The Examination Of Water And Wastewater"

SM22 = Standard Methods For The Examination Of Water And Wastewater, 22nd Edition

SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.

Laboratory References:

TAL PIT = TestAmerica Pittsburgh, 301 Alpha Drive, RIDC Park, Pittsburgh, PA 15238, TEL (412)963-7058

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Client Sample ID: ABB PRETEST

Lab Sample ID: 180-85447-1
Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	2540G		1			267637	01/11/19 08:56	JMS	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268604	01/23/19 07:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ABB pH 13.0

Lab Sample ID: 180-85447-2
Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9056A		5			268208	01/18/19 11:10	CMR	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 17:20	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268204	01/17/19 17:47	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

1 2 3 4 5 6 7 8 9 10 11 12 13

Client Sample ID: ABB pH 12.0

Lab Sample ID: 180-85447-3

Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9056A		1			268079	01/17/19 14:37	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 17:30	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268204	01/17/19 17:48	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ABB pH 10.5

Lab Sample ID: 180-85447-4

Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	EPA 9056A		10			268298	01/19/19 10:55	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268263	01/18/19 12:59	NAM	TAL PIT
Leach	Analysis	EPA 6020A		1			268357	01/19/19 17:28	WTR	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268340	01/21/19 10:49	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268542	01/22/19 18:02	KA	TAL PIT
	Instrument ID: HGZ									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268260	01/18/19 10:20	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268262	01/18/19 10:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT

Client Sample ID: ABB pH 10.5

Lab Sample ID: 180-85447-4

Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Analysis	SM 2580B		1			268261	01/18/19 10:20	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ABB pH 8.0

Lab Sample ID: 180-85447-6

Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9056A		1			268079	01/17/19 14:53	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 17:34	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268204	01/17/19 17:49	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ABB pH 7.0

Lab Sample ID: 180-85447-7

Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9056A		1			268079	01/17/19 15:08	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 17:37	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT

Client Sample ID: ABB pH 7.0 — Lab Sample ID: 180-85447-7

Date Collected: 01/04/19 11:10 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Analysis	EPA 7470A		1			268204	01/17/19 17:50	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ABB pH 5.5 — Lab Sample ID: 180-85447-8

Date Collected: 01/04/19 11:10 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	EPA 9056A		5			268298	01/19/19 11:10	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268263	01/18/19 12:59	NAM	TAL PIT
Leach	Analysis	EPA 6020A		1			268357	01/19/19 17:32	WTR	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268340	01/21/19 10:49	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268542	01/22/19 18:03	KA	TAL PIT
	Instrument ID: HGZ									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268260	01/18/19 10:20	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268262	01/18/19 10:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268261	01/18/19 10:20	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ABB pH 4.0 — Lab Sample ID: 180-85447-9

Date Collected: 01/04/19 11:10 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT

1 2 3 4 5 6 7 8 9 10 11 12 13

Client Sample ID: ABB pH 4.0 — Lab Sample ID: 180-85447-9
Date Collected: 01/04/19 11:10 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Analysis	EPA 9056A		10			268298	01/19/19 11:25	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268263	01/18/19 12:59	NAM	TAL PIT
Leach	Analysis	EPA 6020A		1			268357	01/19/19 17:35	WTR	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268340	01/21/19 10:49	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268542	01/22/19 18:04	KA	TAL PIT
	Instrument ID: HGZ									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268260	01/18/19 10:20	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268262	01/18/19 10:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268261	01/18/19 10:20	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ABB pH 2.0 — Lab Sample ID: 180-85447-10
Date Collected: 01/04/19 11:10 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	935.4 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Analysis	EPA 9056A		50			269858	02/07/19 23:30	CMR	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	935.4 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	269867	02/07/19 11:53	NAM	TAL PIT
Leach	Analysis	EPA 6020A		10	1.0 mL	1.0 mL	270330	02/12/19 18:46	WTR	TAL PIT
	Instrument ID: X									
Leach	Leach	1313			95 g	935.4 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	269834	02/07/19 10:44	RJR	TAL PIT
Leach	Analysis	EPA 7470A		1			269950	02/08/19 10:23	RJR	TAL PIT
	Instrument ID: HGZ									
Leach	Leach	1313			95 g	935.4 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Analysis	EPA 9040C		1			269862	02/07/19 08:30	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Analysis	SM 2510B		1			269868	02/07/19 08:30	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Analysis	SM 2580B		1			269865	02/07/19 08:30	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ABB pH NATURAL

Lab Sample ID: 180-85447-11

Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9056A		1			268079	01/17/19 12:00	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 17:40	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268204	01/17/19 17:45	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ASB PRETEST

Lab Sample ID: 180-85447-12

Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	2540G		1			267637	01/11/19 08:56	JMS	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268604	01/23/19 07:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ASB pH 13.0

Lab Sample ID: 180-85447-13

Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT

Client Sample ID: ASB pH 13.0

Lab Sample ID: 180-85447-13

Date Collected: 01/04/19 11:45
Date Received: 01/05/19 09:30
Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Analysis	EPA 9056A		5			268208	01/18/19 11:26	CMR	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 17:43	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268204	01/17/19 17:51	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ASB pH 12.0

Lab Sample ID: 180-85447-14

Date Collected: 01/04/19 11:45
Date Received: 01/05/19 09:30
Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9056A		5			268079	01/17/19 18:02	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 17:47	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268204	01/17/19 17:56	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ASB pH 10.5

Lab Sample ID: 180-85447-15
Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9056A		1			268079	01/17/19 15:24	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 17:50	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268204	01/17/19 17:57	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ASB pH 8.0

Lab Sample ID: 180-85447-17
Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9056A		1			268079	01/17/19 15:40	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 17:53	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268204	01/17/19 17:58	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT

1 2 3 4 5 6 7 8 9 10 11 12 13

Client Sample ID: ASB pH 8.0 — Lab Sample ID: 180-85447-17

Date Collected: 01/04/19 11:45 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ASB pH 7.0 — Lab Sample ID: 180-85447-18

Date Collected: 01/04/19 11:45 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9056A		2.5			268079	01/17/19 18:18	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 17:57	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268204	01/17/19 17:59	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ASB pH 5.5 — Lab Sample ID: 180-85447-19

Date Collected: 01/04/19 11:45 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	936.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	EPA 9056A		10			268298	01/19/19 11:41	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	936.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268263	01/18/19 12:59	NAM	TAL PIT
Leach	Analysis	EPA 6020A		1			268357	01/19/19 17:38	WTR	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	936.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268340	01/21/19 10:49	KA	TAL PIT

Client Sample ID: ASB pH 5.5
Lab Sample ID: 180-85447-19
Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Analysis	EPA 7470A		1			268542	01/22/19 18:05	KA	TAL PIT
	Instrument ID: HGZ									
Leach	Leach	1313			95 g	936.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268260	01/18/19 10:20	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268262	01/18/19 10:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268261	01/18/19 10:20	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ASB pH 4.0
Lab Sample ID: 180-85447-20
Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	935.4 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Analysis	EPA 9056A		25			268716	01/24/19 19:53	CMR	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	935.4 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268586	01/23/19 12:55	NAM	TAL PIT
Leach	Analysis	EPA 6020A		10			268821	01/25/19 14:30	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	935.4 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	269197	01/31/19 07:10	RJR	TAL PIT
Leach	Analysis	EPA 7470A		1			269298	01/31/19 16:42	RJR	TAL PIT
	Instrument ID: HGZ									
Leach	Leach	1313			95 g	935.4 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268604	01/23/19 07:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268609	01/23/19 07:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268608	01/23/19 07:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ASB pH 2.0
Lab Sample ID: 180-85447-21
Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	936.4 mL	269578	02/05/19 08:30	MTW	TAL PIT

Client Sample ID: ASB pH 2.0 — Lab Sample ID: 180-85447-21

Date Collected: 01/04/19 11:45 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Analysis	EPA 9056A		50			269858	02/07/19 23:46	CMR	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	936.4 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	269867	02/07/19 11:53	NAM	TAL PIT
Leach	Analysis	EPA 6020A		10	1.0 mL	1.0 mL	270330	02/12/19 18:51	WTR	TAL PIT
	Instrument ID: X									
Leach	Leach	1313			95 g	936.4 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	269834	02/07/19 10:44	RJR	TAL PIT
Leach	Analysis	EPA 7470A		1			269950	02/08/19 10:22	RJR	TAL PIT
	Instrument ID: HGZ									
Leach	Leach	1313			95 g	936.4 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Analysis	EPA 9040C		1			269862	02/07/19 08:30	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Analysis	SM 2510B		1			269868	02/07/19 08:30	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Analysis	SM 2580B		1			269865	02/07/19 08:30	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ASB pH NATURAL — Lab Sample ID: 180-85447-22

Date Collected: 01/04/19 11:45 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9056A		1			268079	01/17/19 10:28	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 18:00	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268204	01/17/19 17:46	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	936.4 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Lab Chronicle

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-1

Client Sample ID: MB LOW

Lab Sample ID: 180-85447-23

Date Collected: 01/04/19 00:00
Date Received: 01/05/19 09:30

Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			1.0 g	950 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	EPA 9056A		100			268298	01/19/19 11:56	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			1.0 g	950 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268263	01/18/19 12:59	NAM	TAL PIT
Leach	Analysis	EPA 6020A		1			268357	01/19/19 17:41	WTR	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			1.0 g	950 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268340	01/21/19 10:49	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268542	01/22/19 18:06	KA	TAL PIT
	Instrument ID: HGZ									
Leach	Leach	1313			1.0 g	950 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268260	01/18/19 10:20	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			1.0 g	950 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268262	01/18/19 10:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			1.0 g	950 mL	268246	01/16/19 10:20	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268261	01/18/19 10:20	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: MB NATURAL

Lab Sample ID: 180-85447-24

Date Collected: 01/04/19 00:00
Date Received: 01/05/19 09:30

Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			1.0 g	950 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9056A		1			268079	01/17/19 10:43	MJH	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			1.0 g	950 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 18:10	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			1.0 g	950 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268204	01/17/19 18:03	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			1.0 g	950 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			1.0 g	950 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			1.0 g	950 mL	268040	01/14/19 09:05	LWM	TAL PIT

Client Sample ID: MB NATURAL — Lab Sample ID: 180-85447-24

Date Collected: 01/04/19 00:00 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: MB HIGH — Lab Sample ID: 180-85447-25

Date Collected: 01/04/19 00:00 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			1.0 g	950 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9056A		5			268208	01/18/19 11:41	CMR	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			1.0 g	950 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268107	01/17/19 07:12	RJR	TAL PIT
Leach	Analysis	EPA 6020A		1			268295	01/18/19 18:13	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			1.0 g	950 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	268065	01/16/19 15:06	KA	TAL PIT
Leach	Analysis	EPA 7470A		1			268204	01/17/19 18:00	KA	TAL PIT
	Instrument ID: HGY									
Leach	Leach	1313			1.0 g	950 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268135	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			1.0 g	950 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268142	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			1.0 g	950 mL	268040	01/14/19 09:05	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268140	01/16/19 09:05	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: MB LOW 1 — Lab Sample ID: 180-85447-49

Date Collected: 01/21/19 00:00 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			1.0 g	950 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Analysis	EPA 9056A		100			268716	01/24/19 20:09	CMR	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			1.0 g	950 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268586	01/23/19 12:55	NAM	TAL PIT
Leach	Analysis	EPA 6020A		1			268763	01/24/19 18:46	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			1.0 g	950 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	268586	01/23/19 12:55	NAM	TAL PIT

Client Sample ID: MB LOW 1

Lab Sample ID: 180-85447-49
Date Collected: 01/21/19 00:00
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Analysis	EPA 6020A		1			268821	01/25/19 14:33	RSK	TAL PIT
	Instrument ID: A									
Leach	Leach	1313			1.0 g	950 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	269197	01/31/19 07:10	RJR	TAL PIT
Leach	Analysis	EPA 7470A		1			269298	01/31/19 16:43	RJR	TAL PIT
	Instrument ID: HGZ									
Leach	Leach	1313			1.0 g	950 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Analysis	EPA 9040C		1			268604	01/23/19 07:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			1.0 g	950 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Analysis	SM 2510B		1			268609	01/23/19 07:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			1.0 g	950 mL	268574	01/21/19 07:40	LWM	TAL PIT
Leach	Analysis	SM 2580B		1			268608	01/23/19 07:40	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: MB LOW 2

Lab Sample ID: 180-85447-51
Date Collected: 01/31/19 00:00
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			1.0 g	950 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Analysis	EPA 9056A		100			269858	02/08/19 00:02	CMR	TAL PIT
	Instrument ID: CHIC2100A									
Leach	Leach	1313			1.0 g	950 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Prep	3010A			50 mL	50 mL	269867	02/07/19 11:53	NAM	TAL PIT
Leach	Analysis	EPA 6020A		1			269977	02/08/19 00:37	WTR	TAL PIT
	Instrument ID: M									
Leach	Leach	1313			1.0 g	950 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Prep	7470A			50 mL	50 mL	269834	02/07/19 10:44	RJR	TAL PIT
Leach	Analysis	EPA 7470A		1			269950	02/08/19 10:21	RJR	TAL PIT
	Instrument ID: HGZ									
Leach	Leach	1313			1.0 g	950 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Analysis	EPA 9040C		1			269862	02/07/19 08:30	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			1.0 g	950 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Analysis	SM 2510B		1			269868	02/07/19 08:30	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			1.0 g	950 mL	269578	02/05/19 08:30	MTW	TAL PIT
Leach	Analysis	SM 2580B		1			269865	02/07/19 08:30	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Laboratory References:

TAL PIT = TestAmerica Pittsburgh, 301 Alpha Drive, RIDC Park, Pittsburgh, PA 15238, TEL (412)963-7058

Lab Chronicle

Analyst References:

Lab: TAL PIT

Batch Type: Leach

LWM = Larry Matko

MTW = Michael Wesoloski

Batch Type: Prep

KA = Kayla Kalamasz

NAM = Nicole Marfisi

RJR = Ron Rosenbaum

Batch Type: Analysis

CMR = Carl Reagle

JMS = Jessica Scalise

KA = Kayla Kalamasz

MJH = Matthew Hartman

MTW = Michael Wesoloski

RJR = Ron Rosenbaum

RSK = Robert Kurtz

WTR = Bill Reinheimer

Client Sample Results

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-1

Client Sample ID: ABB PRETEST

Lab Sample ID: 180-85447-1

Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Moisture	1.4		0.1	0.1	%			01/11/19 08:56	1
Percent Solids	98.6		0.1	0.1	%			01/11/19 08:56	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	6.7		0.1	0.1	SU			01/16/19 09:05	1
pH	6.1		0.1	0.1	SU			01/16/19 09:05	1
pH	12.5		0.1	0.1	SU			01/16/19 09:05	1
pH	3.6		0.1	0.1	SU			01/23/19 07:40	1

Client Sample ID: ABB pH 13.0

Lab Sample ID: 180-85447-2

Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	0.62		0.50	0.13	mg/L			01/18/19 11:10	5

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	5.5		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 17:20	1
Barium	150		10	0.37	ug/L		01/17/19 07:12	01/18/19 17:20	1
Cadmium	0.20	J	1.0	0.13	ug/L		01/17/19 07:12	01/18/19 17:20	1
Beryllium	0.14	J	1.0	0.057	ug/L		01/17/19 07:12	01/18/19 17:20	1
Chromium	4.7		2.0	0.63	ug/L		01/17/19 07:12	01/18/19 17:20	1
Lead	2.1	B	1.0	0.094	ug/L		01/17/19 07:12	01/18/19 17:20	1
Selenium	1.6	J	5.0	0.81	ug/L		01/17/19 07:12	01/18/19 17:20	1
Cobalt	1.6		0.50	0.075	ug/L		01/17/19 07:12	01/18/19 17:20	1
Molybdenum	1.6	J	5.0	0.47	ug/L		01/17/19 07:12	01/18/19 17:20	1
Antimony	ND		2.0	1.1	ug/L		01/17/19 07:12	01/18/19 17:20	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 17:20	1
Lithium	ND		5.0	2.6	ug/L		01/17/19 07:12	01/18/19 17:20	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 17:47	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	12.7		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	20000		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	- 166		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: ABB pH 12.0

Lab Sample ID: 180-85447-3

Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	0.88		0.10	0.026	mg/L			01/17/19 14:37	1

Client Sample Results

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-1

Client Sample ID: ABB pH 12.0

Lab Sample ID: 180-85447-3

Date Collected: 01/04/19 11:10
Date Received: 01/05/19 09:30

Matrix: Solid

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	15		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 17:30	1
Barium	440		10	0.37	ug/L		01/17/19 07:12	01/18/19 17:30	1
Cadmium	0.37	J	1.0	0.13	ug/L		01/17/19 07:12	01/18/19 17:30	1
Beryllium	0.32	J	1.0	0.057	ug/L		01/17/19 07:12	01/18/19 17:30	1
Chromium	17		2.0	0.63	ug/L		01/17/19 07:12	01/18/19 17:30	1
Lead	5.8	B	1.0	0.094	ug/L		01/17/19 07:12	01/18/19 17:30	1
Selenium	5.4		5.0	0.81	ug/L		01/17/19 07:12	01/18/19 17:30	1
Cobalt	3.6		0.50	0.075	ug/L		01/17/19 07:12	01/18/19 17:30	1
Molybdenum	6.0		5.0	0.47	ug/L		01/17/19 07:12	01/18/19 17:30	1
Antimony	2.1		2.0	1.1	ug/L		01/17/19 07:12	01/18/19 17:30	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 17:30	1
Lithium	3.8	J	5.0	2.6	ug/L		01/17/19 07:12	01/18/19 17:30	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	0.082	J	0.20	0.065	ug/L		01/16/19 15:06	01/17/19 17:48	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	11.5		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	1200		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	- 25		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: ABB pH 10.5

Lab Sample ID: 180-85447-4

Date Collected: 01/04/19 11:10
Date Received: 01/05/19 09:30

Matrix: Solid

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	0.95	J	1.0	0.26	mg/L			01/19/19 10:55	10

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	10		1.0	0.32	ug/L		01/18/19 12:59	01/19/19 17:28	1
Barium	390		10	0.37	ug/L		01/18/19 12:59	01/19/19 17:28	1
Cadmium	0.35	J	1.0	0.13	ug/L		01/18/19 12:59	01/19/19 17:28	1
Beryllium	0.18	J	1.0	0.057	ug/L		01/18/19 12:59	01/19/19 17:28	1
Chromium	13		2.0	0.63	ug/L		01/18/19 12:59	01/19/19 17:28	1
Lead	3.9		1.0	0.094	ug/L		01/18/19 12:59	01/19/19 17:28	1
Selenium	3.2	J	5.0	0.81	ug/L		01/18/19 12:59	01/19/19 17:28	1
Cobalt	2.9		0.50	0.075	ug/L		01/18/19 12:59	01/19/19 17:28	1
Molybdenum	6.7		5.0	0.47	ug/L		01/18/19 12:59	01/19/19 17:28	1
Antimony	2.0		2.0	1.1	ug/L		01/18/19 12:59	01/19/19 17:28	1
Thallium	0.091	J	1.0	0.063	ug/L		01/18/19 12:59	01/19/19 17:28	1
Lithium	3.0	J	5.0	2.6	ug/L		01/18/19 12:59	01/19/19 17:28	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/21/19 10:49	01/22/19 18:02	1

Client Sample ID: ABB pH 10.5
Lab Sample ID: 180-85447-4
Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	10.8		0.1	0.1	SU			01/18/19 10:20	1
Specific Conductance	590		1.0	1.0	umhos/cm			01/18/19 10:40	1
Oxidation Reduction Potential	96		10	10	millivolts			01/18/19 10:20	1

Client Sample ID: ABB pH 8.0
Lab Sample ID: 180-85447-6
Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	0.72		0.10	0.026	mg/L			01/17/19 14:53	1

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	2.2		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 17:34	1
Barium	340		10	0.37	ug/L		01/17/19 07:12	01/18/19 17:34	1
Cadmium	ND		1.0	0.13	ug/L		01/17/19 07:12	01/18/19 17:34	1
Beryllium	ND		1.0	0.057	ug/L		01/17/19 07:12	01/18/19 17:34	1
Chromium	1.9	J	2.0	0.63	ug/L		01/17/19 07:12	01/18/19 17:34	1
Lead	ND		1.0	0.094	ug/L		01/17/19 07:12	01/18/19 17:34	1
Selenium	ND		5.0	0.81	ug/L		01/17/19 07:12	01/18/19 17:34	1
Cobalt	0.095	J	0.50	0.075	ug/L		01/17/19 07:12	01/18/19 17:34	1
Molybdenum	3.6	J	5.0	0.47	ug/L		01/17/19 07:12	01/18/19 17:34	1
Antimony	ND		2.0	1.1	ug/L		01/17/19 07:12	01/18/19 17:34	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 17:34	1
Lithium	5.0		5.0	2.6	ug/L		01/17/19 07:12	01/18/19 17:34	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 17:49	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	7.9		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	650		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	170		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: ABB pH 7.0
Lab Sample ID: 180-85447-7
Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	0.58		0.10	0.026	mg/L			01/17/19 15:08	1

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	2.3		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 17:37	1
Barium	840		10	0.37	ug/L		01/17/19 07:12	01/18/19 17:37	1
Cadmium	ND		1.0	0.13	ug/L		01/17/19 07:12	01/18/19 17:37	1
Beryllium	ND		1.0	0.057	ug/L		01/17/19 07:12	01/18/19 17:37	1

Client Sample ID: ABB pH 7.0 — Lab Sample ID: 180-85447-7

Date Collected: 01/04/19 11:10 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Method: EPA 6020A - Metals (ICP/MS) - Leach (Continued)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chromium	1.7	J	2.0	0.63	ug/L		01/17/19 07:12	01/18/19 17:37	1
Lead	ND		1.0	0.094	ug/L		01/17/19 07:12	01/18/19 17:37	1
Selenium	ND		5.0	0.81	ug/L		01/17/19 07:12	01/18/19 17:37	1
Cobalt	0.23	J	0.50	0.075	ug/L		01/17/19 07:12	01/18/19 17:37	1
Molybdenum	3.4	J	5.0	0.47	ug/L		01/17/19 07:12	01/18/19 17:37	1
Antimony	ND		2.0	1.1	ug/L		01/17/19 07:12	01/18/19 17:37	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 17:37	1
Lithium	7.4		5.0	2.6	ug/L		01/17/19 07:12	01/18/19 17:37	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 17:50	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	7.2		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	1300		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	210		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: ABB pH 5.5 — Lab Sample ID: 180-85447-8

Date Collected: 01/04/19 11:10 — **Matrix: Solid**
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		0.50	0.13	mg/L			01/19/19 11:10	5

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	1.1		1.0	0.32	ug/L		01/18/19 12:59	01/19/19 17:32	1
Barium	2600		10	0.37	ug/L		01/18/19 12:59	01/19/19 17:32	1
Cadmium	0.55	J	1.0	0.13	ug/L		01/18/19 12:59	01/19/19 17:32	1
Beryllium	ND		1.0	0.057	ug/L		01/18/19 12:59	01/19/19 17:32	1
Chromium	1.7	J	2.0	0.63	ug/L		01/18/19 12:59	01/19/19 17:32	1
Lead	ND		1.0	0.094	ug/L		01/18/19 12:59	01/19/19 17:32	1
Selenium	0.85	J	5.0	0.81	ug/L		01/18/19 12:59	01/19/19 17:32	1
Cobalt	6.7		0.50	0.075	ug/L		01/18/19 12:59	01/19/19 17:32	1
Molybdenum	3.3	J	5.0	0.47	ug/L		01/18/19 12:59	01/19/19 17:32	1
Antimony	ND		2.0	1.1	ug/L		01/18/19 12:59	01/19/19 17:32	1
Thallium	0.15	J	1.0	0.063	ug/L		01/18/19 12:59	01/19/19 17:32	1
Lithium	34		5.0	2.6	ug/L		01/18/19 12:59	01/19/19 17:32	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/21/19 10:49	01/22/19 18:03	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	5.9		0.1	0.1	SU			01/18/19 10:20	1
Specific Conductance	4400		1.0	1.0	umhos/cm			01/18/19 10:40	1
Oxidation Reduction Potential	240		10	10	millivolts			01/18/19 10:20	1

Client Sample ID: ABB pH 4.0
Lab Sample ID: 180-85447-9

Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	3.4		1.0	0.26	mg/L			01/19/19 11:25	10

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	3.5		1.0	0.32	ug/L		01/18/19 12:59	01/19/19 17:35	1
Barium	6900		10	0.37	ug/L		01/18/19 12:59	01/19/19 17:35	1
Cadmium	12		1.0	0.13	ug/L		01/18/19 12:59	01/19/19 17:35	1
Beryllium	16		1.0	0.057	ug/L		01/18/19 12:59	01/19/19 17:35	1
Chromium	29		2.0	0.63	ug/L		01/18/19 12:59	01/19/19 17:35	1
Lead	4.5		1.0	0.094	ug/L		01/18/19 12:59	01/19/19 17:35	1
Selenium	9.1		5.0	0.81	ug/L		01/18/19 12:59	01/19/19 17:35	1
Cobalt	160		0.50	0.075	ug/L		01/18/19 12:59	01/19/19 17:35	1
Molybdenum	0.83	J	5.0	0.47	ug/L		01/18/19 12:59	01/19/19 17:35	1
Antimony	ND		2.0	1.1	ug/L		01/18/19 12:59	01/19/19 17:35	1
Thallium	1.1		1.0	0.063	ug/L		01/18/19 12:59	01/19/19 17:35	1
Lithium	310		5.0	2.6	ug/L		01/18/19 12:59	01/19/19 17:35	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/21/19 10:49	01/22/19 18:04	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	3.8		0.1	0.1	SU			01/18/19 10:20	1
Specific Conductance	14000		1.0	1.0	umhos/cm			01/18/19 10:40	1
Oxidation Reduction Potential	350		10	10	millivolts			01/18/19 10:20	1

Client Sample ID: ABB pH 2.0
Lab Sample ID: 180-85447-10

Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		5.0	1.3	mg/L			02/07/19 23:30	50

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	40		10	3.2	ug/L		02/07/19 11:53	02/12/19 18:46	10
Barium	300000		100	3.7	ug/L		02/07/19 11:53	02/12/19 18:46	10
Cadmium	17		10	1.3	ug/L		02/07/19 11:53	02/12/19 18:46	10
Beryllium	160		10	0.57	ug/L		02/07/19 11:53	02/12/19 18:46	10
Chromium	2400		20	6.3	ug/L		02/07/19 11:53	02/12/19 18:46	10
Lead	180		10	0.94	ug/L		02/07/19 11:53	02/12/19 18:46	10
Selenium	28	J	50	8.1	ug/L		02/07/19 11:53	02/12/19 18:46	10
Cobalt	1300		5.0	0.75	ug/L		02/07/19 11:53	02/12/19 18:46	10
Molybdenum	ND		50	4.7	ug/L		02/07/19 11:53	02/12/19 18:46	10
Antimony	ND		20	11	ug/L		02/07/19 11:53	02/12/19 18:46	10
Thallium	4.7	J	10	0.63	ug/L		02/07/19 11:53	02/12/19 18:46	10
Lithium	2800		50	26	ug/L		02/07/19 11:53	02/12/19 18:46	10

Client Sample Results

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-1

Client Sample ID: ABB pH 2.0

Lab Sample ID: 180-85447-10
Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	0.97		0.20	0.065	ug/L		02/07/19 10:44	02/08/19 10:23	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	2.2		0.1	0.1	SU			02/07/19 08:30	1
Specific Conductance	78000		1.0	1.0	umhos/cm			02/07/19 08:30	1
Oxidation Reduction Potential	590		10	10	millivolts			02/07/19 08:30	1

Client Sample ID: ABB pH NATURAL

Lab Sample ID: 180-85447-11
Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	1.4		0.10	0.026	mg/L			01/17/19 12:00	1

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	4.8		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 17:40	1
Barium	350		10	0.37	ug/L		01/17/19 07:12	01/18/19 17:40	1
Cadmium	0.18	J	1.0	0.13	ug/L		01/17/19 07:12	01/18/19 17:40	1
Beryllium	0.11	J	1.0	0.057	ug/L		01/17/19 07:12	01/18/19 17:40	1
Chromium	8.5		2.0	0.63	ug/L		01/17/19 07:12	01/18/19 17:40	1
Lead	3.3	B	1.0	0.094	ug/L		01/17/19 07:12	01/18/19 17:40	1
Selenium	ND		5.0	0.81	ug/L		01/17/19 07:12	01/18/19 17:40	1
Cobalt	1.4		0.50	0.075	ug/L		01/17/19 07:12	01/18/19 17:40	1
Molybdenum	3.9	J	5.0	0.47	ug/L		01/17/19 07:12	01/18/19 17:40	1
Antimony	ND		2.0	1.1	ug/L		01/17/19 07:12	01/18/19 17:40	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 17:40	1
Lithium	3.4	J	5.0	2.6	ug/L		01/17/19 07:12	01/18/19 17:40	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 17:45	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	9.0		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	210		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	310		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: ASB PRETEST

Lab Sample ID: 180-85447-12
Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Moisture	1.3		0.1	0.1	%			01/11/19 08:56	1
Percent Solids	98.7		0.1	0.1	%			01/11/19 08:56	1

1 2 3 4 5 6 7 8 9 10 11 12 13

Client Sample ID: ASB PRETEST

Lab Sample ID: 180-85447-12

Date Collected: 01/04/19 11:45
Date Received: 01/05/19 09:30

Matrix: Solid

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	8.0		0.1	0.1	SU			01/16/19 09:05	1
pH	7.8		0.1	0.1	SU			01/16/19 09:05	1
pH	4.9		0.1	0.1	SU			01/23/19 07:40	1

Client Sample ID: ASB pH 13.0

Lab Sample ID: 180-85447-13

Date Collected: 01/04/19 11:45
Date Received: 01/05/19 09:30

Matrix: Solid

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	0.62		0.50	0.13	mg/L			01/18/19 11:26	5

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	30		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 17:43	1
Barium	29		10	0.37	ug/L		01/17/19 07:12	01/18/19 17:43	1
Cadmium	ND		1.0	0.13	ug/L		01/17/19 07:12	01/18/19 17:43	1
Beryllium	ND		1.0	0.057	ug/L		01/17/19 07:12	01/18/19 17:43	1
Chromium	3.2		2.0	0.63	ug/L		01/17/19 07:12	01/18/19 17:43	1
Lead	0.43	J B	1.0	0.094	ug/L		01/17/19 07:12	01/18/19 17:43	1
Selenium	11		5.0	0.81	ug/L		01/17/19 07:12	01/18/19 17:43	1
Cobalt	0.97		0.50	0.075	ug/L		01/17/19 07:12	01/18/19 17:43	1
Molybdenum	6.4		5.0	0.47	ug/L		01/17/19 07:12	01/18/19 17:43	1
Antimony	4.1		2.0	1.1	ug/L		01/17/19 07:12	01/18/19 17:43	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 17:43	1
Lithium	ND		5.0	2.6	ug/L		01/17/19 07:12	01/18/19 17:43	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 17:51	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	12.7		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	16000		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	- 86		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: ASB pH 12.0

Lab Sample ID: 180-85447-14

Date Collected: 01/04/19 11:45
Date Received: 01/05/19 09:30

Matrix: Solid

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	2.0		0.50	0.13	mg/L			01/17/19 18:02	5

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	23		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 17:47	1
Barium	30		10	0.37	ug/L		01/17/19 07:12	01/18/19 17:47	1
Cadmium	ND		1.0	0.13	ug/L		01/17/19 07:12	01/18/19 17:47	1
Beryllium	ND		1.0	0.057	ug/L		01/17/19 07:12	01/18/19 17:47	1

Client Sample ID: ASB pH 12.0
Lab Sample ID: 180-85447-14
Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 6020A - Metals (ICP/MS) - Leach (Continued)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chromium	3.9		2.0	0.63	ug/L		01/17/19 07:12	01/18/19 17:47	1
Lead	0.24	J B	1.0	0.094	ug/L		01/17/19 07:12	01/18/19 17:47	1
Selenium	8.8		5.0	0.81	ug/L		01/17/19 07:12	01/18/19 17:47	1
Cobalt	0.39	J	0.50	0.075	ug/L		01/17/19 07:12	01/18/19 17:47	1
Molybdenum	5.6		5.0	0.47	ug/L		01/17/19 07:12	01/18/19 17:47	1
Antimony	3.2		2.0	1.1	ug/L		01/17/19 07:12	01/18/19 17:47	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 17:47	1
Lithium	ND		5.0	2.6	ug/L		01/17/19 07:12	01/18/19 17:47	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 17:56	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	12.4		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	6200		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	- 24		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: ASB pH 10.5
Lab Sample ID: 180-85447-15
Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	1.2		0.10	0.026	mg/L			01/17/19 15:24	1

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	12		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 17:50	1
Barium	44		10	0.37	ug/L		01/17/19 07:12	01/18/19 17:50	1
Cadmium	ND		1.0	0.13	ug/L		01/17/19 07:12	01/18/19 17:50	1
Beryllium	ND		1.0	0.057	ug/L		01/17/19 07:12	01/18/19 17:50	1
Chromium	4.1		2.0	0.63	ug/L		01/17/19 07:12	01/18/19 17:50	1
Lead	0.19	J B	1.0	0.094	ug/L		01/17/19 07:12	01/18/19 17:50	1
Selenium	3.8	J	5.0	0.81	ug/L		01/17/19 07:12	01/18/19 17:50	1
Cobalt	0.21	J	0.50	0.075	ug/L		01/17/19 07:12	01/18/19 17:50	1
Molybdenum	3.8	J	5.0	0.47	ug/L		01/17/19 07:12	01/18/19 17:50	1
Antimony	2.2		2.0	1.1	ug/L		01/17/19 07:12	01/18/19 17:50	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 17:50	1
Lithium	ND		5.0	2.6	ug/L		01/17/19 07:12	01/18/19 17:50	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 17:57	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	10.8		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	760		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	45		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: ASB pH 8.0
Lab Sample ID: 180-85447-17
Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	0.41		0.10	0.026	mg/L			01/17/19 15:40	1

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	2.3		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 17:53	1
Barium	270		10	0.37	ug/L		01/17/19 07:12	01/18/19 17:53	1
Cadmium	ND		1.0	0.13	ug/L		01/17/19 07:12	01/18/19 17:53	1
Beryllium	ND		1.0	0.057	ug/L		01/17/19 07:12	01/18/19 17:53	1
Chromium	1.8	J	2.0	0.63	ug/L		01/17/19 07:12	01/18/19 17:53	1
Lead	ND		1.0	0.094	ug/L		01/17/19 07:12	01/18/19 17:53	1
Selenium	ND		5.0	0.81	ug/L		01/17/19 07:12	01/18/19 17:53	1
Cobalt	0.081	J	0.50	0.075	ug/L		01/17/19 07:12	01/18/19 17:53	1
Molybdenum	2.7	J	5.0	0.47	ug/L		01/17/19 07:12	01/18/19 17:53	1
Antimony	1.1	J	2.0	1.1	ug/L		01/17/19 07:12	01/18/19 17:53	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 17:53	1
Lithium	14		5.0	2.6	ug/L		01/17/19 07:12	01/18/19 17:53	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 17:58	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	8.3		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	720		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	160		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: ASB pH 7.0
Lab Sample ID: 180-85447-18
Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	0.29		0.25	0.066	mg/L			01/17/19 18:18	2.5

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	4.2		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 17:57	1
Barium	1300		10	0.37	ug/L		01/17/19 07:12	01/18/19 17:57	1
Cadmium	ND		1.0	0.13	ug/L		01/17/19 07:12	01/18/19 17:57	1
Beryllium	ND		1.0	0.057	ug/L		01/17/19 07:12	01/18/19 17:57	1
Chromium	1.6	J	2.0	0.63	ug/L		01/17/19 07:12	01/18/19 17:57	1
Lead	ND		1.0	0.094	ug/L		01/17/19 07:12	01/18/19 17:57	1
Selenium	0.96	J	5.0	0.81	ug/L		01/17/19 07:12	01/18/19 17:57	1
Cobalt	0.59		0.50	0.075	ug/L		01/17/19 07:12	01/18/19 17:57	1
Molybdenum	3.4	J	5.0	0.47	ug/L		01/17/19 07:12	01/18/19 17:57	1
Antimony	1.1	J	2.0	1.1	ug/L		01/17/19 07:12	01/18/19 17:57	1
Thallium	0.088	J	1.0	0.063	ug/L		01/17/19 07:12	01/18/19 17:57	1
Lithium	35		5.0	2.6	ug/L		01/17/19 07:12	01/18/19 17:57	1

Client Sample ID: ASB pH 7.0

Lab Sample ID: 180-85447-18
Date Collected: 01/04/19 11:45 Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 17:59	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	7.4		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	4200		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	210		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: ASB pH 5.5

Lab Sample ID: 180-85447-19
Date Collected: 01/04/19 11:45 Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		1.0	0.26	mg/L			01/19/19 11:41	10

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	2.1		1.0	0.32	ug/L		01/18/19 12:59	01/19/19 17:38	1
Barium	2100		10	0.37	ug/L		01/18/19 12:59	01/19/19 17:38	1
Cadmium	1.6		1.0	0.13	ug/L		01/18/19 12:59	01/19/19 17:38	1
Beryllium	ND		1.0	0.057	ug/L		01/18/19 12:59	01/19/19 17:38	1
Chromium	1.7	J	2.0	0.63	ug/L		01/18/19 12:59	01/19/19 17:38	1
Lead	ND		1.0	0.094	ug/L		01/18/19 12:59	01/19/19 17:38	1
Selenium	1.2	J	5.0	0.81	ug/L		01/18/19 12:59	01/19/19 17:38	1
Cobalt	33		0.50	0.075	ug/L		01/18/19 12:59	01/19/19 17:38	1
Molybdenum	3.9	J	5.0	0.47	ug/L		01/18/19 12:59	01/19/19 17:38	1
Antimony	ND		2.0	1.1	ug/L		01/18/19 12:59	01/19/19 17:38	1
Thallium	0.40	J	1.0	0.063	ug/L		01/18/19 12:59	01/19/19 17:38	1
Lithium	140		5.0	2.6	ug/L		01/18/19 12:59	01/19/19 17:38	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/21/19 10:49	01/22/19 18:05	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	5.7		0.1	0.1	SU			01/18/19 10:20	1
Specific Conductance	15000		1.0	1.0	umhos/cm			01/18/19 10:40	1
Oxidation Reduction Potential	240		10	10	millivolts			01/18/19 10:20	1

Client Sample ID: ASB pH 4.0

Lab Sample ID: 180-85447-20
Date Collected: 01/04/19 11:45 Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	7.9		2.5	0.66	mg/L			01/24/19 19:53	25

1 2 3 4 5 6 7 8 9 10 11 12 13

Client Sample ID: ASB pH 4.0
Lab Sample ID: 180-85447-20
Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	14		10	3.2	ug/L		01/23/19 12:55	01/25/19 14:30	10
Barium	3800		100	3.7	ug/L		01/23/19 12:55	01/25/19 14:30	10
Cadmium	29		10	1.3	ug/L		01/23/19 12:55	01/25/19 14:30	10
Beryllium	22		10	0.57	ug/L		01/23/19 12:55	01/25/19 14:30	10
Chromium	21	B	20	6.3	ug/L		01/23/19 12:55	01/25/19 14:30	10
Lead	5.9	J	10	0.94	ug/L		01/23/19 12:55	01/25/19 14:30	10
Selenium	32	J	50	8.1	ug/L		01/23/19 12:55	01/25/19 14:30	10
Cobalt	360		5.0	0.75	ug/L		01/23/19 12:55	01/25/19 14:30	10
Molybdenum	ND		50	4.7	ug/L		01/23/19 12:55	01/25/19 14:30	10
Antimony	ND		20	11	ug/L		01/23/19 12:55	01/25/19 14:30	10
Thallium	2.3	J	10	0.63	ug/L		01/23/19 12:55	01/25/19 14:30	10
Lithium	520		50	26	ug/L		01/23/19 12:55	01/25/19 14:30	10

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/31/19 07:10	01/31/19 16:42	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	4.1		0.1	0.1	SU			01/23/19 07:40	1
Specific Conductance	26000		1.0	1.0	umhos/cm			01/23/19 07:40	1
Oxidation Reduction Potential	360		10	10	millivolts			01/23/19 07:40	1

Client Sample ID: ASB pH 2.0
Lab Sample ID: 180-85447-21
Date Collected: 01/04/19 11:45
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	1.9	J	5.0	1.3	mg/L			02/07/19 23:46	50

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	42		10	3.2	ug/L		02/07/19 11:53	02/12/19 18:51	10
Barium	50000		100	3.7	ug/L		02/07/19 11:53	02/12/19 18:51	10
Cadmium	37		10	1.3	ug/L		02/07/19 11:53	02/12/19 18:51	10
Beryllium	150		10	0.57	ug/L		02/07/19 11:53	02/12/19 18:51	10
Chromium	700		20	6.3	ug/L		02/07/19 11:53	02/12/19 18:51	10
Lead	200		10	0.94	ug/L		02/07/19 11:53	02/12/19 18:51	10
Selenium	41	J	50	8.1	ug/L		02/07/19 11:53	02/12/19 18:51	10
Cobalt	1200		5.0	0.75	ug/L		02/07/19 11:53	02/12/19 18:51	10
Molybdenum	ND		50	4.7	ug/L		02/07/19 11:53	02/12/19 18:51	10
Antimony	ND		20	11	ug/L		02/07/19 11:53	02/12/19 18:51	10
Thallium	8.8	J	10	0.63	ug/L		02/07/19 11:53	02/12/19 18:51	10
Lithium	2400		50	26	ug/L		02/07/19 11:53	02/12/19 18:51	10

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		02/07/19 10:44	02/08/19 10:22	1

Client Sample Results

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-1

Client Sample ID: ASB pH 2.0

Lab Sample ID: 180-85447-21

Date Collected: 01/04/19 11:45
Date Received: 01/05/19 09:30

Matrix: Solid

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	**2.4**		0.1	0.1	SU			02/07/19 08:30	1
Specific Conductance	**77000**		1.0	1.0	umhos/cm			02/07/19 08:30	1
Oxidation Reduction Potential	**550**		10	10	millivolts			02/07/19 08:30	1

Client Sample ID: ASB pH NATURAL

Lab Sample ID: 180-85447-22

Date Collected: 01/04/19 11:45
Date Received: 01/05/19 09:30

Matrix: Solid

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	**0.45**		0.10	0.026	mg/L			01/17/19 10:28	1

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	**3.3**		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 18:00	1
Barium	**150**		10	0.37	ug/L		01/17/19 07:12	01/18/19 18:00	1
Cadmium	ND		1.0	0.13	ug/L		01/17/19 07:12	01/18/19 18:00	1
Beryllium	ND		1.0	0.057	ug/L		01/17/19 07:12	01/18/19 18:00	1
Chromium	**2.0**		2.0	0.63	ug/L		01/17/19 07:12	01/18/19 18:00	1
Lead	ND		1.0	0.094	ug/L		01/17/19 07:12	01/18/19 18:00	1
Selenium	ND		5.0	0.81	ug/L		01/17/19 07:12	01/18/19 18:00	1
Cobalt	ND		0.50	0.075	ug/L		01/17/19 07:12	01/18/19 18:00	1
Molybdenum	**2.9**	**J**	5.0	0.47	ug/L		01/17/19 07:12	01/18/19 18:00	1
Antimony	**1.3**	**J**	2.0	1.1	ug/L		01/17/19 07:12	01/18/19 18:00	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 18:00	1
Lithium	**9.7**		5.0	2.6	ug/L		01/17/19 07:12	01/18/19 18:00	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 17:46	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	**8.6**		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	**300**		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	**180**		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: MB LOW

Lab Sample ID: 180-85447-23

Date Collected: 01/04/19 00:00
Date Received: 01/05/19 09:30

Matrix: Solid

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		10	2.6	mg/L			01/19/19 11:56	100

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	ND		1.0	0.32	ug/L		01/18/19 12:59	01/19/19 17:41	1
Barium	**1.9**	**J**	10	0.37	ug/L		01/18/19 12:59	01/19/19 17:41	1
Cadmium	ND		1.0	0.13	ug/L		01/18/19 12:59	01/19/19 17:41	1
Beryllium	ND		1.0	0.057	ug/L		01/18/19 12:59	01/19/19 17:41	1

Client Sample ID: MB LOW

Lab Sample ID: 180-85447-23

Date Collected: 01/04/19 00:00
Date Received: 01/05/19 09:30

Matrix: Solid

Method: EPA 6020A - Metals (ICP/MS) - Leach (Continued)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Chromium	**1.6**	**J**	2.0	0.63	ug/L		01/18/19 12:59	01/19/19 17:41	1
Lead	ND		1.0	0.094	ug/L		01/18/19 12:59	01/19/19 17:41	1
Selenium	ND		5.0	0.81	ug/L		01/18/19 12:59	01/19/19 17:41	1
Cobalt	ND		0.50	0.075	ug/L		01/18/19 12:59	01/19/19 17:41	1
Molybdenum	ND		5.0	0.47	ug/L		01/18/19 12:59	01/19/19 17:41	1
Antimony	ND		2.0	1.1	ug/L		01/18/19 12:59	01/19/19 17:41	1
Thallium	ND		1.0	0.063	ug/L		01/18/19 12:59	01/19/19 17:41	1
Lithium	ND		5.0	2.6	ug/L		01/18/19 12:59	01/19/19 17:41	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/21/19 10:49	01/22/19 18:06	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	**0.8**		0.1	0.1	SU			01/18/19 10:20	1
Specific Conductance	**120000**		1.0	1.0	umhos/cm			01/18/19 10:40	1
Oxidation Reduction Potential	**580**		10	10	millivolts			01/18/19 10:20	1

Client Sample ID: MB NATURAL

Lab Sample ID: 180-85447-24

Date Collected: 01/04/19 00:00
Date Received: 01/05/19 09:30

Matrix: Solid

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		0.10	0.026	mg/L			01/17/19 10:43	1

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	ND		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 18:10	1
Barium	**7.5**	**J**	10	0.37	ug/L		01/17/19 07:12	01/18/19 18:10	1
Cadmium	ND		1.0	0.13	ug/L		01/17/19 07:12	01/18/19 18:10	1
Beryllium	ND		1.0	0.057	ug/L		01/17/19 07:12	01/18/19 18:10	1
Chromium	**1.8**	**J**	2.0	0.63	ug/L		01/17/19 07:12	01/18/19 18:10	1
Lead	ND		1.0	0.094	ug/L		01/17/19 07:12	01/18/19 18:10	1
Selenium	ND		5.0	0.81	ug/L		01/17/19 07:12	01/18/19 18:10	1
Cobalt	ND		0.50	0.075	ug/L		01/17/19 07:12	01/18/19 18:10	1
Molybdenum	ND		5.0	0.47	ug/L		01/17/19 07:12	01/18/19 18:10	1
Antimony	ND		2.0	1.1	ug/L		01/17/19 07:12	01/18/19 18:10	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 18:10	1
Lithium	ND		5.0	2.6	ug/L		01/17/19 07:12	01/18/19 18:10	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 18:03	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	**7.5**		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	**4.2**		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	**140**		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: MB HIGH
Lab Sample ID: 180-85447-25
Date Collected: 01/04/19 00:00
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		0.50	0.13	mg/L			01/18/19 11:41	5

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	ND		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 18:13	1
Barium	**1.7**	**J**	10	0.37	ug/L		01/17/19 07:12	01/18/19 18:13	1
Cadmium	ND		1.0	0.13	ug/L		01/17/19 07:12	01/18/19 18:13	1
Beryllium	ND		1.0	0.057	ug/L		01/17/19 07:12	01/18/19 18:13	1
Chromium	**2.1**		2.0	0.63	ug/L		01/17/19 07:12	01/18/19 18:13	1
Lead	ND		1.0	0.094	ug/L		01/17/19 07:12	01/18/19 18:13	1
Selenium	ND		5.0	0.81	ug/L		01/17/19 07:12	01/18/19 18:13	1
Cobalt	ND		0.50	0.075	ug/L		01/17/19 07:12	01/18/19 18:13	1
Molybdenum	ND		5.0	0.47	ug/L		01/17/19 07:12	01/18/19 18:13	1
Antimony	ND		2.0	1.1	ug/L		01/17/19 07:12	01/18/19 18:13	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 18:13	1
Lithium	ND		5.0	2.6	ug/L		01/17/19 07:12	01/18/19 18:13	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 18:00	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	**12.8**		0.1	0.1	SU			01/16/19 09:05	1
Specific Conductance	**23000**		1.0	1.0	umhos/cm			01/16/19 09:05	1
Oxidation Reduction Potential	**- 34**		10	10	millivolts			01/16/19 09:05	1

Client Sample ID: MB LOW 1
Lab Sample ID: 180-85447-49
Date Collected: 01/21/19 00:00
Matrix: Solid
Date Received: 01/05/19 09:30

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		10	2.6	mg/L			01/24/19 20:09	100

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	ND		1.0	0.32	ug/L		01/23/19 12:55	01/24/19 18:46	1
Barium	**2.5**	**J**	10	0.37	ug/L		01/23/19 12:55	01/24/19 18:46	1
Cadmium	ND		1.0	0.13	ug/L		01/23/19 12:55	01/24/19 18:46	1
Beryllium	ND		1.0	0.057	ug/L		01/23/19 12:55	01/24/19 18:46	1
Chromium	**1.4**	**J B**	2.0	0.63	ug/L		01/23/19 12:55	01/24/19 18:46	1
Lead	ND		1.0	0.094	ug/L		01/23/19 12:55	01/24/19 18:46	1
Selenium	ND		5.0	0.81	ug/L		01/23/19 12:55	01/24/19 18:46	1
Cobalt	ND		0.50	0.075	ug/L		01/23/19 12:55	01/24/19 18:46	1
Molybdenum	ND		5.0	0.47	ug/L		01/23/19 12:55	01/24/19 18:46	1
Antimony	ND		2.0	1.1	ug/L		01/23/19 12:55	01/24/19 18:46	1
Thallium	ND		1.0	0.063	ug/L		01/23/19 12:55	01/24/19 18:46	1
Lithium	**3.2**	**J**	5.0	2.6	ug/L		01/23/19 12:55	01/25/19 14:33	1

Client Sample Results

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-1

Client Sample ID: MB LOW 1

Lab Sample ID: 180-85447-49

Date Collected: 01/21/19 00:00
Date Received: 01/05/19 09:30

Matrix: Solid

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/31/19 07:10	01/31/19 16:43	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	**0.8**		0.1	0.1	SU			01/23/19 07:40	1
Specific Conductance	**120000**		1.0	1.0	umhos/cm			01/23/19 07:40	1
Oxidation Reduction Potential	**600**		10	10	millivolts			01/23/19 07:40	1

Client Sample ID: MB LOW 2

Lab Sample ID: 180-85447-51

Date Collected: 01/31/19 00:00
Date Received: 01/05/19 09:30

Matrix: Solid

Method: EPA 9056A - Anions, Ion Chromatography - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		10	2.6	mg/L			02/08/19 00:02	100

Method: EPA 6020A - Metals (ICP/MS) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	ND		1.0	0.32	ug/L		02/07/19 11:53	02/08/19 00:37	1
Barium	ND		10	0.37	ug/L		02/07/19 11:53	02/08/19 00:37	1
Cadmium	ND		1.0	0.13	ug/L		02/07/19 11:53	02/08/19 00:37	1
Beryllium	ND		1.0	0.057	ug/L		02/07/19 11:53	02/08/19 00:37	1
Chromium	**0.74**	**J**	2.0	0.63	ug/L		02/07/19 11:53	02/08/19 00:37	1
Lead	ND		1.0	0.094	ug/L		02/07/19 11:53	02/08/19 00:37	1
Selenium	ND		5.0	0.81	ug/L		02/07/19 11:53	02/08/19 00:37	1
Cobalt	ND		0.50	0.075	ug/L		02/07/19 11:53	02/08/19 00:37	1
Molybdenum	**0.85**	**J**	5.0	0.47	ug/L		02/07/19 11:53	02/08/19 00:37	1
Antimony	ND		2.0	1.1	ug/L		02/07/19 11:53	02/08/19 00:37	1
Thallium	ND		1.0	0.063	ug/L		02/07/19 11:53	02/08/19 00:37	1
Lithium	ND		5.0	2.6	ug/L		02/07/19 11:53	02/08/19 00:37	1

Method: EPA 7470A - Mercury (CVAA) - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		02/07/19 10:44	02/08/19 10:21	1

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	**0.4**		0.1	0.1	SU			02/07/19 08:30	1
Specific Conductance	**100000**	**E**	1.0	1.0	umhos/cm			02/07/19 08:30	1
Oxidation Reduction Potential	**540**		10	10	millivolts			02/07/19 08:30	1

Method: EPA 9056A - Anions, Ion Chromatography

Lab Sample ID: MB 180-268079/6
Matrix: Solid
Analysis Batch: 268079

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		0.10	0.026	mg/L			01/17/19 08:23	1

Lab Sample ID: LCS 180-268079/5
Matrix: Solid
Analysis Batch: 268079

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Fluoride	1.25	1.36		mg/L		109	80 - 120

Lab Sample ID: MB 180-268208/6
Matrix: Solid
Analysis Batch: 268208

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		0.10	0.026	mg/L			01/18/19 10:55	1

Lab Sample ID: LCS 180-268208/5
Matrix: Solid
Analysis Batch: 268208

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Fluoride	1.25	1.15		mg/L		92	80 - 120

Lab Sample ID: MB 180-268298/6
Matrix: Solid
Analysis Batch: 268298

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		0.10	0.026	mg/L			01/19/19 10:04	1

Lab Sample ID: LCS 180-268298/5
Matrix: Solid
Analysis Batch: 268298

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Fluoride	1.25	1.27		mg/L		102	80 - 120

Lab Sample ID: MB 180-268716/6
Matrix: Solid
Analysis Batch: 268716

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		0.10	0.026	mg/L			01/24/19 10:54	1

Lab Sample ID: LCS 180-268716/5
Matrix: Solid
Analysis Batch: 268716

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Fluoride	1.25	1.28		mg/L		102	80 - 120

Lab Sample ID: MB 180-269858/61
Matrix: Solid
Analysis Batch: 269858
Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Fluoride	ND		0.10	0.026	mg/L			02/07/19 20:36	1

Lab Sample ID: LCS 180-269858/60
Matrix: Solid
Analysis Batch: 269858
Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Fluoride	1.25	1.23		mg/L		98	80 - 120

Lab Sample ID: 180-85447-11 MS
Matrix: Solid
Analysis Batch: 268079
Client Sample ID: ABB pH NATURAL
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Fluoride	1.4		1.25	2.46		mg/L		84	80 - 120

Lab Sample ID: 180-85447-11 MSD
Matrix: Solid
Analysis Batch: 268079
Client Sample ID: ABB pH NATURAL
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Fluoride	1.4		1.25	2.43		mg/L		81	80 - 120	2	15

Method: EPA 6020A - Metals (ICP/MS)

Lab Sample ID: MB 180-268107/1-A
Matrix: Solid
Analysis Batch: 268295
Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 268107

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	ND		1.0	0.32	ug/L		01/17/19 07:12	01/18/19 16:37	1
Barium	ND		10	0.37	ug/L		01/17/19 07:12	01/18/19 16:37	1
Cadmium	ND		1.0	0.13	ug/L		01/17/19 07:12	01/18/19 16:37	1
Beryllium	ND		1.0	0.057	ug/L		01/17/19 07:12	01/18/19 16:37	1
Chromium	ND		2.0	0.63	ug/L		01/17/19 07:12	01/18/19 16:37	1
Lead	0.110	J	1.0	0.094	ug/L		01/17/19 07:12	01/18/19 16:37	1
Selenium	ND		5.0	0.81	ug/L		01/17/19 07:12	01/18/19 16:37	1
Cobalt	ND		0.50	0.075	ug/L		01/17/19 07:12	01/18/19 16:37	1
Molybdenum	ND		5.0	0.47	ug/L		01/17/19 07:12	01/18/19 16:37	1
Antimony	ND		2.0	1.1	ug/L		01/17/19 07:12	01/18/19 16:37	1
Thallium	ND		1.0	0.063	ug/L		01/17/19 07:12	01/18/19 16:37	1
Lithium	ND		5.0	2.6	ug/L		01/17/19 07:12	01/18/19 16:37	1

Lab Sample ID: LCS 180-268107/2-A
Matrix: Solid
Analysis Batch: 268295
Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 268107

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Arsenic	40.0	35.4		ug/L		89	80 - 120
Barium	2000	1880		ug/L		94	80 - 120
Cadmium	50.0	50.7		ug/L		101	80 - 120

Method: EPA 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: LCS 180-268107/2-A
Matrix: Solid
Analysis Batch: 268295

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 268107

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Beryllium	50.0	49.7		ug/L		99	80 - 120
Chromium	200	209		ug/L		104	80 - 120
Lead	20.0	21.3		ug/L		107	80 - 120
Selenium	10.0	10.2		ug/L		102	80 - 120
Cobalt	500	445		ug/L		89	80 - 120
Molybdenum	1000	1000		ug/L		100	80 - 120
Antimony	500	492		ug/L		98	80 - 120
Thallium	50.0	51.5		ug/L		103	80 - 120
Lithium	50.0	47.3		ug/L		95	80 - 120

Lab Sample ID: MB 180-268263/1-A
Matrix: Solid
Analysis Batch: 268357

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 268263

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	ND		1.0	0.32	ug/L		01/18/19 12:59	01/19/19 17:12	1
Barium	ND		10	0.37	ug/L		01/18/19 12:59	01/19/19 17:12	1
Cadmium	ND		1.0	0.13	ug/L		01/18/19 12:59	01/19/19 17:12	1
Beryllium	ND		1.0	0.057	ug/L		01/18/19 12:59	01/19/19 17:12	1
Chromium	ND		2.0	0.63	ug/L		01/18/19 12:59	01/19/19 17:12	1
Lead	ND		1.0	0.094	ug/L		01/18/19 12:59	01/19/19 17:12	1
Selenium	ND		5.0	0.81	ug/L		01/18/19 12:59	01/19/19 17:12	1
Cobalt	ND		0.50	0.075	ug/L		01/18/19 12:59	01/19/19 17:12	1
Molybdenum	ND		5.0	0.47	ug/L		01/18/19 12:59	01/19/19 17:12	1
Antimony	ND		2.0	1.1	ug/L		01/18/19 12:59	01/19/19 17:12	1
Thallium	ND		1.0	0.063	ug/L		01/18/19 12:59	01/19/19 17:12	1
Lithium	ND		5.0	2.6	ug/L		01/18/19 12:59	01/19/19 17:12	1

Lab Sample ID: LCS 180-268263/2-A
Matrix: Solid
Analysis Batch: 268357

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 268263

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Arsenic	40.0	38.2		ug/L		95	80 - 120
Barium	2000	2090		ug/L		105	80 - 120
Cadmium	50.0	56.4		ug/L		113	80 - 120
Beryllium	50.0	52.6		ug/L		105	80 - 120
Chromium	200	223		ug/L		112	80 - 120
Lead	20.0	21.5		ug/L		108	80 - 120
Selenium	10.0	8.28		ug/L		83	80 - 120
Cobalt	500	490		ug/L		98	80 - 120
Molybdenum	1000	1070		ug/L		107	80 - 120
Antimony	500	538		ug/L		108	80 - 120
Thallium	50.0	49.2		ug/L		98	80 - 120
Lithium	50.0	49.1		ug/L		98	80 - 120

Method: EPA 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: MB 180-268586/1-A
Matrix: Solid
Analysis Batch: 268763

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 268586

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	ND		1.0	0.32	ug/L		01/23/19 12:55	01/24/19 18:36	1
Barium	ND		10	0.37	ug/L		01/23/19 12:55	01/24/19 18:36	1
Cadmium	ND		1.0	0.13	ug/L		01/23/19 12:55	01/24/19 18:36	1
Beryllium	ND		1.0	0.057	ug/L		01/23/19 12:55	01/24/19 18:36	1
Chromium	1.33	J	2.0	0.63	ug/L		01/23/19 12:55	01/24/19 18:36	1
Lead	ND		1.0	0.094	ug/L		01/23/19 12:55	01/24/19 18:36	1
Selenium	ND		5.0	0.81	ug/L		01/23/19 12:55	01/24/19 18:36	1
Cobalt	0.0870	J	0.50	0.075	ug/L		01/23/19 12:55	01/24/19 18:36	1
Molybdenum	ND		5.0	0.47	ug/L		01/23/19 12:55	01/24/19 18:36	1
Antimony	ND		2.0	1.1	ug/L		01/23/19 12:55	01/24/19 18:36	1
Thallium	ND		1.0	0.063	ug/L		01/23/19 12:55	01/24/19 18:36	1

Lab Sample ID: MB 180-268586/1-A
Matrix: Solid
Analysis Batch: 268821

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 268586

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lithium	ND		5.0	2.6	ug/L		01/23/19 12:55	01/25/19 14:23	1

Lab Sample ID: LCS 180-268586/2-A
Matrix: Solid
Analysis Batch: 268763

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 268586

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Arsenic	40.0	40.2		ug/L		100	80 - 120
Barium	2000	2090		ug/L		105	80 - 120
Cadmium	50.0	55.2		ug/L		110	80 - 120
Beryllium	50.0	46.3		ug/L		93	80 - 120
Chromium	200	227		ug/L		113	80 - 120
Lead	20.0	21.7		ug/L		109	80 - 120
Selenium	10.0	9.45		ug/L		94	80 - 120
Cobalt	500	507		ug/L		101	80 - 120
Molybdenum	1000	1100		ug/L		110	80 - 120
Antimony	500	534		ug/L		107	80 - 120
Thallium	50.0	52.7		ug/L		105	80 - 120

Lab Sample ID: LCS 180-268586/2-A
Matrix: Solid
Analysis Batch: 268821

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 268586

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Lithium	50.0	59.5		ug/L		119	80 - 120

Lab Sample ID: MB 180-269867/1-A
Matrix: Solid
Analysis Batch: 269977

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 269867

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Arsenic	ND		1.0	0.32	ug/L		02/07/19 11:53	02/08/19 00:28	1

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-1

Method: EPA 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: MB 180-269867/1-A
Matrix: Solid
Analysis Batch: 269977

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 269867

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Barium	ND		10	0.37	ug/L		02/07/19 11:53	02/08/19 00:28	1
Cadmium	ND		1.0	0.13	ug/L		02/07/19 11:53	02/08/19 00:28	1
Beryllium	ND		1.0	0.057	ug/L		02/07/19 11:53	02/08/19 00:28	1
Chromium	ND		2.0	0.63	ug/L		02/07/19 11:53	02/08/19 00:28	1
Lead	ND		1.0	0.094	ug/L		02/07/19 11:53	02/08/19 00:28	1
Selenium	ND		5.0	0.81	ug/L		02/07/19 11:53	02/08/19 00:28	1
Cobalt	ND		0.50	0.075	ug/L		02/07/19 11:53	02/08/19 00:28	1
Molybdenum	ND		5.0	0.47	ug/L		02/07/19 11:53	02/08/19 00:28	1
Antimony	ND		2.0	1.1	ug/L		02/07/19 11:53	02/08/19 00:28	1
Thallium	ND		1.0	0.063	ug/L		02/07/19 11:53	02/08/19 00:28	1
Lithium	ND		5.0	2.6	ug/L		02/07/19 11:53	02/08/19 00:28	1

Lab Sample ID: LCS 180-269867/2-A
Matrix: Solid
Analysis Batch: 269977

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 269867

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Arsenic	40.0	40.7		ug/L		102	80 - 120
Barium	2000	1940		ug/L		97	80 - 120
Cadmium	50.0	50.6		ug/L		101	80 - 120
Beryllium	50.0	52.2		ug/L		104	80 - 120
Chromium	200	188		ug/L		94	80 - 120
Lead	20.0	20.3		ug/L		101	80 - 120
Selenium	10.0	8.48		ug/L		85	80 - 120
Cobalt	500	485		ug/L		97	80 - 120
Molybdenum	1000	995		ug/L		99	80 - 120
Antimony	500	478		ug/L		96	80 - 120
Thallium	50.0	48.7		ug/L		97	80 - 120
Lithium	50.0	51.7		ug/L		103	80 - 120

Lab Sample ID: 180-85447-23 MS
Matrix: Solid
Analysis Batch: 268357

Client Sample ID: MB LOW
Prep Type: Leach
Prep Batch: 268263

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Arsenic	ND		40.0	38.9		ug/L		97	75 - 125
Barium	1.9	J	2000	2120		ug/L		106	75 - 125
Cadmium	ND		50.0	55.6		ug/L		111	75 - 125
Beryllium	ND		50.0	51.8		ug/L		104	75 - 125
Chromium	1.6	J	200	224		ug/L		111	75 - 125
Lead	ND		20.0	21.3		ug/L		107	75 - 125
Selenium	ND		10.0	9.68		ug/L		97	75 - 125
Cobalt	ND		500	497		ug/L		99	75 - 125
Molybdenum	ND		1000	1100		ug/L		110	75 - 125
Antimony	ND		500	543		ug/L		109	75 - 125
Thallium	ND		50.0	50.0		ug/L		100	75 - 125
Lithium	ND		50.0	49.8		ug/L		100	75 - 125

Method: EPA 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: 180-85447-23 MSD
Client Sample ID: MB LOW
Matrix: Solid
Prep Type: Leach
Analysis Batch: 268357
Prep Batch: 268263

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Arsenic	ND		40.0	38.3		ug/L		96	75 - 125	1	20
Barium	1.9	J	2000	2100		ug/L		105	75 - 125	1	20
Cadmium	ND		50.0	55.4		ug/L		111	75 - 125	0	20
Beryllium	ND		50.0	52.7		ug/L		105	75 - 125	2	20
Chromium	1.6	J	200	226		ug/L		112	75 - 125	1	20
Lead	ND		20.0	21.5		ug/L		107	75 - 125	0	20
Selenium	ND		10.0	8.60		ug/L		86	75 - 125	12	20
Cobalt	ND		500	494		ug/L		99	75 - 125	1	20
Molybdenum	ND		1000	1100		ug/L		110	75 - 125	0	20
Antimony	ND		500	533		ug/L		107	75 - 125	2	20
Thallium	ND		50.0	50.1		ug/L		100	75 - 125	0	20
Lithium	ND		50.0	49.2		ug/L		98	75 - 125	1	20

Lab Sample ID: 180-85447-49 MS
Client Sample ID: MB LOW 1
Matrix: Solid
Prep Type: Leach
Analysis Batch: 268763
Prep Batch: 268586

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Arsenic	ND		40.0	38.6		ug/L		97	75 - 125
Barium	2.5	J	2000	2090		ug/L		104	75 - 125
Cadmium	ND		50.0	54.6		ug/L		109	75 - 125
Beryllium	ND		50.0	49.7		ug/L		99	75 - 125
Chromium	1.4	J B	200	224		ug/L		111	75 - 125
Lead	ND		20.0	21.8		ug/L		109	75 - 125
Selenium	ND		10.0	8.68		ug/L		87	75 - 125
Cobalt	ND		500	495		ug/L		99	75 - 125
Molybdenum	ND		1000	1060		ug/L		106	75 - 125
Antimony	ND		500	539		ug/L		108	75 - 125
Thallium	ND		50.0	52.4		ug/L		105	75 - 125

Lab Sample ID: 180-85447-49 MS
Client Sample ID: MB LOW 1
Matrix: Solid
Prep Type: Leach
Analysis Batch: 268821
Prep Batch: 268586

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Lithium	3.2	J	50.0	61.8		ug/L		117	75 - 125

Lab Sample ID: 180-85447-49 MSD
Client Sample ID: MB LOW 1
Matrix: Solid
Prep Type: Leach
Analysis Batch: 268763
Prep Batch: 268586

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Arsenic	ND		40.0	39.3		ug/L		98	75 - 125	2	20
Barium	2.5	J	2000	2080		ug/L		104	75 - 125	0	20
Cadmium	ND		50.0	54.5		ug/L		109	75 - 125	0	20
Beryllium	ND		50.0	49.8		ug/L		100	75 - 125	0	20
Chromium	1.4	J B	200	226		ug/L		112	75 - 125	1	20
Lead	ND		20.0	21.7		ug/L		109	75 - 125	0	20
Selenium	ND		10.0	9.44		ug/L		94	75 - 125	8	20

Method: EPA 6020A - Metals (ICP/MS) (Continued)

Lab Sample ID: 180-85447-49 MSD
Matrix: Solid
Analysis Batch: 268763

Client Sample ID: MB LOW 1
Prep Type: Leach
Prep Batch: 268586

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Cobalt	ND		500	489		ug/L		98	75 - 125	1	20
Molybdenum	ND		1000	1070		ug/L		107	75 - 125	2	20
Antimony	ND		500	530		ug/L		106	75 - 125	2	20
Thallium	ND		50.0	52.0		ug/L		104	75 - 125	1	20

Lab Sample ID: 180-85447-49 MSD
Matrix: Solid
Analysis Batch: 268821

Client Sample ID: MB LOW 1
Prep Type: Leach
Prep Batch: 268586

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Lithium	3.2	J	50.0	59.8		ug/L		113	75 - 125	3	20

Lab Sample ID: 180-85447-51 MS
Matrix: Solid
Analysis Batch: 269977

Client Sample ID: MB LOW 2
Prep Type: Leach
Prep Batch: 269867

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Arsenic	ND		40.0	40.3		ug/L		101	75 - 125
Barium	ND		2000	1920		ug/L		96	75 - 125
Cadmium	ND		50.0	49.7		ug/L		99	75 - 125
Beryllium	ND		50.0	52.6		ug/L		105	75 - 125
Chromium	0.74	J	200	204		ug/L		102	75 - 125
Lead	ND		20.0	20.5		ug/L		103	75 - 125
Selenium	ND		10.0	8.67		ug/L		87	75 - 125
Cobalt	ND		500	515		ug/L		103	75 - 125
Molybdenum	0.85	J	1000	981		ug/L		98	75 - 125
Antimony	ND		500	467		ug/L		93	75 - 125
Thallium	ND		50.0	48.8		ug/L		98	75 - 125
Lithium	ND		50.0	52.6		ug/L		105	75 - 125

Lab Sample ID: 180-85447-51 MSD
Matrix: Solid
Analysis Batch: 269977

Client Sample ID: MB LOW 2
Prep Type: Leach
Prep Batch: 269867

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Arsenic	ND		40.0	39.8		ug/L		100	75 - 125	1	20
Barium	ND		2000	1910		ug/L		95	75 - 125	1	20
Cadmium	ND		50.0	50.0		ug/L		100	75 - 125	1	20
Beryllium	ND		50.0	51.3		ug/L		103	75 - 125	2	20
Chromium	0.74	J	200	207		ug/L		103	75 - 125	1	20
Lead	ND		20.0	20.6		ug/L		103	75 - 125	1	20
Selenium	ND		10.0	8.44		ug/L		84	75 - 125	3	20
Cobalt	ND		500	524		ug/L		105	75 - 125	2	20
Molybdenum	0.85	J	1000	1000		ug/L		100	75 - 125	2	20
Antimony	ND		500	454		ug/L		91	75 - 125	3	20
Thallium	ND		50.0	49.1		ug/L		98	75 - 125	1	20
Lithium	ND		50.0	53.4		ug/L		107	75 - 125	1	20

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-1

Method: EPA 7470A - Mercury (CVAA)

Lab Sample ID: MB 180-268065/1-A
Matrix: Solid
Analysis Batch: 268204

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 268065

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/16/19 15:06	01/17/19 17:43	1

Lab Sample ID: LCS 180-268065/2-A
Matrix: Solid
Analysis Batch: 268204

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 268065

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Mercury	2.50	2.50		ug/L		100	80 - 120

Lab Sample ID: MB 180-268340/1-A
Matrix: Solid
Analysis Batch: 268542

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 268340

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/21/19 10:49	01/22/19 18:00	1

Lab Sample ID: LCS 180-268340/2-A
Matrix: Solid
Analysis Batch: 268542

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 268340

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Mercury	2.50	2.32		ug/L		93	80 - 120

Lab Sample ID: LCSD 180-268340/3-A
Matrix: Solid
Analysis Batch: 268542

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 268340

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Mercury	2.50	2.34		ug/L		93	80 - 120	1	20

Lab Sample ID: MB 180-269197/1-A
Matrix: Solid
Analysis Batch: 269298

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 269197

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		01/31/19 07:10	01/31/19 16:40	1

Lab Sample ID: LCS 180-269197/2-A
Matrix: Solid
Analysis Batch: 269298

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 269197

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Mercury	2.50	2.41		ug/L		96	80 - 120

Lab Sample ID: MB 180-269834/1-A
Matrix: Solid
Analysis Batch: 269950

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 269834

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Mercury	ND		0.20	0.065	ug/L		02/07/19 10:44	02/08/19 10:06	1

Lab Sample ID: LCS 180-269834/2-A
Client Sample ID: Lab Control Sample
Matrix: Solid
Prep Type: Total/NA
Analysis Batch: 269950
Prep Batch: 269834

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits		
Mercury			2.50	2.50		ug/L		100	80 - 120		

Lab Sample ID: 180-85447-25 MS
Client Sample ID: MB HIGH
Matrix: Solid
Prep Type: Leach
Analysis Batch: 268204
Prep Batch: 268065

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits		
Mercury	ND		1.00	1.00		ug/L		100	75 - 125		

Lab Sample ID: 180-85447-25 MSD
Client Sample ID: MB HIGH
Matrix: Solid
Prep Type: Leach
Analysis Batch: 268204
Prep Batch: 268065

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Mercury	ND		1.00	1.01		ug/L		101	75 - 125	0	20

Method: EPA 9040C - pH

Lab Sample ID: LCS 180-268135/1
Client Sample ID: Lab Control Sample
Matrix: Solid
Prep Type: Total/NA
Analysis Batch: 268135

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits		
pH			7.00	7.0		SU		100	99 - 101		

Lab Sample ID: LCS 180-268260/1
Client Sample ID: Lab Control Sample
Matrix: Solid
Prep Type: Total/NA
Analysis Batch: 268260

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits		
pH			7.00	7.0		SU		100	99 - 101		

Lab Sample ID: LCS 180-268604/1
Client Sample ID: Lab Control Sample
Matrix: Solid
Prep Type: Total/NA
Analysis Batch: 268604

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits		
pH			7.00	7.0		SU		100	99 - 101		

Lab Sample ID: LCS 180-269862/1
Client Sample ID: Lab Control Sample
Matrix: Solid
Prep Type: Total/NA
Analysis Batch: 269862

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits		
pH			7.00	7.0		SU		100	99 - 101		

Method: EPA 9040C - pH (Continued)

Lab Sample ID: 180-85447-11 DU
Matrix: Solid
Analysis Batch: 268135
Client Sample ID: ABB pH NATURAL
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier		DU Result	DU Qualifier	Unit	D			RPD	RPD Limit
pH	9.0			9.0		SU				0.1	2

Lab Sample ID: 180-85447-14 DU
Matrix: Solid
Analysis Batch: 268135
Client Sample ID: ASB pH 12.0
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier		DU Result	DU Qualifier	Unit	D			RPD	RPD Limit
pH	12.4			12.4		SU				0	2

Lab Sample ID: 180-85447-8 DU
Matrix: Solid
Analysis Batch: 268260
Client Sample ID: ABB pH 5.5
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier		DU Result	DU Qualifier	Unit	D			RPD	RPD Limit
pH	5.9			5.8		SU				0.2	2

Lab Sample ID: 180-85447-20 DU
Matrix: Solid
Analysis Batch: 268604
Client Sample ID: ASB pH 4.0
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier		DU Result	DU Qualifier	Unit	D			RPD	RPD Limit
pH	4.1			4.1		SU				0.2	2

Lab Sample ID: 180-85447-10 DU
Matrix: Solid
Analysis Batch: 269862
Client Sample ID: ABB pH 2.0
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier		DU Result	DU Qualifier	Unit	D			RPD	RPD Limit
pH	2.2			2.2		SU				0.5	2

Method: SM 2510B - Conductivity, Specific Conductance

Lab Sample ID: MB 180-268142/2
Matrix: Solid
Analysis Batch: 268142
Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Specific Conductance	ND		1.0	1.0	umhos/cm			01/16/19 09:05	1

Lab Sample ID: LCS 180-268142/1
Matrix: Solid
Analysis Batch: 268142
Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits		
Specific Conductance			84.0	85.8		umhos/cm		102	90 - 110		

Method: SM 2510B - Conductivity, Specific Conductance (Continued)

Lab Sample ID: MB 180-268262/2 — **Client Sample ID: Method Blank**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 268262

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Specific Conductance	ND		1.0	1.0	umhos/cm			01/18/19 10:40	1

Lab Sample ID: LCS 180-268262/1 — **Client Sample ID: Lab Control Sample**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 268262

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Specific Conductance	84.0	87.2		umhos/cm		104	90 - 110

Lab Sample ID: MB 180-268609/2 — **Client Sample ID: Method Blank**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 268609

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Specific Conductance	ND		1.0	1.0	umhos/cm			01/23/19 07:40	1

Lab Sample ID: LCS 180-268609/1 — **Client Sample ID: Lab Control Sample**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 268609

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Specific Conductance	84.0	86.2		umhos/cm		103	90 - 110

Lab Sample ID: MB 180-269868/2 — **Client Sample ID: Method Blank**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 269868

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Specific Conductance	ND		1.0	1.0	umhos/cm			02/07/19 08:30	1

Lab Sample ID: LCS 180-269868/1 — **Client Sample ID: Lab Control Sample**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 269868

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Specific Conductance	84.0	86.8		umhos/cm		103	90 - 110

Lab Sample ID: 180-85447-11 DU — **Client Sample ID: ABB pH NATURAL**
Matrix: Solid — **Prep Type: Leach**
Analysis Batch: 268142

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Specific Conductance	210		214		umhos/cm		0.3	20

Lab Sample ID: 180-85447-14 DU — **Client Sample ID: ASB pH 12.0**
Matrix: Solid — **Prep Type: Leach**
Analysis Batch: 268142

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Specific Conductance	6200		6240		umhos/cm		0.05	20

Lab Sample ID: 180-85447-8 DU
Matrix: Solid
Analysis Batch: 268262
Client Sample ID: ABB pH 5.5
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Specific Conductance	4400		4440		umhos/cm		0.07	20

Lab Sample ID: 180-85447-20 DU
Matrix: Solid
Analysis Batch: 268609
Client Sample ID: ASB pH 4.0
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Specific Conductance	26000		26000		umhos/cm		0.08	20

Lab Sample ID: 180-85447-10 DU
Matrix: Solid
Analysis Batch: 269868
Client Sample ID: ABB pH 2.0
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Specific Conductance	78000		78200		umhos/cm		0	20

Method: SM 2580B - Reduction-Oxidation (REDOX) Potential

Lab Sample ID: LCS 180-268140/1
Matrix: Solid
Analysis Batch: 268140
Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Oxidation Reduction Potential	475	470		millivolts		99	90 - 110

Lab Sample ID: LCS 180-268261/1
Matrix: Solid
Analysis Batch: 268261
Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Oxidation Reduction Potential	475	475		millivolts		100	90 - 110

Lab Sample ID: LCS 180-268608/1
Matrix: Solid
Analysis Batch: 268608
Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Oxidation Reduction Potential	475	476		millivolts		100	90 - 110

Lab Sample ID: LCS 180-269865/1
Matrix: Solid
Analysis Batch: 269865
Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Oxidation Reduction Potential	475	475		millivolts		100	90 - 110

Method: SM 2580B - Reduction-Oxidation (REDOX) Potential (Continued)

Lab Sample ID: 180-85447-11 DU
Matrix: Solid
Analysis Batch: 268140

Client Sample ID: ABB pH NATURAL
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Oxidation Reduction Potential	310		311		millivolts		1	20

Lab Sample ID: 180-85447-14 DU
Matrix: Solid
Analysis Batch: 268140

Client Sample ID: ASB pH 12.0
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Oxidation Reduction Potential	- 24		- 25		millivolts		NC	20

Lab Sample ID: 180-85447-8 DU
Matrix: Solid
Analysis Batch: 268261

Client Sample ID: ABB pH 5.5
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Oxidation Reduction Potential	240		237		millivolts		0.8	20

Lab Sample ID: 180-85447-20 DU
Matrix: Solid
Analysis Batch: 268608

Client Sample ID: ASB pH 4.0
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Oxidation Reduction Potential	360		353		millivolts		0.8	20

Lab Sample ID: 180-85447-10 DU
Matrix: Solid
Analysis Batch: 269865

Client Sample ID: ABB pH 2.0
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Oxidation Reduction Potential	590		584		millivolts		0.3	20

HPLC/IC

Leach Batch: 268040

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-2	ABB pH 13.0	Leach	Solid	1313	
180-85447-3	ABB pH 12.0	Leach	Solid	1313	
180-85447-6	ABB pH 8.0	Leach	Solid	1313	
180-85447-7	ABB pH 7.0	Leach	Solid	1313	
180-85447-11	ABB pH NATURAL	Leach	Solid	1313	
180-85447-13	ASB pH 13.0	Leach	Solid	1313	
180-85447-14	ASB pH 12.0	Leach	Solid	1313	
180-85447-15	ASB pH 10.5	Leach	Solid	1313	
180-85447-17	ASB pH 8.0	Leach	Solid	1313	
180-85447-18	ASB pH 7.0	Leach	Solid	1313	
180-85447-22	ASB pH NATURAL	Leach	Solid	1313	
180-85447-24	MB NATURAL	Leach	Solid	1313	
180-85447-25	MB HIGH	Leach	Solid	1313	
180-85447-11 MS	ABB pH NATURAL	Leach	Solid	1313	
180-85447-11 MSD	ABB pH NATURAL	Leach	Solid	1313	

Analysis Batch: 268079

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-3	ABB pH 12.0	Leach	Solid	EPA 9056A	268040
180-85447-6	ABB pH 8.0	Leach	Solid	EPA 9056A	268040
180-85447-7	ABB pH 7.0	Leach	Solid	EPA 9056A	268040
180-85447-11	ABB pH NATURAL	Leach	Solid	EPA 9056A	268040
180-85447-14	ASB pH 12.0	Leach	Solid	EPA 9056A	268040
180-85447-15	ASB pH 10.5	Leach	Solid	EPA 9056A	268040
180-85447-17	ASB pH 8.0	Leach	Solid	EPA 9056A	268040
180-85447-18	ASB pH 7.0	Leach	Solid	EPA 9056A	268040
180-85447-22	ASB pH NATURAL	Leach	Solid	EPA 9056A	268040
180-85447-24	MB NATURAL	Leach	Solid	EPA 9056A	268040
MB 180-268079/6	Method Blank	Total/NA	Solid	EPA 9056A	
LCS 180-268079/5	Lab Control Sample	Total/NA	Solid	EPA 9056A	
180-85447-11 MS	ABB pH NATURAL	Leach	Solid	EPA 9056A	268040
180-85447-11 MSD	ABB pH NATURAL	Leach	Solid	EPA 9056A	268040

Analysis Batch: 268208

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-2	ABB pH 13.0	Leach	Solid	EPA 9056A	268040
180-85447-13	ASB pH 13.0	Leach	Solid	EPA 9056A	268040
180-85447-25	MB HIGH	Leach	Solid	EPA 9056A	268040
MB 180-268208/6	Method Blank	Total/NA	Solid	EPA 9056A	
LCS 180-268208/5	Lab Control Sample	Total/NA	Solid	EPA 9056A	

Leach Batch: 268246

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-4	ABB pH 10.5	Leach	Solid	1313	
180-85447-8	ABB pH 5.5	Leach	Solid	1313	
180-85447-9	ABB pH 4.0	Leach	Solid	1313	
180-85447-19	ASB pH 5.5	Leach	Solid	1313	
180-85447-23	MB LOW	Leach	Solid	1313	

HPLC/IC (Continued)

Analysis Batch: 268298

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-4	ABB pH 10.5	Leach	Solid	EPA 9056A	268246
180-85447-8	ABB pH 5.5	Leach	Solid	EPA 9056A	268246
180-85447-9	ABB pH 4.0	Leach	Solid	EPA 9056A	268246
180-85447-19	ASB pH 5.5	Leach	Solid	EPA 9056A	268246
180-85447-23	MB LOW	Leach	Solid	EPA 9056A	268246
MB 180-268298/6	Method Blank	Total/NA	Solid	EPA 9056A	
LCS 180-268298/5	Lab Control Sample	Total/NA	Solid	EPA 9056A	

Leach Batch: 268574

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-20	ASB pH 4.0	Leach	Solid	1313	
180-85447-49	MB LOW 1	Leach	Solid	1313	

Analysis Batch: 268716

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-20	ASB pH 4.0	Leach	Solid	EPA 9056A	268574
180-85447-49	MB LOW 1	Leach	Solid	EPA 9056A	268574
MB 180-268716/6	Method Blank	Total/NA	Solid	EPA 9056A	
LCS 180-268716/5	Lab Control Sample	Total/NA	Solid	EPA 9056A	

Leach Batch: 269578

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	1313	
180-85447-21	ASB pH 2.0	Leach	Solid	1313	
180-85447-51	MB LOW 2	Leach	Solid	1313	

Analysis Batch: 269858

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	EPA 9056A	269578
180-85447-21	ASB pH 2.0	Leach	Solid	EPA 9056A	269578
180-85447-51	MB LOW 2	Leach	Solid	EPA 9056A	269578
MB 180-269858/61	Method Blank	Total/NA	Solid	EPA 9056A	
LCS 180-269858/60	Lab Control Sample	Total/NA	Solid	EPA 9056A	

Metals

Leach Batch: 268040

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-2	ABB pH 13.0	Leach	Solid	1313	
180-85447-3	ABB pH 12.0	Leach	Solid	1313	
180-85447-6	ABB pH 8.0	Leach	Solid	1313	
180-85447-7	ABB pH 7.0	Leach	Solid	1313	
180-85447-11	ABB pH NATURAL	Leach	Solid	1313	
180-85447-13	ASB pH 13.0	Leach	Solid	1313	
180-85447-14	ASB pH 12.0	Leach	Solid	1313	
180-85447-15	ASB pH 10.5	Leach	Solid	1313	
180-85447-17	ASB pH 8.0	Leach	Solid	1313	
180-85447-18	ASB pH 7.0	Leach	Solid	1313	
180-85447-22	ASB pH NATURAL	Leach	Solid	1313	
180-85447-24	MB NATURAL	Leach	Solid	1313	

Metals (Continued)

Leach Batch: 268040 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-25	MB HIGH	Leach	Solid	1313	
180-85447-25 MS	MB HIGH	Leach	Solid	1313	
180-85447-25 MSD	MB HIGH	Leach	Solid	1313	

Prep Batch: 268065

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-2	ABB pH 13.0	Leach	Solid	7470A	268040
180-85447-3	ABB pH 12.0	Leach	Solid	7470A	268040
180-85447-6	ABB pH 8.0	Leach	Solid	7470A	268040
180-85447-7	ABB pH 7.0	Leach	Solid	7470A	268040
180-85447-11	ABB pH NATURAL	Leach	Solid	7470A	268040
180-85447-13	ASB pH 13.0	Leach	Solid	7470A	268040
180-85447-14	ASB pH 12.0	Leach	Solid	7470A	268040
180-85447-15	ASB pH 10.5	Leach	Solid	7470A	268040
180-85447-17	ASB pH 8.0	Leach	Solid	7470A	268040
180-85447-18	ASB pH 7.0	Leach	Solid	7470A	268040
180-85447-22	ASB pH NATURAL	Leach	Solid	7470A	268040
180-85447-24	MB NATURAL	Leach	Solid	7470A	268040
180-85447-25	MB HIGH	Leach	Solid	7470A	268040
MB 180-268065/1-A	Method Blank	Total/NA	Solid	7470A	
LCS 180-268065/2-A	Lab Control Sample	Total/NA	Solid	7470A	
180-85447-25 MS	MB HIGH	Leach	Solid	7470A	268040
180-85447-25 MSD	MB HIGH	Leach	Solid	7470A	268040

Prep Batch: 268107

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-2	ABB pH 13.0	Leach	Solid	3010A	268040
180-85447-3	ABB pH 12.0	Leach	Solid	3010A	268040
180-85447-6	ABB pH 8.0	Leach	Solid	3010A	268040
180-85447-7	ABB pH 7.0	Leach	Solid	3010A	268040
180-85447-11	ABB pH NATURAL	Leach	Solid	3010A	268040
180-85447-13	ASB pH 13.0	Leach	Solid	3010A	268040
180-85447-14	ASB pH 12.0	Leach	Solid	3010A	268040
180-85447-15	ASB pH 10.5	Leach	Solid	3010A	268040
180-85447-17	ASB pH 8.0	Leach	Solid	3010A	268040
180-85447-18	ASB pH 7.0	Leach	Solid	3010A	268040
180-85447-22	ASB pH NATURAL	Leach	Solid	3010A	268040
180-85447-24	MB NATURAL	Leach	Solid	3010A	268040
180-85447-25	MB HIGH	Leach	Solid	3010A	268040
MB 180-268107/1-A	Method Blank	Total/NA	Solid	3010A	
LCS 180-268107/2-A	Lab Control Sample	Total/NA	Solid	3010A	

Analysis Batch: 268204

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-2	ABB pH 13.0	Leach	Solid	EPA 7470A	268065
180-85447-3	ABB pH 12.0	Leach	Solid	EPA 7470A	268065
180-85447-6	ABB pH 8.0	Leach	Solid	EPA 7470A	268065
180-85447-7	ABB pH 7.0	Leach	Solid	EPA 7470A	268065
180-85447-11	ABB pH NATURAL	Leach	Solid	EPA 7470A	268065
180-85447-13	ASB pH 13.0	Leach	Solid	EPA 7470A	268065
180-85447-14	ASB pH 12.0	Leach	Solid	EPA 7470A	268065

Metals (Continued)

Analysis Batch: 268204 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-15	ASB pH 10.5	Leach	Solid	EPA 7470A	268065
180-85447-17	ASB pH 8.0	Leach	Solid	EPA 7470A	268065
180-85447-18	ASB pH 7.0	Leach	Solid	EPA 7470A	268065
180-85447-22	ASB pH NATURAL	Leach	Solid	EPA 7470A	268065
180-85447-24	MB NATURAL	Leach	Solid	EPA 7470A	268065
180-85447-25	MB HIGH	Leach	Solid	EPA 7470A	268065
MB 180-268065/1-A	Method Blank	Total/NA	Solid	EPA 7470A	268065
LCS 180-268065/2-A	Lab Control Sample	Total/NA	Solid	EPA 7470A	268065
180-85447-25 MS	MB HIGH	Leach	Solid	EPA 7470A	268065
180-85447-25 MSD	MB HIGH	Leach	Solid	EPA 7470A	268065

Leach Batch: 268246

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-4	ABB pH 10.5	Leach	Solid	1313	
180-85447-8	ABB pH 5.5	Leach	Solid	1313	
180-85447-9	ABB pH 4.0	Leach	Solid	1313	
180-85447-19	ASB pH 5.5	Leach	Solid	1313	
180-85447-23	MB LOW	Leach	Solid	1313	
180-85447-23 MS	MB LOW	Leach	Solid	1313	
180-85447-23 MSD	MB LOW	Leach	Solid	1313	

Prep Batch: 268263

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-4	ABB pH 10.5	Leach	Solid	3010A	268246
180-85447-8	ABB pH 5.5	Leach	Solid	3010A	268246
180-85447-9	ABB pH 4.0	Leach	Solid	3010A	268246
180-85447-19	ASB pH 5.5	Leach	Solid	3010A	268246
180-85447-23	MB LOW	Leach	Solid	3010A	268246
MB 180-268263/1-A	Method Blank	Total/NA	Solid	3010A	
LCS 180-268263/2-A	Lab Control Sample	Total/NA	Solid	3010A	
180-85447-23 MS	MB LOW	Leach	Solid	3010A	268246
180-85447-23 MSD	MB LOW	Leach	Solid	3010A	268246

Analysis Batch: 268295

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-2	ABB pH 13.0	Leach	Solid	EPA 6020A	268107
180-85447-3	ABB pH 12.0	Leach	Solid	EPA 6020A	268107
180-85447-6	ABB pH 8.0	Leach	Solid	EPA 6020A	268107
180-85447-7	ABB pH 7.0	Leach	Solid	EPA 6020A	268107
180-85447-11	ABB pH NATURAL	Leach	Solid	EPA 6020A	268107
180-85447-13	ASB pH 13.0	Leach	Solid	EPA 6020A	268107
180-85447-14	ASB pH 12.0	Leach	Solid	EPA 6020A	268107
180-85447-15	ASB pH 10.5	Leach	Solid	EPA 6020A	268107
180-85447-17	ASB pH 8.0	Leach	Solid	EPA 6020A	268107
180-85447-18	ASB pH 7.0	Leach	Solid	EPA 6020A	268107
180-85447-22	ASB pH NATURAL	Leach	Solid	EPA 6020A	268107
180-85447-24	MB NATURAL	Leach	Solid	EPA 6020A	268107
180-85447-25	MB HIGH	Leach	Solid	EPA 6020A	268107
MB 180-268107/1-A	Method Blank	Total/NA	Solid	EPA 6020A	268107
LCS 180-268107/2-A	Lab Control Sample	Total/NA	Solid	EPA 6020A	268107

Metals (Continued)

Prep Batch: 268340

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-4	ABB pH 10.5	Leach	Solid	7470A	268246
180-85447-8	ABB pH 5.5	Leach	Solid	7470A	268246
180-85447-9	ABB pH 4.0	Leach	Solid	7470A	268246
180-85447-19	ASB pH 5.5	Leach	Solid	7470A	268246
180-85447-23	MB LOW	Leach	Solid	7470A	268246
MB 180-268340/1-A	Method Blank	Total/NA	Solid	7470A	
LCS 180-268340/2-A	Lab Control Sample	Total/NA	Solid	7470A	
LCSD 180-268340/3-A	Lab Control Sample Dup	Total/NA	Solid	7470A	

Analysis Batch: 268357

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-4	ABB pH 10.5	Leach	Solid	EPA 6020A	268263
180-85447-8	ABB pH 5.5	Leach	Solid	EPA 6020A	268263
180-85447-9	ABB pH 4.0	Leach	Solid	EPA 6020A	268263
180-85447-19	ASB pH 5.5	Leach	Solid	EPA 6020A	268263
180-85447-23	MB LOW	Leach	Solid	EPA 6020A	268263
MB 180-268263/1-A	Method Blank	Total/NA	Solid	EPA 6020A	268263
LCS 180-268263/2-A	Lab Control Sample	Total/NA	Solid	EPA 6020A	268263
180-85447-23 MS	MB LOW	Leach	Solid	EPA 6020A	268263
180-85447-23 MSD	MB LOW	Leach	Solid	EPA 6020A	268263

Analysis Batch: 268542

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-4	ABB pH 10.5	Leach	Solid	EPA 7470A	268340
180-85447-8	ABB pH 5.5	Leach	Solid	EPA 7470A	268340
180-85447-9	ABB pH 4.0	Leach	Solid	EPA 7470A	268340
180-85447-19	ASB pH 5.5	Leach	Solid	EPA 7470A	268340
180-85447-23	MB LOW	Leach	Solid	EPA 7470A	268340
MB 180-268340/1-A	Method Blank	Total/NA	Solid	EPA 7470A	268340
LCS 180-268340/2-A	Lab Control Sample	Total/NA	Solid	EPA 7470A	268340
LCSD 180-268340/3-A	Lab Control Sample Dup	Total/NA	Solid	EPA 7470A	268340

Leach Batch: 268574

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-20	ASB pH 4.0	Leach	Solid	1313	
180-85447-49	MB LOW 1	Leach	Solid	1313	
180-85447-49 MS	MB LOW 1	Leach	Solid	1313	
180-85447-49 MSD	MB LOW 1	Leach	Solid	1313	

Prep Batch: 268586

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-20	ASB pH 4.0	Leach	Solid	3010A	268574
180-85447-49	MB LOW 1	Leach	Solid	3010A	268574
MB 180-268586/1-A	Method Blank	Total/NA	Solid	3010A	
LCS 180-268586/2-A	Lab Control Sample	Total/NA	Solid	3010A	
180-85447-49 MS	MB LOW 1	Leach	Solid	3010A	268574
180-85447-49 MSD	MB LOW 1	Leach	Solid	3010A	268574

Analysis Batch: 268763

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-49	MB LOW 1	Leach	Solid	EPA 6020A	268586

QC Association Summary

Client: KPRG and Associates, Inc. TestAmerica Job ID: 180-85447-1
Project/Site: Midwest Generation

Metals (Continued)

Analysis Batch: 268763 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
MB 180-268586/1-A	Method Blank	Total/NA	Solid	EPA 6020A	268586
LCS 180-268586/2-A	Lab Control Sample	Total/NA	Solid	EPA 6020A	268586
180-85447-49 MS	MB LOW 1	Leach	Solid	EPA 6020A	268586
180-85447-49 MSD	MB LOW 1	Leach	Solid	EPA 6020A	268586

Analysis Batch: 268821

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-20	ASB pH 4.0	Leach	Solid	EPA 6020A	268586
180-85447-49	MB LOW 1	Leach	Solid	EPA 6020A	268586
MB 180-268586/1-A	Method Blank	Total/NA	Solid	EPA 6020A	268586
LCS 180-268586/2-A	Lab Control Sample	Total/NA	Solid	EPA 6020A	268586
180-85447-49 MS	MB LOW 1	Leach	Solid	EPA 6020A	268586
180-85447-49 MSD	MB LOW 1	Leach	Solid	EPA 6020A	268586

Prep Batch: 269197

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-20	ASB pH 4.0	Leach	Solid	7470A	268574
180-85447-49	MB LOW 1	Leach	Solid	7470A	268574
MB 180-269197/1-A	Method Blank	Total/NA	Solid	7470A	
LCS 180-269197/2-A	Lab Control Sample	Total/NA	Solid	7470A	

Analysis Batch: 269298

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-20	ASB pH 4.0	Leach	Solid	EPA 7470A	269197
180-85447-49	MB LOW 1	Leach	Solid	EPA 7470A	269197
MB 180-269197/1-A	Method Blank	Total/NA	Solid	EPA 7470A	269197
LCS 180-269197/2-A	Lab Control Sample	Total/NA	Solid	EPA 7470A	269197

Leach Batch: 269578

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	1313	
180-85447-21	ASB pH 2.0	Leach	Solid	1313	
180-85447-51	MB LOW 2	Leach	Solid	1313	
180-85447-51 MS	MB LOW 2	Leach	Solid	1313	
180-85447-51 MSD	MB LOW 2	Leach	Solid	1313	

Prep Batch: 269834

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	7470A	269578
180-85447-21	ASB pH 2.0	Leach	Solid	7470A	269578
180-85447-51	MB LOW 2	Leach	Solid	7470A	269578
MB 180-269834/1-A	Method Blank	Total/NA	Solid	7470A	
LCS 180-269834/2-A	Lab Control Sample	Total/NA	Solid	7470A	

Prep Batch: 269867

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	3010A	269578
180-85447-21	ASB pH 2.0	Leach	Solid	3010A	269578
180-85447-51	MB LOW 2	Leach	Solid	3010A	269578
MB 180-269867/1-A	Method Blank	Total/NA	Solid	3010A	
LCS 180-269867/2-A	Lab Control Sample	Total/NA	Solid	3010A	

Metals (Continued)

Prep Batch: 269867 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-51 MS	MB LOW 2	Leach	Solid	3010A	269578
180-85447-51 MSD	MB LOW 2	Leach	Solid	3010A	269578

Analysis Batch: 269950

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	EPA 7470A	269834
180-85447-21	ASB pH 2.0	Leach	Solid	EPA 7470A	269834
180-85447-51	MB LOW 2	Leach	Solid	EPA 7470A	269834
MB 180-269834/1-A	Method Blank	Total/NA	Solid	EPA 7470A	269834
LCS 180-269834/2-A	Lab Control Sample	Total/NA	Solid	EPA 7470A	269834

Analysis Batch: 269977

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-51	MB LOW 2	Leach	Solid	EPA 6020A	269867
MB 180-269867/1-A	Method Blank	Total/NA	Solid	EPA 6020A	269867
LCS 180-269867/2-A	Lab Control Sample	Total/NA	Solid	EPA 6020A	269867
180-85447-51 MS	MB LOW 2	Leach	Solid	EPA 6020A	269867
180-85447-51 MSD	MB LOW 2	Leach	Solid	EPA 6020A	269867

Analysis Batch: 270330

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	EPA 6020A	269867
180-85447-21	ASB pH 2.0	Leach	Solid	EPA 6020A	269867

General Chemistry

Analysis Batch: 267637

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-1	ABB PRETEST	Total/NA	Solid	2540G	
180-85447-12	ASB PRETEST	Total/NA	Solid	2540G	

Leach Batch: 268040

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-1	ABB PRETEST	Leach	Solid	1313	
180-85447-1	ABB PRETEST	Leach	Solid	1313	
180-85447-1	ABB PRETEST	Leach	Solid	1313	
180-85447-2	ABB pH 13.0	Leach	Solid	1313	
180-85447-3	ABB pH 12.0	Leach	Solid	1313	
180-85447-6	ABB pH 8.0	Leach	Solid	1313	
180-85447-7	ABB pH 7.0	Leach	Solid	1313	
180-85447-11	ABB pH NATURAL	Leach	Solid	1313	
180-85447-12	ASB PRETEST	Leach	Solid	1313	
180-85447-12	ASB PRETEST	Leach	Solid	1313	
180-85447-13	ASB pH 13.0	Leach	Solid	1313	
180-85447-14	ASB pH 12.0	Leach	Solid	1313	
180-85447-15	ASB pH 10.5	Leach	Solid	1313	
180-85447-17	ASB pH 8.0	Leach	Solid	1313	
180-85447-18	ASB pH 7.0	Leach	Solid	1313	
180-85447-22	ASB pH NATURAL	Leach	Solid	1313	
180-85447-24	MB NATURAL	Leach	Solid	1313	

General Chemistry (Continued)

Leach Batch: 268040 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-25	MB HIGH	Leach	Solid	1313	
180-85447-11 DU	ABB pH NATURAL	Leach	Solid	1313	
180-85447-14 DU	ASB pH 12.0	Leach	Solid	1313	

Analysis Batch: 268135

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-1	ABB PRETEST	Leach	Solid	EPA 9040C	268040
180-85447-1	ABB PRETEST	Leach	Solid	EPA 9040C	268040
180-85447-1	ABB PRETEST	Leach	Solid	EPA 9040C	268040
180-85447-2	ABB pH 13.0	Leach	Solid	EPA 9040C	268040
180-85447-3	ABB pH 12.0	Leach	Solid	EPA 9040C	268040
180-85447-6	ABB pH 8.0	Leach	Solid	EPA 9040C	268040
180-85447-7	ABB pH 7.0	Leach	Solid	EPA 9040C	268040
180-85447-11	ABB pH NATURAL	Leach	Solid	EPA 9040C	268040
180-85447-12	ASB PRETEST	Leach	Solid	EPA 9040C	268040
180-85447-12	ASB PRETEST	Leach	Solid	EPA 9040C	268040
180-85447-13	ASB pH 13.0	Leach	Solid	EPA 9040C	268040
180-85447-14	ASB pH 12.0	Leach	Solid	EPA 9040C	268040
180-85447-15	ASB pH 10.5	Leach	Solid	EPA 9040C	268040
180-85447-17	ASB pH 8.0	Leach	Solid	EPA 9040C	268040
180-85447-18	ASB pH 7.0	Leach	Solid	EPA 9040C	268040
180-85447-22	ASB pH NATURAL	Leach	Solid	EPA 9040C	268040
180-85447-24	MB NATURAL	Leach	Solid	EPA 9040C	268040
180-85447-25	MB HIGH	Leach	Solid	EPA 9040C	268040
LCS 180-268135/1	Lab Control Sample	Total/NA	Solid	EPA 9040C	
180-85447-11 DU	ABB pH NATURAL	Leach	Solid	EPA 9040C	268040
180-85447-14 DU	ASB pH 12.0	Leach	Solid	EPA 9040C	268040

Analysis Batch: 268140

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-2	ABB pH 13.0	Leach	Solid	SM 2580B	268040
180-85447-3	ABB pH 12.0	Leach	Solid	SM 2580B	268040
180-85447-6	ABB pH 8.0	Leach	Solid	SM 2580B	268040
180-85447-7	ABB pH 7.0	Leach	Solid	SM 2580B	268040
180-85447-11	ABB pH NATURAL	Leach	Solid	SM 2580B	268040
180-85447-13	ASB pH 13.0	Leach	Solid	SM 2580B	268040
180-85447-14	ASB pH 12.0	Leach	Solid	SM 2580B	268040
180-85447-15	ASB pH 10.5	Leach	Solid	SM 2580B	268040
180-85447-17	ASB pH 8.0	Leach	Solid	SM 2580B	268040
180-85447-18	ASB pH 7.0	Leach	Solid	SM 2580B	268040
180-85447-22	ASB pH NATURAL	Leach	Solid	SM 2580B	268040
180-85447-24	MB NATURAL	Leach	Solid	SM 2580B	268040
180-85447-25	MB HIGH	Leach	Solid	SM 2580B	268040
LCS 180-268140/1	Lab Control Sample	Total/NA	Solid	SM 2580B	
180-85447-11 DU	ABB pH NATURAL	Leach	Solid	SM 2580B	268040
180-85447-14 DU	ASB pH 12.0	Leach	Solid	SM 2580B	268040

Analysis Batch: 268142

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-2	ABB pH 13.0	Leach	Solid	SM 2510B	268040
180-85447-3	ABB pH 12.0	Leach	Solid	SM 2510B	268040

General Chemistry (Continued)

Analysis Batch: 268142 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-6	ABB pH 8.0	Leach	Solid	SM 2510B	268040
180-85447-7	ABB pH 7.0	Leach	Solid	SM 2510B	268040
180-85447-11	ABB pH NATURAL	Leach	Solid	SM 2510B	268040
180-85447-13	ASB pH 13.0	Leach	Solid	SM 2510B	268040
180-85447-14	ASB pH 12.0	Leach	Solid	SM 2510B	268040
180-85447-15	ASB pH 10.5	Leach	Solid	SM 2510B	268040
180-85447-17	ASB pH 8.0	Leach	Solid	SM 2510B	268040
180-85447-18	ASB pH 7.0	Leach	Solid	SM 2510B	268040
180-85447-22	ASB pH NATURAL	Leach	Solid	SM 2510B	268040
180-85447-24	MB NATURAL	Leach	Solid	SM 2510B	268040
180-85447-25	MB HIGH	Leach	Solid	SM 2510B	268040
MB 180-268142/2	Method Blank	Total/NA	Solid	SM 2510B	
LCS 180-268142/1	Lab Control Sample	Total/NA	Solid	SM 2510B	
180-85447-11 DU	ABB pH NATURAL	Leach	Solid	SM 2510B	268040
180-85447-14 DU	ASB pH 12.0	Leach	Solid	SM 2510B	268040

Leach Batch: 268246

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-4	ABB pH 10.5	Leach	Solid	1313	
180-85447-8	ABB pH 5.5	Leach	Solid	1313	
180-85447-9	ABB pH 4.0	Leach	Solid	1313	
180-85447-19	ASB pH 5.5	Leach	Solid	1313	
180-85447-23	MB LOW	Leach	Solid	1313	
180-85447-8 DU	ABB pH 5.5	Leach	Solid	1313	

Analysis Batch: 268260

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-4	ABB pH 10.5	Leach	Solid	EPA 9040C	268246
180-85447-8	ABB pH 5.5	Leach	Solid	EPA 9040C	268246
180-85447-9	ABB pH 4.0	Leach	Solid	EPA 9040C	268246
180-85447-19	ASB pH 5.5	Leach	Solid	EPA 9040C	268246
180-85447-23	MB LOW	Leach	Solid	EPA 9040C	268246
LCS 180-268260/1	Lab Control Sample	Total/NA	Solid	EPA 9040C	
180-85447-8 DU	ABB pH 5.5	Leach	Solid	EPA 9040C	268246

Analysis Batch: 268261

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-4	ABB pH 10.5	Leach	Solid	SM 2580B	268246
180-85447-8	ABB pH 5.5	Leach	Solid	SM 2580B	268246
180-85447-9	ABB pH 4.0	Leach	Solid	SM 2580B	268246
180-85447-19	ASB pH 5.5	Leach	Solid	SM 2580B	268246
180-85447-23	MB LOW	Leach	Solid	SM 2580B	268246
LCS 180-268261/1	Lab Control Sample	Total/NA	Solid	SM 2580B	
180-85447-8 DU	ABB pH 5.5	Leach	Solid	SM 2580B	268246

Analysis Batch: 268262

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-4	ABB pH 10.5	Leach	Solid	SM 2510B	268246
180-85447-8	ABB pH 5.5	Leach	Solid	SM 2510B	268246
180-85447-9	ABB pH 4.0	Leach	Solid	SM 2510B	268246
180-85447-19	ASB pH 5.5	Leach	Solid	SM 2510B	268246

General Chemistry (Continued)

Analysis Batch: 268262 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-23	MB LOW	Leach	Solid	SM 2510B	268246
MB 180-268262/2	Method Blank	Total/NA	Solid	SM 2510B	
LCS 180-268262/1	Lab Control Sample	Total/NA	Solid	SM 2510B	
180-85447-8 DU	ABB pH 5.5	Leach	Solid	SM 2510B	268246

Leach Batch: 268574

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-1	ABB PRETEST	Leach	Solid	1313	
180-85447-12	ASB PRETEST	Leach	Solid	1313	
180-85447-20	ASB pH 4.0	Leach	Solid	1313	
180-85447-49	MB LOW 1	Leach	Solid	1313	
180-85447-20 DU	ASB pH 4.0	Leach	Solid	1313	

Analysis Batch: 268604

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-1	ABB PRETEST	Leach	Solid	EPA 9040C	268574
180-85447-12	ASB PRETEST	Leach	Solid	EPA 9040C	268574
180-85447-20	ASB pH 4.0	Leach	Solid	EPA 9040C	268574
180-85447-49	MB LOW 1	Leach	Solid	EPA 9040C	268574
LCS 180-268604/1	Lab Control Sample	Total/NA	Solid	EPA 9040C	
180-85447-20 DU	ASB pH 4.0	Leach	Solid	EPA 9040C	268574

Analysis Batch: 268608

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-20	ASB pH 4.0	Leach	Solid	SM 2580B	268574
180-85447-49	MB LOW 1	Leach	Solid	SM 2580B	268574
LCS 180-268608/1	Lab Control Sample	Total/NA	Solid	SM 2580B	
180-85447-20 DU	ASB pH 4.0	Leach	Solid	SM 2580B	268574

Analysis Batch: 268609

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-20	ASB pH 4.0	Leach	Solid	SM 2510B	268574
180-85447-49	MB LOW 1	Leach	Solid	SM 2510B	268574
MB 180-268609/2	Method Blank	Total/NA	Solid	SM 2510B	
LCS 180-268609/1	Lab Control Sample	Total/NA	Solid	SM 2510B	
180-85447-20 DU	ASB pH 4.0	Leach	Solid	SM 2510B	268574

Leach Batch: 269578

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	1313	
180-85447-21	ASB pH 2.0	Leach	Solid	1313	
180-85447-51	MB LOW 2	Leach	Solid	1313	
180-85447-10 DU	ABB pH 2.0	Leach	Solid	1313	

Analysis Batch: 269862

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	EPA 9040C	269578
180-85447-21	ASB pH 2.0	Leach	Solid	EPA 9040C	269578
180-85447-51	MB LOW 2	Leach	Solid	EPA 9040C	269578
LCS 180-269862/1	Lab Control Sample	Total/NA	Solid	EPA 9040C	
180-85447-10 DU	ABB pH 2.0	Leach	Solid	EPA 9040C	269578

QC Association Summary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-1

Analysis Batch: 269865

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	SM 2580B	269578
180-85447-21	ASB pH 2.0	Leach	Solid	SM 2580B	269578
180-85447-51	MB LOW 2	Leach	Solid	SM 2580B	269578
LCS 180-269865/1	Lab Control Sample	Total/NA	Solid	SM 2580B	
180-85447-10 DU	ABB pH 2.0	Leach	Solid	SM 2580B	269578

Analysis Batch: 269868

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	SM 2510B	269578
180-85447-21	ASB pH 2.0	Leach	Solid	SM 2510B	269578
180-85447-51	MB LOW 2	Leach	Solid	SM 2510B	269578
MB 180-269868/2	Method Blank	Total/NA	Solid	SM 2510B	
LCS 180-269868/1	Lab Control Sample	Total/NA	Solid	SM 2510B	
180-85447-10 DU	ABB pH 2.0	Leach	Solid	SM 2510B	269578

Chain of Custody Record

273171

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING
TestAmerica Laboratories, Inc.
TAL-8210 (0713)

Regulatory Program: ☐ DW ☐ NPDES ☐ RCRA ☐ Other:

Client Contact	Project Manager:	Site Contact:	Date:	COC No:
Company Name: KPRG and Associates	Tel/Fax:	Lab Contact:	Carrier:	___ of ___ COCs
Address: 14665 W. Lisbon Rd. Ste 1A	Analysis Turnaround Time			Sampler:
City/State/Zip: Brookfield / WI / 53005	☐ CALENDAR DAYS ☐ WORKING DAYS			For Lab Use Only:
Phone: 262-781-0475	TAT if different from Below ____			Walk-in Client:
Fax:	☐ 2 weeks			Lab Sampling:
Project Name: NRG	☐ 1 week			
Site: Powerton	☐ 2 days			Job / SDG No.:
PO# 23517.0	☐ 1 day			

Sample Identification	Sample Date	Sample Time	Sample Type (C=Comp, G=Grab)	Matrix	# of Cont.	Filtered Sample (Y / N)	Perform MS / MSD (Y / N)	LEAF Method 1313	Sample Specific Notes:
ABB	1-4-19	1110	C	S	2	N	N	X	
ASB	1-4-19	1145	C	S	2	N	N	X	

180-85447 Chain of Custody

Preservation Used: 1= Ice, 2= HCl; 3= H2SO4; 4=HNO3; 5=NaOH; 6= Other ____

Possible Hazard Identification:
Are any samples from a listed EPA Hazardous Waste? Please List any EPA Waste Codes for the sample in the Comments Section if the lab is to dispose of the sample.
☐ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ Return to Client ☐ Disposal by Lab ☐ Archive for ____ Months

Special Instructions/QC Requirements & Comments:
CCR Appendix 4 compounds → As, Ba, Cd, Co, F, Pb, Li, Hg, Mo, Rad 226/228, Se, Tl / Sample Date is 1-4-19

Custody Seals Intact: ☐ Yes ☐ No | Custody Seal No.: | Cooler Temp. (°C): Obs'd: ____ Corr'd: ____ | Therm ID No.: ____

Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Mitchel Dolan	KPRG	1-4-19 / 1400	FEDEX		1-4-19 / 1400
Relinquished by:	Company:	Date/Time:	Received by: Julie Watson	Company: TAPitt	Date/Time: 1-5-19 9:30
Relinquished by:	Company:	Date/Time:	Received in Laboratory by:	Company:	Date/Time:

FedEx

180-85447 Waybill

Do Not Lift Usin

erica

ST 3 9 1 12:00 A G
0897
01.05

ORIGIN ID:PIAA (000) 000-0000
KPRG ASSOCIATES
414 PLAZA DR STE 106
WESTMONT, IL 60559
UNITED STATES US

SHIP DATE: 04JAN19
ACTWGT: 50.00 LB
CAD: 006994779/SSFE1922
DIMS: 22x12x12 IN
BILL THIRD PARTY

TO ATTN CARRIE GAMBER
TEST AMERICA
301 ALPHA DR RIDC PARK

PITTSBURGH PA 15238
(412) 963-7058 REF:
INV:
PO: DEPT:

FedEx Express
E

SATURDAY 12:00P
PRIORITY OVERNIGHT

TRK# 0201 7848 0408 0897

XO AGCA

15238
US PIT

Uncorrected temp 1.9 °C
Thermometer ID 10
CF 0 Initials JS
PT-WI-SR-001 effective 11/8/18

FedEx Express

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc.　　　　Job Number: 180-85447-1

Login Number: 85447　　　　**List Source: TestAmerica Pittsburgh**
List Number: 1
Creator: Watson, Debbie

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	False	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica Pittsburgh
301 Alpha Drive
RIDC Park
Pittsburgh, PA 15238
Tel: (412)963-7058

TestAmerica Job ID: 180-85447-2
Client Project/Site: Midwest Generation

For:
KPRG and Associates, Inc.
14665 West Lisbon Road,
Suite 2B
Brookfield, Wisconsin 53005

Attn: Richard Gnat

Authorized for release by:
3/22/2019 8:10:17 AM

Carrie Gamber, Senior Project Manager
(412)963-2428
carrie.gamber@testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

PA Lab ID: 02-00416

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Job ID: 180-85447-2

Laboratory: TestAmerica Pittsburgh

Narrative

CASE NARRATIVE

Client: KPRG and Associates, Inc.

Project: Midwest Generation

Report Number: 180-85447-2

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

RECEIPT
The samples were received on 01/05/2019; the samples arrived in good condition, properly preserved and on ice. The temperature of the coolers at receipt was 1.9 C.

The Field Sampler was not listed on the Chain of Custody.

One out of two containers for the following sample did not match the information listed on the Chain-of-Custody (COC): ABB PRETEST (180-85447-1). The container label lists a sample collection time of 11:00, while the COC lists 11:10. The time on the COC was used.

METALS
No analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

GENERAL CHEMISTRY
No analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

901.1
Many isotopes requested for analysis do not have any gamma emissions, or the gamma emissions they do have are very poor. Often, such analytes are reported by gamma spectrometry assuming secular equilibrium with a longer-lived parent. The client should ensure that such inference is acceptable for their sample based upon process knowledge. The following assumptions were made for this report:

Inferred from	Reported to Analyte
Th-234	Pa-234
Th-234	U-238
Pb-210	Po-210
Pb-210	Bi-210
Cs-137	Ba-137m
Pb-212	Po-216
Xe-131m	Xe-131
Sb-125	Te-125m
Ag-108m	Ag-108
Rh-106	Ru-106
Pb-212	Th-228
Pb-212	Ra-224
U-235	Th-231
Ac-228	Th-232

1 2 3 4 5 6 7 8 9 10 11 12 13

Job ID: 180-85447-2 (Continued)

Laboratory: TestAmerica Pittsburgh (Continued)

Ac-228	Ra-228
Th-227	Ra-223
Th-227	Ac-227
Th-227	Bi-211
Th-227	Pb-211
Bi-214	Ra-226

ABB pH 2.0 (180-85447-34), (LCS 160-417071/2-A), (MB 160-417071/1-A), (490-168989-I-1-A) and (490-168989-I-1-B DU)

903.0

Several samples were prepared at a reduced aliquot due to limited volume or due to brown discoloration and heavy sediment. . All available containers were consumed.

The following sample boiled over while heating and a minimal amount was lost: ASB pH 4.0 (180-85447-43) and ASB pH 2.0 (180-85447-44). This will affect the barium carrier recoveries, possibly causing a slightly lower recovery. The sample created a crystallized precipitate that does not work with the chemistry of this method. Barium was not able to be carried through the process, so the sample was removed from this batch and canceled.

Radiochemistry sample results are reported with the count date/time applied as the Activity Reference Date: MB LOW 2 (180-85447-52), (LCS 160-414637/1-A), (MB 160-414637/18-A).

904.0

Several samples were prepared at a reduced aliquot due to limited volume due to brown discoloration and heavy sediment. All available containers were consumed.

The following samples boiled over while heating and a minimal amount was lost: ASB pH 4.0 (180-85447-43) and ASB pH 2.0 (180-85447-44). This will affect the barium carrier recoveries, possibly causing a slightly lower recovery. The sample created a crystallized precipitate that does not work with the chemistry of this method. Barium was not able to be carried through the process, so the sample was removed from this batch and canceled.

The following sample exhibited a negative result greater in magnitude than the 3 sigma TPU. This occurrence was evaluated and determined to be random in nature. Sporadic occurrences such as this are statistically expected. No further action is required. MB LOW 2 (180-85447-52)

The following samples did not meet the requested limit (RL) due to the reduced sample volume attributed to the presence of matrix interferences. The data have been reported with this narrative. ABB pH 10.5 (180-85447-28) and ASB pH 5.5 (180-85447-42)

The following samples did not meet the requested limit (RL) due to the reduced sample volume attributed to the presence of matrix interferences. The data have been reported with this narrative. ABB pH 13.0 (180-85447-26) and ABB pH 12.0 (180-85447-27)

Definitions/Glossary

Qualifiers

Rad

Qualifier	Qualifier Description
G	The Sample MDC is greater than the requested RL.
U	Result is less than the sample detection limit.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Accreditation/Certification Summary

Client: KPRG and Associates, Inc. TestAmerica Job ID: 180-85447-2
Project/Site: Midwest Generation

Laboratory: TestAmerica Pittsburgh

Unless otherwise noted, all analytes for this laboratory were covered under each accreditation/certification below.

Authority	Program	EPA Region	Identification Number	Expiration Date
Illinois	NELAP	5	200005	06-30-19

The following analytes are included in this report, but the laboratory is not certified by the governing authority. This list may include analytes for which the agency does not offer certification.

Analysis Method	Prep Method	Matrix	Analyte
SM 2510B		Solid	Specific Conductance
SM 2580B		Solid	Oxidation Reduction Potential

Laboratory: TestAmerica St. Louis

All accreditations/certifications held by this laboratory are listed. Not all accreditations/certifications are applicable to this report.

Authority	Program	EPA Region	Identification Number	Expiration Date
Alaska	State Program	10	MO00054	06-30-19
ANAB	DoD / DOE		L2305	04-06-22
Arizona	State Program	9	AZ0813	12-08-19
California	State Program	9	2886	06-30-19
Connecticut	State Program	1	PH-0241	03-31-19 *
Florida	NELAP	4	E87689	06-30-19
Hawaii	State Program	9	NA	06-30-19
Illinois	NELAP	5	200023	11-30-19
Iowa	State Program	7	373	12-01-20
Kansas	NELAP	7	E-10236	10-31-19
Kentucky (DW)	State Program	4	KY90125	12-31-19
Louisiana	NELAP	6	04080	06-30-19
Louisiana (DW)	NELAP	6	LA011	12-31-19
Maryland	State Program	3	310	09-30-19
Michigan	State Program	5	9005	06-30-19
Missouri	State Program	7	780	06-30-19
Nevada	State Program	9	MO000542018-1	07-31-19
New Jersey	NELAP	2	MO002	06-30-19
New York	NELAP	2	11616	03-31-19 *
North Dakota	State Program	8	R207	06-30-19
NRC	NRC		24-24817-01	12-31-22
Oklahoma	State Program	6	9997	08-31-19
Pennsylvania	NELAP	3	68-00540	02-28-19 *
South Carolina	State Program	4	85002001	06-30-19
Texas	NELAP	6	T104704193-18-13	07-31-19
US Fish & Wildlife	Federal		058448	07-31-19
USDA	Federal		P330-17-0028	02-02-20
Utah	NELAP	8	MO000542018-10	07-31-19
Virginia	NELAP	3	460230	06-14-19
Washington	State Program	10	C592	08-30-19
West Virginia DEP	State Program	3	381	08-31-19

* Accreditation/Certification renewal pending - accreditation/certification considered valid.

Sample Summary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-2

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
180-85447-10	ABB pH 2.0	Solid	01/04/19 11:10	01/05/19 09:30
180-85447-26	ABB pH 13.0	Water	01/16/19 09:05	01/05/19 09:30
180-85447-27	ABB pH 12.0	Water	01/16/19 09:05	01/05/19 09:30
180-85447-28	ABB pH 10.5	Water	01/18/19 09:20	01/05/19 09:30
180-85447-30	ABB pH 8.0	Water	01/16/19 09:05	01/05/19 09:30
180-85447-31	ABB pH 7.0	Water	01/16/19 09:05	01/05/19 09:30
180-85447-32	ABB pH 5.5	Water	01/18/19 09:20	01/05/19 09:30
180-85447-33	ABB pH 4.0	Water	01/18/19 09:20	01/05/19 09:30
180-85447-34	ABB pH 2.0	Water	02/07/19 07:30	01/05/19 09:30
180-85447-35	ABB pH NATURAL	Water	01/16/19 09:05	01/05/19 09:30
180-85447-36	ASB pH 13.0	Water	01/16/19 09:05	01/05/19 09:30
180-85447-37	ASB pH 12.0	Water	01/16/19 09:05	01/05/19 09:30
180-85447-38	ASB pH 10.5	Water	01/16/19 09:05	01/05/19 09:30
180-85447-40	ASB pH 8.0	Water	01/16/19 09:05	01/05/19 09:30
180-85447-41	ASB pH 7.0	Water	01/16/19 09:05	01/05/19 09:30
180-85447-42	ASB pH 5.5	Water	01/18/19 09:20	01/05/19 09:30
180-85447-45	ASB pH NATURAL	Water	01/16/19 09:05	01/05/19 09:30
180-85447-46	MB LOW	Water	01/18/19 09:20	01/05/19 09:30
180-85447-47	MB NATURAL	Water	01/16/19 09:05	01/05/19 09:30
180-85447-48	MB HIGH	Water	01/16/19 09:05	01/05/19 09:30
180-85447-50	MB LOW 1	Water	01/23/19 07:40	01/05/19 09:30
180-85447-51	MB LOW 2	Solid	01/31/19 00:00	01/05/19 09:30
180-85447-52	MB LOW 2	Water	02/07/19 07:30	01/05/19 09:30

Method Summary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-2

Method	Method Description	Protocol	Laboratory
EPA 9040C	pH	SW846	TAL PIT
SM 2510B	Conductivity, Specific Conductance	SM	TAL PIT
SM 2580B	Reduction-Oxidation (REDOX) Potential	SM	TAL PIT
901.1	Radium-226 & Other Gamma Emitters (GS)	EPA	TAL SL
903.0	Radium-226 (GFPC)	EPA	TAL SL
904.0	Radium-228 (GFPC)	EPA	TAL SL
1313	Liquid-Solid Partitioning as a Function of pH via Parallel Batch	SW846	TAL PIT
Fill_Geo-21	Fill Geometry, 21-Day In-Growth	None	TAL SL
PrecSep_0	Preparation, Precipitate Separation	None	TAL SL
PrecSep-21	Preparation, Precipitate Separation (21-Day In-Growth)	None	TAL SL

Protocol References:

EPA = US Environmental Protection Agency

None = None

SM = "Standard Methods For The Examination Of Water And Wastewater"

SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.

Laboratory References:

TAL PIT = TestAmerica Pittsburgh, 301 Alpha Drive, RIDC Park, Pittsburgh, PA 15238, TEL (412)963-7058

TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Client Sample ID: ABB pH 2.0
Lab Sample ID: 180-85447-10
Date Collected: 01/04/19 11:10
Matrix: Solid
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			95 g	935.4 mL	270898	02/18/19 09:15	MTW	TAL PIT
Leach	Analysis	EPA 9040C		1			270930	02/20/19 09:15	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	270898	02/18/19 09:15	MTW	TAL PIT
Leach	Analysis	SM 2510B		1			270933	02/20/19 09:15	MTW	TAL PIT
	Instrument ID: NOEQUIP									
Leach	Leach	1313			95 g	935.4 mL	270898	02/18/19 09:15	MTW	TAL PIT
Leach	Analysis	SM 2580B		1			270932	02/20/19 09:15	MTW	TAL PIT
	Instrument ID: NOEQUIP									

Client Sample ID: ABB pH 13.0
Lab Sample ID: 180-85447-26
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			249.96 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414506	02/12/19 05:41	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			249.96 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:14	KLS	TAL SL
	Instrument ID: GFPCPURPLE									

Client Sample ID: ABB pH 12.0
Lab Sample ID: 180-85447-27
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			249.91 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414506	02/12/19 05:42	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			249.91 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:14	KLS	TAL SL
	Instrument ID: GFPCPURPLE									

Client Sample ID: ABB pH 10.5
Lab Sample ID: 180-85447-28
Date Collected: 01/18/19 09:20
Matrix: Water
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			292.54 mL	1.0 g	411711	01/22/19 13:04	CLP	TAL SL
Total/NA	Analysis	903.0		1			414693	02/13/19 05:51	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			292.54 mL	1.0 g	411716	01/22/19 14:01	CLP	TAL SL

Lab Chronicle

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-2

Client Sample ID: ABB pH 10.5

Lab Sample ID: 180-85447-28
Date Collected: 01/18/19 09:20
Date Received: 01/05/19 09:30
Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	904.0		1			413722	02/05/19 15:57	CDR	TAL SL
	Instrument ID: GFPCORANGE									

Client Sample ID: ABB pH 8.0

Lab Sample ID: 180-85447-30
Date Collected: 01/16/19 09:05
Date Received: 01/05/19 09:30
Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			556.67 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414506	02/12/19 05:42	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			556.67 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:14	KLS	TAL SL
	Instrument ID: GFPCPURPLE									

Client Sample ID: ABB pH 7.0

Lab Sample ID: 180-85447-31
Date Collected: 01/16/19 09:05
Date Received: 01/05/19 09:30
Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			550.54 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414506	02/12/19 05:42	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			550.54 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:15	KLS	TAL SL
	Instrument ID: GFPCPURPLE									

Client Sample ID: ABB pH 5.5

Lab Sample ID: 180-85447-32
Date Collected: 01/18/19 09:20
Date Received: 01/05/19 09:30
Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			582.99 mL	1.0 g	411711	01/22/19 13:04	CLP	TAL SL
Total/NA	Analysis	903.0		1			414693	02/13/19 05:51	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			582.99 mL	1.0 g	411716	01/22/19 14:01	CLP	TAL SL
Total/NA	Analysis	904.0		1			413722	02/05/19 15:57	CDR	TAL SL
	Instrument ID: GFPCORANGE									

Client Sample ID: ABB pH 4.0
Lab Sample ID: 180-85447-33
Date Collected: 01/18/19 09:20
Matrix: Water
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			587.67 mL	1.0 g	411711	01/22/19 13:04	CLP	TAL SL
Total/NA	Analysis	903.0		1			414693	02/13/19 05:51	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			587.67 mL	1.0 g	411716	01/22/19 14:01	CLP	TAL SL
Total/NA	Analysis	904.0		1			413722	02/05/19 15:57	CDR	TAL SL
	Instrument ID: GFPCORANGE									

Client Sample ID: ABB pH 2.0
Lab Sample ID: 180-85447-34
Date Collected: 02/07/19 07:30
Matrix: Water
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	Fill_Geo-21			500 mL	1.0 g	417071	02/27/19 15:04	KRS	TAL SL
Total/NA	Analysis	901.1		1			420133	03/20/19 10:34	KLS	TAL SL
	Instrument ID: GAMMAVISION									

Client Sample ID: ABB pH NATURAL
Lab Sample ID: 180-85447-35
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			549.43 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414506	02/12/19 05:42	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			549.43 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:15	KLS	TAL SL
	Instrument ID: GFPCPURPLE									

Client Sample ID: ASB pH 13.0
Lab Sample ID: 180-85447-36
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			563.20 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414506	02/12/19 05:42	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			563.20 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:15	KLS	TAL SL
	Instrument ID: GFPCPURPLE									

Lab Chronicle

Client: KPRG and Associates, Inc. TestAmerica Job ID: 180-85447-2
Project/Site: Midwest Generation

1 2 3 4 5 6 7 8 9 10 11 12 13

Client Sample ID: ASB pH 12.0 Lab Sample ID: 180-85447-37

Date Collected: 01/16/19 09:05 **Matrix: Water**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			571.25 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414506	02/12/19 05:42	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			571.25 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:15	KLS	TAL SL
	Instrument ID: GFPCPURPLE									

Client Sample ID: ASB pH 10.5 Lab Sample ID: 180-85447-38

Date Collected: 01/16/19 09:05 **Matrix: Water**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			547.60 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414506	02/12/19 05:42	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			547.60 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:15	KLS	TAL SL
	Instrument ID: GFPCPURPLE									

Client Sample ID: ASB pH 8.0 Lab Sample ID: 180-85447-40

Date Collected: 01/16/19 09:05 **Matrix: Water**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			558.12 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414506	02/12/19 05:42	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			558.12 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:15	KLS	TAL SL
	Instrument ID: GFPCPURPLE									

Client Sample ID: ASB pH 7.0 Lab Sample ID: 180-85447-41

Date Collected: 01/16/19 09:05 **Matrix: Water**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			565.90 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414507	02/12/19 05:44	KLS	TAL SL
	Instrument ID: GFPCPURPLE									
Total/NA	Prep	PrecSep_0			565.90 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:15	KLS	TAL SL
	Instrument ID: GFPCPURPLE									

Client Sample ID: ASB pH 5.5 Lab Sample ID: 180-85447-42
Date Collected: 01/18/19 09:20 **Matrix: Water**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			582.05 mL	1.0 g	411711	01/22/19 13:04	CLP	TAL SL
Total/NA	Analysis	903.0		1			414693	02/13/19 05:51	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			582.05 mL	1.0 g	411716	01/22/19 14:01	CLP	TAL SL
Total/NA	Analysis	904.0		1			413722	02/05/19 15:57	CDR	TAL SL
	Instrument ID: GFPCORANGE									

Client Sample ID: ASB pH NATURAL Lab Sample ID: 180-85447-45
Date Collected: 01/16/19 09:05 **Matrix: Water**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			548.67 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414507	02/12/19 05:44	KLS	TAL SL
	Instrument ID: GFPCPURPLE									
Total/NA	Prep	PrecSep_0			548.67 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:15	KLS	TAL SL
	Instrument ID: GFPCPURPLE									

Client Sample ID: MB LOW Lab Sample ID: 180-85447-46
Date Collected: 01/18/19 09:20 **Matrix: Water**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			557.25 mL	1.0 g	411711	01/22/19 13:04	CLP	TAL SL
Total/NA	Analysis	903.0		1			414693	02/13/19 05:51	KLS	TAL SL
	Instrument ID: GFPCORANGE									
Total/NA	Prep	PrecSep_0			557.25 mL	1.0 g	411716	01/22/19 14:01	CLP	TAL SL
Total/NA	Analysis	904.0		1			413722	02/05/19 15:57	CDR	TAL SL
	Instrument ID: GFPCORANGE									

Client Sample ID: MB NATURAL Lab Sample ID: 180-85447-47
Date Collected: 01/16/19 09:05 **Matrix: Water**
Date Received: 01/05/19 09:30

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			561.92 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414507	02/12/19 05:44	KLS	TAL SL
	Instrument ID: GFPCPURPLE									
Total/NA	Prep	PrecSep_0			561.92 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:15	KLS	TAL SL
	Instrument ID: GFPCPURPLE									

Lab Chronicle

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-2

1 2 3 4 5 6 7 8 9 10 11 12 13

Client Sample ID: MB HIGH

Lab Sample ID: 180-85447-48

Date Collected: 01/16/19 09:05
Date Received: 01/05/19 09:30

Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			569.08 mL	1.0 g	411366	01/21/19 08:18	JLC	TAL SL
Total/NA	Analysis	903.0		1			414507	02/12/19 05:44	KLS	TAL SL
	Instrument ID:	GFPCPURPLE								
Total/NA	Prep	PrecSep_0			569.08 mL	1.0 g	411374	01/21/19 09:34	JLC	TAL SL
Total/NA	Analysis	904.0		1			413455	02/04/19 16:16	KLS	TAL SL
	Instrument ID:	GFPCPURPLE								

Client Sample ID: MB LOW 1

Lab Sample ID: 180-85447-50

Date Collected: 01/23/19 07:40
Date Received: 01/05/19 09:30

Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			575.94 mL	1.0 g	412109	01/25/19 08:41	HET	TAL SL
Total/NA	Analysis	903.0		1			415289	02/18/19 06:02	CDR	TAL SL
	Instrument ID:	GFPCORANGE								
Total/NA	Prep	PrecSep_0			575.94 mL	1.0 g	412125	01/25/19 10:48	HET	TAL SL
Total/NA	Analysis	904.0		1			413930	02/07/19 15:47	CDR	TAL SL
	Instrument ID:	GFPCPURPLE								

Client Sample ID: MB LOW 2

Lab Sample ID: 180-85447-51

Date Collected: 01/31/19 00:00
Date Received: 01/05/19 09:30

Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Leach	Leach	1313			1.0 g	950 mL	270898	02/18/19 09:15	MTW	TAL PIT
Leach	Analysis	EPA 9040C		1			270930	02/20/19 09:15	MTW	TAL PIT
	Instrument ID:	NOEQUIP								
Leach	Leach	1313			1.0 g	950 mL	270898	02/18/19 09:15	MTW	TAL PIT
Leach	Analysis	SM 2510B		1			270933	02/20/19 09:15	MTW	TAL PIT
	Instrument ID:	NOEQUIP								
Leach	Leach	1313			1.0 g	950 mL	270898	02/18/19 09:15	MTW	TAL PIT
Leach	Analysis	SM 2580B		1			270932	02/20/19 09:15	MTW	TAL PIT
	Instrument ID:	NOEQUIP								

Client Sample ID: MB LOW 2

Lab Sample ID: 180-85447-52

Date Collected: 02/07/19 07:30
Date Received: 01/05/19 09:30

Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	PrecSep-21			606.25 mL	1.0 g	414637	02/12/19 15:24	CLP	TAL SL
Total/NA	Analysis	903.0		1			417879	03/06/19 05:43	CDR	TAL SL
	Instrument ID:	GFPCPURPLE								
Total/NA	Prep	PrecSep_0			606.25 mL	1.0 g	414649	02/12/19 16:59	CLP	TAL SL

Lab Chronicle

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-2

Client Sample ID: MB LOW 2
Date Collected: 02/07/19 07:30
Date Received: 01/05/19 09:30

Lab Sample ID: 180-85447-52
Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	904.0		1	1.0 mL	1.0 mL	415904	02/21/19 09:10	KLS	TAL SL
	Instrument ID: GFPCORANGE									

Laboratory References:

TAL PIT = TestAmerica Pittsburgh, 301 Alpha Drive, RIDC Park, Pittsburgh, PA 15238, TEL (412)963-7058
TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Analyst References:

Lab: TAL PIT
- Batch Type: Leach
  - MTW = Michael Wesoloski
- Batch Type: Analysis
  - MTW = Michael Wesoloski

Lab: TAL SL
- Batch Type: Prep
  - CLP = Cassandra Park
  - HET = Hailey Thompson
  - JLC = Jessica Chapman
  - KRS = Kurt Slama
- Batch Type: Analysis
  - CDR = Conrad Reuscher
  - KLS = Kody Saulters

Client Sample ID: ABB pH 2.0 **Lab Sample ID: 180-85447-10**
Date Collected: 01/04/19 11:10 **Matrix: Solid**
Date Received: 01/05/19 09:30

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	2.2		0.1	0.1	SU			02/20/19 09:15	1
Specific Conductance	78000		1.0	1.0	umhos/cm			02/20/19 09:15	1
Oxidation Reduction Potential	580		10	10	millivolts			02/20/19 09:15	1

Client Sample ID: ABB pH 13.0 **Lab Sample ID: 180-85447-26**
Date Collected: 01/16/19 09:05 **Matrix: Water**
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0662	U	0.237	0.237	1.00	0.454	pCi/L	01/21/19 08:18	02/12/19 05:41	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*89.7*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:41*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.874	U G	1.18	1.18	1.00	1.97	pCi/L	01/21/19 09:34	02/04/19 16:14	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*89.7*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:14*	*1*
Y Carrier	*65.8*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:14*	*1*

Client Sample ID: ABB pH 12.0 **Lab Sample ID: 180-85447-27**
Date Collected: 01/16/19 09:05 **Matrix: Water**
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0994	U	0.225	0.225	1.00	0.414	pCi/L	01/21/19 08:18	02/12/19 05:42	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*94.4*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:42*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	-0.785	U G	1.01	1.01	1.00	1.92	pCi/L	01/21/19 09:34	02/04/19 16:14	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*94.4*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:14*	*1*
Y Carrier	*78.9*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:14*	*1*

Client Sample Results

Client Sample ID: ABB pH 10.5

Lab Sample ID: 180-85447-28
Date Collected: 01/18/19 09:20
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.151	U	0.185	0.185	1.00	0.298	pCi/L	01/22/19 13:04	02/13/19 05:51	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*83.5*		*40 - 110*	*01/22/19 13:04*	*02/13/19 05:51*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.664	U G	1.05	1.05	1.00	1.78	pCi/L	01/22/19 14:01	02/05/19 15:57	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*83.5*		*40 - 110*	*01/22/19 14:01*	*02/05/19 15:57*	*1*
Y Carrier	*65.8*		*40 - 110*	*01/22/19 14:01*	*02/05/19 15:57*	*1*

Client Sample ID: ABB pH 8.0

Lab Sample ID: 180-85447-30
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.122	U	0.131	0.131	1.00	0.209	pCi/L	01/21/19 08:18	02/12/19 05:42	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*97.6*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:42*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.208	U	0.408	0.409	1.00	0.697	pCi/L	01/21/19 09:34	02/04/19 16:14	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*97.6*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:14*	*1*
Y Carrier	*83.4*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:14*	*1*

Client Sample ID: ABB pH 7.0

Lab Sample ID: 180-85447-31
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0835	U	0.104	0.104	1.00	0.171	pCi/L	01/21/19 08:18	02/12/19 05:42	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*102*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:42*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.255	U	0.409	0.410	1.00	0.689	pCi/L	01/21/19 09:34	02/04/19 16:15	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*102*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*
Y Carrier	*87.1*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*

Client Sample ID: ABB pH 5.5
Lab Sample ID: 180-85447-32
Date Collected: 01/18/19 09:20
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.258**		0.149	0.150	1.00	0.189	pCi/L	01/22/19 13:04	02/13/19 05:51	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*92.3*		*40 - 110*	*01/22/19 13:04*	*02/13/19 05:51*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.454	U	0.408	0.410	1.00	0.653	pCi/L	01/22/19 14:01	02/05/19 15:57	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*92.3*		*40 - 110*	*01/22/19 14:01*	*02/05/19 15:57*	*1*
Y Carrier	*81.1*		*40 - 110*	*01/22/19 14:01*	*02/05/19 15:57*	*1*

Client Sample ID: ABB pH 4.0
Lab Sample ID: 180-85447-33
Date Collected: 01/18/19 09:20
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.909**		0.216	0.231	1.00	0.141	pCi/L	01/22/19 13:04	02/13/19 05:51	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*109*		*40 - 110*	*01/22/19 13:04*	*02/13/19 05:51*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	**0.919**		0.454	0.462	1.00	0.674	pCi/L	01/22/19 14:01	02/05/19 15:57	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*109*		*40 - 110*	*01/22/19 14:01*	*02/05/19 15:57*	*1*
Y Carrier	*82.2*		*40 - 110*	*01/22/19 14:01*	*02/05/19 15:57*	*1*

1 2 3 4 5 6 7 8 9 10 11 12 13

Client Sample ID: ABB pH 2.0

Lab Sample ID: 180-85447-34
Date Collected: 02/07/19 07:30
Matrix: Water
Date Received: 01/05/19 09:30

Method: 901.1 - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**82.1**		23.3	24.7	50.0	23.5	pCi/L	02/27/19 15:04	03/20/19 10:34	1
Radium-228	**142**		27.0	30.2	50.0	31.0	pCi/L	02/27/19 15:04	03/20/19 10:34	1

Client Sample ID: ABB pH NATURAL

Lab Sample ID: 180-85447-35
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.109	U	0.112	0.113	1.00	0.174	pCi/L	01/21/19 08:18	02/12/19 05:42	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*92.0*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:42*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.453	U	0.454	0.456	1.00	0.737	pCi/L	01/21/19 09:34	02/04/19 16:15	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*92.0*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*
Y Carrier	*82.6*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*

Client Sample ID: ASB pH 13.0

Lab Sample ID: 180-85447-36
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0427	U	0.114	0.114	1.00	0.214	pCi/L	01/21/19 08:18	02/12/19 05:42	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*76.1*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:42*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	**0.836**		0.546	0.551	1.00	0.835	pCi/L	01/21/19 09:34	02/04/19 16:15	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*76.1*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*
Y Carrier	*83.0*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*

Client Sample ID: ASB pH 12.0

Lab Sample ID: 180-85447-37
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.00931	U	0.0834	0.0834	1.00	0.172	pCi/L	01/21/19 08:18	02/12/19 05:42	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*93.2*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:42*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	-0.0375	U	0.408	0.408	1.00	0.741	pCi/L	01/21/19 09:34	02/04/19 16:15	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*93.2*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*
Y Carrier	*83.4*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*

Client Sample ID: ASB pH 10.5

Lab Sample ID: 180-85447-38
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0538	U	0.106	0.106	1.00	0.191	pCi/L	01/21/19 08:18	02/12/19 05:42	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*91.2*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:42*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	-0.433	U	0.336	0.339	1.00	0.703	pCi/L	01/21/19 09:34	02/04/19 16:15	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*91.2*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*
Y Carrier	*84.5*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*

Client Sample ID: ASB pH 8.0

Lab Sample ID: 180-85447-40
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0452	U	0.0940	0.0941	1.00	0.172	pCi/L	01/21/19 08:18	02/12/19 05:42	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*97.3*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:42*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.312	U	0.371	0.372	1.00	0.612	pCi/L	01/21/19 09:34	02/04/19 16:15	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*97.3*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*
Y Carrier	*85.2*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*

Client Sample ID: ASB pH 7.0

Lab Sample ID: 180-85447-41

Date Collected: 01/16/19 09:05
Date Received: 01/05/19 09:30

Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.282**		0.136	0.138	1.00	0.158	pCi/L	01/21/19 08:18	02/12/19 05:44	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*106*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:44*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.357	U	0.402	0.404	1.00	0.661	pCi/L	01/21/19 09:34	02/04/19 16:15	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*106*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*
Y Carrier	*86.7*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*

Client Sample ID: ASB pH 5.5

Lab Sample ID: 180-85447-42

Date Collected: 01/18/19 09:20
Date Received: 01/05/19 09:30

Matrix: Water

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	**0.274**		0.173	0.175	1.00	0.224	pCi/L	01/22/19 13:04	02/13/19 05:51	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*65.8*		*40 - 110*	*01/22/19 13:04*	*02/13/19 05:51*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.477	U G	0.635	0.636	1.00	1.06	pCi/L	01/22/19 14:01	02/05/19 15:57	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*65.8*		*40 - 110*	*01/22/19 14:01*	*02/05/19 15:57*	*1*
Y Carrier	*83.0*		*40 - 110*	*01/22/19 14:01*	*02/05/19 15:57*	*1*

Client Sample ID: ASB pH NATURAL

Lab Sample ID: 180-85447-45
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	-0.0153	U	0.0848	0.0848	1.00	0.185	pCi/L	01/21/19 08:18	02/12/19 05:44	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*97.1*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:44*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.240	U	0.407	0.407	1.00	0.689	pCi/L	01/21/19 09:34	02/04/19 16:15	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*97.1*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*
Y Carrier	*86.0*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*

Client Sample ID: MB LOW

Lab Sample ID: 180-85447-46
Date Collected: 01/18/19 09:20
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	-0.0321	U	0.0963	0.0963	1.00	0.223	pCi/L	01/22/19 13:04	02/13/19 05:51	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*75.5*		*40 - 110*	*01/22/19 13:04*	*02/13/19 05:51*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.360	U	0.545	0.546	1.00	0.916	pCi/L	01/22/19 14:01	02/05/19 15:57	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*75.5*		*40 - 110*	*01/22/19 14:01*	*02/05/19 15:57*	*1*
Y Carrier	*81.1*		*40 - 110*	*01/22/19 14:01*	*02/05/19 15:57*	*1*

Client Sample ID: MB NATURAL

Lab Sample ID: 180-85447-47
Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	-0.00488	U	0.0678	0.0678	1.00	0.151	pCi/L	01/21/19 08:18	02/12/19 05:44	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*102*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:44*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.0316	U	0.340	0.340	1.00	0.613	pCi/L	01/21/19 09:34	02/04/19 16:15	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*102*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*
Y Carrier	*85.2*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:15*	*1*

Client Sample ID: MB HIGH
Lab Sample ID: 180-85447-48

Date Collected: 01/16/19 09:05
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0528	U	0.0880	0.0882	1.00	0.155	pCi/L	01/21/19 08:18	02/12/19 05:44	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*95.0*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:44*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.288	U	0.382	0.383	1.00	0.636	pCi/L	01/21/19 09:34	02/04/19 16:16	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*95.0*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:16*	*1*
Y Carrier	*84.1*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:16*	*1*

Client Sample ID: MB LOW 1
Lab Sample ID: 180-85447-50

Date Collected: 01/23/19 07:40
Matrix: Water
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.0480	U	0.0696	0.0697	1.00	0.119	pCi/L	01/25/19 08:41	02/18/19 06:02	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*101*		*40 - 110*	*01/25/19 08:41*	*02/18/19 06:02*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.107	U	0.415	0.415	1.00	0.725	pCi/L	01/25/19 10:48	02/07/19 15:47	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*101*		*40 - 110*	*01/25/19 10:48*	*02/07/19 15:47*	*1*
Y Carrier	*77.8*		*40 - 110*	*01/25/19 10:48*	*02/07/19 15:47*	*1*

Client Sample ID: MB LOW 2 — Lab Sample ID: 180-85447-51

Date Collected: 01/31/19 00:00 — **Matrix: Solid**
Date Received: 01/05/19 09:30

General Chemistry - Leach

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
pH	**0.4**		0.1	0.1	SU			02/20/19 09:15	1
Specific Conductance	**100000**		1.0	1.0	umhos/cm			02/20/19 09:15	1
Oxidation Reduction Potential	**550**		10	10	millivolts			02/20/19 09:15	1

Client Sample ID: MB LOW 2 — Lab Sample ID: 180-85447-52

Date Collected: 02/07/19 07:30 — **Matrix: Water**
Date Received: 01/05/19 09:30

Method: 903.0 - Radium-226 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.000	U	0.0644	0.0644	1.00	0.139	pCi/L	02/12/19 15:24	03/06/19 05:43	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*88.5*		*40 - 110*	*02/12/19 15:24*	*03/06/19 05:43*	*1*

Method: 904.0 - Radium-228 (GFPC)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	-0.545	U	0.313	0.317	1.00	0.666	pCi/L	02/12/19 16:59	02/21/19 09:10	1

Carrier	*%Yield*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*88.5*		*40 - 110*	*02/12/19 16:59*	*02/21/19 09:10*	*1*
Y Carrier	*91.2*		*40 - 110*	*02/12/19 16:59*	*02/21/19 09:10*	*1*

QC Sample Results

Method: EPA 9040C - pH

Lab Sample ID: LCS 180-270930/1
Matrix: Solid
Analysis Batch: 270930
Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
pH			7.00	7.0		SU		100	99 - 101

Lab Sample ID: 180-85447-10 DU
Matrix: Solid
Analysis Batch: 270930
Client Sample ID: ABB pH 2.0
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
pH	2.2		2.2		SU		0.4	2

Method: SM 2510B - Conductivity, Specific Conductance

Lab Sample ID: MB 180-270933/2
Matrix: Solid
Analysis Batch: 270933
Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Specific Conductance	ND		1.0	1.0	umhos/cm			02/20/19 09:15	1

Lab Sample ID: LCS 180-270933/1
Matrix: Solid
Analysis Batch: 270933
Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Specific Conductance			84.0	86.6		umhos/cm		103	90 - 110

Lab Sample ID: 180-85447-10 DU
Matrix: Solid
Analysis Batch: 270933
Client Sample ID: ABB pH 2.0
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Specific Conductance	78000		78200		umhos/cm		0	20

Method: SM 2580B - Reduction-Oxidation (REDOX) Potential

Lab Sample ID: LCS 180-270932/1
Matrix: Solid
Analysis Batch: 270932
Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Oxidation Reduction Potential			475	474		millivolts		100	90 - 110

Lab Sample ID: 180-85447-10 DU
Matrix: Solid
Analysis Batch: 270932
Client Sample ID: ABB pH 2.0
Prep Type: Leach

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Oxidation Reduction Potential	580		581		millivolts		0.3	20

Method: 901.1 - Radium-226 & Other Gamma Emitters (GS)

Lab Sample ID: MB 160-417071/1-A
Matrix: Water
Analysis Batch: 420131

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 417071

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	-5.956	U	19.8	19.8	50.0	33.9	pCi/L	02/27/19 15:04	03/20/19 08:19	1
Radium-228	16.40	U	15.9	16.0	50.0	19.3	pCi/L	02/27/19 15:04	03/20/19 08:19	1

Lab Sample ID: LCS 160-417071/2-A
Matrix: Water
Analysis Batch: 420132

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 417071

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Americium-241	136000	130900		15100		370	pCi/L	96	90 - 111
Cesium-137	44800	43740		4380		110	pCi/L	98	90 - 111
Cobalt-60	30200	29540		2920		66.5	pCi/L	98	89 - 110

Method: 903.0 - Radium-226 (GFPC)

Lab Sample ID: MB 160-411366/23-A
Matrix: Water
Analysis Batch: 414507

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 411366

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.08482	U	0.115	0.115	1.00	0.193	pCi/L	01/21/19 08:18	02/12/19 05:45	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*100*		*40 - 110*	*01/21/19 08:18*	*02/12/19 05:45*	*1*

Lab Sample ID: LCS 160-411366/1-A
Matrix: Water
Analysis Batch: 414506

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 411366

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-226	22.7	20.28		2.13	1.00	0.178	pCi/L	89	68 - 137

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*99.4*		*40 - 110*

Lab Sample ID: MB 160-411711/22-A
Matrix: Water
Analysis Batch: 414688

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 411711

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.006351	U	0.0536	0.0536	1.00	0.112	pCi/L	01/22/19 13:04	02/13/19 05:55	1

Method: 903.0 - Radium-226 (GFPC) (Continued)

Lab Sample ID: MB 160-411711/22-A
Matrix: Water
Analysis Batch: 414688

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 411711

Carrier	MB %Yield	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
Ba Carrier	72.0		40 - 110	01/22/19 13:04	02/13/19 05:55	1

Lab Sample ID: LCS 160-411711/1-A
Matrix: Water
Analysis Batch: 414693

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 411711

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-226	11.4	10.82		1.16	1.00	0.108	pCi/L	95	68 - 137

Carrier	LCS %Yield	LCS Qualifier	Limits
Ba Carrier	76.1		40 - 110

Lab Sample ID: MB 160-412109/18-A
Matrix: Water
Analysis Batch: 415289

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 412109

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.004897	U	0.0405	0.0405	1.00	0.0824	pCi/L	01/25/19 08:41	02/18/19 06:05	1

Carrier	MB %Yield	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
Ba Carrier	109		40 - 110	01/25/19 08:41	02/18/19 06:05	1

Lab Sample ID: LCS 160-412109/1-A
Matrix: Water
Analysis Batch: 415289

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 412109

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-226	11.4	11.37		1.16	1.00	0.0749	pCi/L	100	68 - 137

Carrier	LCS %Yield	LCS Qualifier	Limits
Ba Carrier	107		40 - 110

Lab Sample ID: MB 160-414637/18-A
Matrix: Water
Analysis Batch: 417879

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 414637

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-226	0.009030	U	0.0456	0.0456	1.00	0.0882	pCi/L	02/12/19 15:24	03/06/19 05:44	1

Carrier	MB %Yield	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
Ba Carrier	99.7		40 - 110	02/12/19 15:24	03/06/19 05:44	1

Method: 903.0 - Radium-226 (GFPC) (Continued)

Lab Sample ID: LCS 160-414637/1-A
Matrix: Water
Analysis Batch: 417878

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 414637

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-226	11.4	8.870		0.923	1.00	0.0740	pCi/L	78	68 - 137

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*106*		*40 - 110*

Method: 904.0 - Radium-228 (GFPC)

Lab Sample ID: MB 160-411374/23-A
Matrix: Water
Analysis Batch: 413681

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 411374

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.6720	U	0.465	0.469	1.00	0.719	pCi/L	01/21/19 09:34	02/04/19 16:17	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*100*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:17*	*1*
Y Carrier	*86.7*		*40 - 110*	*01/21/19 09:34*	*02/04/19 16:17*	*1*

Lab Sample ID: LCS 160-411374/1-A
Matrix: Water
Analysis Batch: 413455

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 411374

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-228	19.0	19.35		2.34	1.00	0.976	pCi/L	102	56 - 140

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*99.4*		*40 - 110*
Y Carrier	*70.3*		*40 - 110*

Lab Sample ID: MB 160-411716/22-A
Matrix: Water
Analysis Batch: 413722

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 411716

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.3180	U	0.295	0.297	1.00	0.475	pCi/L	01/22/19 14:01	02/05/19 15:59	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*72.0*		*40 - 110*	*01/22/19 14:01*	*02/05/19 15:59*	*1*
Y Carrier	*85.6*		*40 - 110*	*01/22/19 14:01*	*02/05/19 15:59*	*1*

Method: 904.0 - Radium-228 (GFPC) (Continued)

Lab Sample ID: LCS 160-411716/1-A
Matrix: Water
Analysis Batch: 413722
Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 411716

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-228	9.51	9.667		1.23	1.00	0.570	pCi/L	102	56 - 140

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*76.1*		*40 - 110*
Y Carrier	*73.6*		*40 - 110*

Lab Sample ID: MB 160-412125/18-A
Matrix: Water
Analysis Batch: 413930
Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 412125

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.006120	U	0.174	0.174	1.00	0.316	pCi/L	01/25/19 10:48	02/07/19 15:49	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*109*		*40 - 110*	*01/25/19 10:48*	*02/07/19 15:49*	*1*
Y Carrier	*85.2*		*40 - 110*	*01/25/19 10:48*	*02/07/19 15:49*	*1*

Lab Sample ID: LCS 160-412125/1-A
Matrix: Water
Analysis Batch: 413930
Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 412125

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-228	9.51	9.530		1.12	1.00	0.425	pCi/L	100	56 - 140

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*107*		*40 - 110*
Y Carrier	*74.0*		*40 - 110*

Lab Sample ID: MB 160-414649/18-A
Matrix: Water
Analysis Batch: 415904
Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 414649

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	RL	MDC	Unit	Prepared	Analyzed	Dil Fac
Radium-228	0.1381	U	0.237	0.237	1.00	0.400	pCi/L	02/12/19 16:59	02/21/19 09:10	1

Carrier	*MB %Yield*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
Ba Carrier	*99.7*		*40 - 110*	*02/12/19 16:59*	*02/21/19 09:10*	*1*
Y Carrier	*87.9*		*40 - 110*	*02/12/19 16:59*	*02/21/19 09:10*	*1*

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-2

Method: 904.0 - Radium-228 (GFPC) (Continued)

Lab Sample ID: LCS 160-414649/1-A
Matrix: Water
Analysis Batch: 415904

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 414649

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	RL	MDC	Unit	%Rec	%Rec. Limits
Radium-228	9.46	7.096		0.860	1.00	0.349	pCi/L	75	56 - 140

Carrier	*LCS %Yield*	*LCS Qualifier*	*Limits*
Ba Carrier	*106*		*40 - 110*
Y Carrier	*85.2*		*40 - 110*

QC Association Summary

General Chemistry

Leach Batch: 270898

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	1313	
180-85447-51	MB LOW 2	Leach	Solid	1313	
180-85447-10 DU	ABB pH 2.0	Leach	Solid	1313	

Analysis Batch: 270930

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	EPA 9040C	270898
180-85447-51	MB LOW 2	Leach	Solid	EPA 9040C	270898
LCS 180-270930/1	Lab Control Sample	Total/NA	Solid	EPA 9040C	
180-85447-10 DU	ABB pH 2.0	Leach	Solid	EPA 9040C	270898

Analysis Batch: 270932

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	SM 2580B	270898
180-85447-51	MB LOW 2	Leach	Solid	SM 2580B	270898
LCS 180-270932/1	Lab Control Sample	Total/NA	Solid	SM 2580B	
180-85447-10 DU	ABB pH 2.0	Leach	Solid	SM 2580B	270898

Analysis Batch: 270933

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-10	ABB pH 2.0	Leach	Solid	SM 2510B	270898
180-85447-51	MB LOW 2	Leach	Solid	SM 2510B	270898
MB 180-270933/2	Method Blank	Total/NA	Solid	SM 2510B	
LCS 180-270933/1	Lab Control Sample	Total/NA	Solid	SM 2510B	
180-85447-10 DU	ABB pH 2.0	Leach	Solid	SM 2510B	270898

Rad

Prep Batch: 411366

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-26	ABB pH 13.0	Total/NA	Water	PrecSep-21	
180-85447-27	ABB pH 12.0	Total/NA	Water	PrecSep-21	
180-85447-30	ABB pH 8.0	Total/NA	Water	PrecSep-21	
180-85447-31	ABB pH 7.0	Total/NA	Water	PrecSep-21	
180-85447-35	ABB pH NATURAL	Total/NA	Water	PrecSep-21	
180-85447-36	ASB pH 13.0	Total/NA	Water	PrecSep-21	
180-85447-37	ASB pH 12.0	Total/NA	Water	PrecSep-21	
180-85447-38	ASB pH 10.5	Total/NA	Water	PrecSep-21	
180-85447-40	ASB pH 8.0	Total/NA	Water	PrecSep-21	
180-85447-41	ASB pH 7.0	Total/NA	Water	PrecSep-21	
180-85447-45	ASB pH NATURAL	Total/NA	Water	PrecSep-21	
180-85447-47	MB NATURAL	Total/NA	Water	PrecSep-21	
180-85447-48	MB HIGH	Total/NA	Water	PrecSep-21	
MB 160-411366/23-A	Method Blank	Total/NA	Water	PrecSep-21	
LCS 160-411366/1-A	Lab Control Sample	Total/NA	Water	PrecSep-21	

Prep Batch: 411374

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-26	ABB pH 13.0	Total/NA	Water	PrecSep_0	
180-85447-27	ABB pH 12.0	Total/NA	Water	PrecSep_0	

Rad (Continued)

Prep Batch: 411374 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-30	ABB pH 8.0	Total/NA	Water	PrecSep_0	
180-85447-31	ABB pH 7.0	Total/NA	Water	PrecSep_0	
180-85447-35	ABB pH NATURAL	Total/NA	Water	PrecSep_0	
180-85447-36	ASB pH 13.0	Total/NA	Water	PrecSep_0	
180-85447-37	ASB pH 12.0	Total/NA	Water	PrecSep_0	
180-85447-38	ASB pH 10.5	Total/NA	Water	PrecSep_0	
180-85447-40	ASB pH 8.0	Total/NA	Water	PrecSep_0	
180-85447-41	ASB pH 7.0	Total/NA	Water	PrecSep_0	
180-85447-45	ASB pH NATURAL	Total/NA	Water	PrecSep_0	
180-85447-47	MB NATURAL	Total/NA	Water	PrecSep_0	
180-85447-48	MB HIGH	Total/NA	Water	PrecSep_0	
MB 160-411374/23-A	Method Blank	Total/NA	Water	PrecSep_0	
LCS 160-411374/1-A	Lab Control Sample	Total/NA	Water	PrecSep_0	

Prep Batch: 411711

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-28	ABB pH 10.5	Total/NA	Water	PrecSep-21	
180-85447-32	ABB pH 5.5	Total/NA	Water	PrecSep-21	
180-85447-33	ABB pH 4.0	Total/NA	Water	PrecSep-21	
180-85447-42	ASB pH 5.5	Total/NA	Water	PrecSep-21	
180-85447-46	MB LOW	Total/NA	Water	PrecSep-21	
MB 160-411711/22-A	Method Blank	Total/NA	Water	PrecSep-21	
LCS 160-411711/1-A	Lab Control Sample	Total/NA	Water	PrecSep-21	

Prep Batch: 411716

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-28	ABB pH 10.5	Total/NA	Water	PrecSep_0	
180-85447-32	ABB pH 5.5	Total/NA	Water	PrecSep_0	
180-85447-33	ABB pH 4.0	Total/NA	Water	PrecSep_0	
180-85447-42	ASB pH 5.5	Total/NA	Water	PrecSep_0	
180-85447-46	MB LOW	Total/NA	Water	PrecSep_0	
MB 160-411716/22-A	Method Blank	Total/NA	Water	PrecSep_0	
LCS 160-411716/1-A	Lab Control Sample	Total/NA	Water	PrecSep_0	

Prep Batch: 412109

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-50	MB LOW 1	Total/NA	Water	PrecSep-21	
MB 160-412109/18-A	Method Blank	Total/NA	Water	PrecSep-21	
LCS 160-412109/1-A	Lab Control Sample	Total/NA	Water	PrecSep-21	

Prep Batch: 412125

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-50	MB LOW 1	Total/NA	Water	PrecSep_0	
MB 160-412125/18-A	Method Blank	Total/NA	Water	PrecSep_0	
LCS 160-412125/1-A	Lab Control Sample	Total/NA	Water	PrecSep_0	

Prep Batch: 414637

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-52	MB LOW 2	Total/NA	Water	PrecSep-21	
MB 160-414637/18-A	Method Blank	Total/NA	Water	PrecSep-21	
LCS 160-414637/1-A	Lab Control Sample	Total/NA	Water	PrecSep-21	

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QC Association Summary

Client: KPRG and Associates, Inc.
Project/Site: Midwest Generation

TestAmerica Job ID: 180-85447-2

Prep Batch: 414649

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-52	MB LOW 2	Total/NA	Water	PrecSep_0	
MB 160-414649/18-A	Method Blank	Total/NA	Water	PrecSep_0	
LCS 160-414649/1-A	Lab Control Sample	Total/NA	Water	PrecSep_0	

Prep Batch: 417071

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-85447-34	ABB pH 2.0	Total/NA	Water	Fill_Geo-21	
MB 160-417071/1-A	Method Blank	Total/NA	Water	Fill_Geo-21	
LCS 160-417071/2-A	Lab Control Sample	Total/NA	Water	Fill_Geo-21	

Chain of Custody Record

273171

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING
TestAmerica Laboratories, Inc.
TAL-8210 (0713)

Regulatory Program: ☐ DW ☐ NPDES ☐ RCRA ☐ Other:

Client Contact	Project Manager:	Site Contact:	Date:	COC No:
Company Name: KPRG and Associates	Tel/Fax:	Lab Contact:	Carrier:	____ of ____ COCs
Address: 14665 W. Lisbon Rd. Ste 1A	**Analysis Turnaround Time**			Sampler:
City/State/Zip: Brookfield / WI / 53005	☐ CALENDAR DAYS ☐ WORKING DAYS			**For Lab Use Only:**
Phone: 262-781-0475	TAT if different from Below ____			Walk-in Client:
Fax:	☐ 2 weeks			Lab Sampling:
Project Name: NRG	☐ 1 week			
Site: Powerton	☐ 2 days			Job / SDG No.:
PO# 23517.0	☐ 1 day			

Sample Identification	Sample Date	Sample Time	Sample Type (C=Comp, G=Grab)	Matrix	# of Cont.	Filtered Sample (Y / N)	Perform MS / MSD (Y / N)	LEAF Method 1313	Sample Specific Notes:
ABB	1-4-19	1110	C	S	2	N	N	X	
ASB	1-4-19	1145	C	S	2	N	N	X	

180-85447 Chain of Custody

Preservation Used: 1= Ice, 2= HCl; 3= H2SO4; 4=HNO3; 5=NaOH; 6= Other ____

Possible Hazard Identification:
Are any samples from a listed EPA Hazardous Waste? Please List any EPA Waste Codes for the sample in the Comments Section if the lab is to dispose of the sample.
☐ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ Return to Client ☐ Disposal by Lab ☐ Archive for ____ Months

Special Instructions/QC Requirements & Comments:
CCR Appendix 4 compounds → As, Ba, Cd, Co, F, Pb, Li, Hg, Mo, Rad 226/228, Se, Tl / Sample Date is 1-4-19

Custody Seals Intact: ☐ Yes ☐ No	Custody Seal No.:		Cooler Temp. (°C): Obs'd: ____ Corr'd: ____		Therm ID No.: ____
Relinquished by: Mitchel Dolan	Company: KPRG	Date/Time: 1-4-19/1400	Received by: FEDEX	Company:	Date/Time: 1-4-19 / 1400
Relinquished by:	Company:	Date/Time:	Received by: Julie Watson	Company: TAPitt	Date/Time: 1-5-19 9:30
Relinquished by:	Company:	Date/Time:	Received in Laboratory by:	Company:	Date/Time:

FedEx®

180-85447 Waybill

Do Not Lift Usin

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ST 3 9 1 12:00 A 0897 01.05

ORIGIN ID:PIAA (000) 000-0000
KPRG ASSOCIATES
414 PLAZA DR STE 106
WESTMONT, IL 60559
UNITED STATES US

SHIP DATE: 04JAN19
ACTWGT: 50.00 LB
CAD: 006994779/SSFE1922
DIMS: 22x12x12 IN
BILL THIRD PARTY

TO ATTN CARRIE GAMBER
TEST AMERICA
301 ALPHA DR RIDC PARK

PITTSBURGH PA 15238
(412) 963-7058 REF:
INV:
PO: DEPT:

FedEx Express E

SATURDAY 12:00P
PRIORITY OVERNIGHT

TRK# 0201 7848 0408 0897

XO AGCA

15238 US PIT

Uncorrected temp 1.9 °C
Thermometer ID 10
CF 0 Initials TS
PT-WI-SR-001 effective 11/8/18

FedEx Express

TestAmerica Pittsburgh
301 Alpha Drive RIDC Park
Pittsburgh, PA 15238
Phone (412) 963-7058 Fax (412) 963-2468

Chain of Custody Record

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Client Information (Sub Contract Lab)	Sampler:	Lab PM: Gamber, Carrie L	Carrier Tracking No(s):	COC No: 180-352603.1
Client Contact: Shipping/Receiving	Phone:	E-Mail: carrie.gamber@testamericainc.com	State of Origin: Illinois	Page: Page 1 of 2
Company: TestAmerica Laboratories, Inc.		Accreditations Required (See note): NELAP - Illinois		Job #: 180-85447-2
Address: 13715 Rider Trail North, ,	Due Date Requested: 1/17/2019			
City: Earth City	TAT Requested (days):			
State, Zip: MO, 63045				
Phone: 314-298-8566(Tel) 314-298-8757(Fax)	PO #:			
Email:	WO #:			
Project Name: Midwest Generation	Project #: 18018377			
Site:	SSOW#:			

Preservation Codes:
A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA
M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
Other:

Analysis Requested

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	903.0/PrecSep_21 Standard Target List	904.0/PrecSep_0 Standard Target List	Total Number of containers	Special Instructions/Note:
			Preservation Code:							
ABB pH 13.0 (180-85447-26)	1/16/19	09:05 Central		Water			X	X	2	
ABB pH 12.0 (180-85447-27)	1/16/19	09:05 Central		Water			X	X	2	
ABB pH 8.0 (180-85447-30)	1/16/19	09:05 Central		Water			X	X	2	
ABB pH 7.0 (180-85447-31)	1/16/19	09:05 Central		Water			X	X	2	
ABB pH NATURAL (180-85447-35)	1/16/19	09:05 Central		Water			X	X	2	
ASB pH 13.0 (180-85447-36)	1/16/19	09:05 Central		Water			X	X	2	
ASB pH 12.0 (180-85447-37)	1/16/19	09:05 Central		Water			X	X	2	
ASB pH 10.5 (180-85447-38)	1/16/19	09:05 Central		Water			X	X	2	
ASB pH 8.0 (180-85447-40)	1/16/19	09:05 Central		Water			X	X	2	

Note: Since laboratory accreditations are subject to change, TestAmerica Laboratories, Inc. places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody. If the laboratory does not currently maintain accreditation in the State of Origin listed above for analysis/tests/matrix being analyzed, the samples must be shipped back to the TestAmerica laboratory or other instructions will be provided. Any changes to accreditation status should be brought to TestAmerica Laboratories, Inc. attention immediately. If all requested accreditations are current to date, return the signed Chain of Custody attesting to said complicance to TestAmerica Laboratories, Inc.

Possible Hazard Identification
Unconfirmed

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For ______ Months*

Deliverable Requested: I, II, III, IV, Other (specify) | Primary Deliverable Rank: 2

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:		Time:	Method of Shipment:	
Relinquished by: [signature]	Date/Time: 1/16/19 1700	Company: [illegible]	Received by: Michael Heem	Date/Time: 1-17-19 0915	Company: TA STL
Relinquished by:	Date/Time:	Company:	Received by:	Date/Time:	Company:
Relinquished by:	Date/Time:	Company:	Received by:	Date/Time:	Company:
Custody Seals Intact: Δ Yes Δ No	Custody Seal No.:		Cooler Temperature(s) °C and Other Remarks:		

Ver: 09/20/2016

TestAmerica Pittsburgh
301 Alpha Drive RIDC Park
Pittsburgh, PA 15238
Phone (412) 963-7058 Fax (412) 963-2468

Chain of Custody Record

TestAmerica — THE LEADER IN ENVIRONMENTAL TESTING

Client Information (Sub Contract Lab)

Client Contact	Shipping/Receiving
Company	TestAmerica Laboratories, Inc.
Address	13715 Rider Trail North,
City	Earth City
State, Zip	MO, 63045
Phone	314-298-8566(Tel) 314-298-8757(Fax)
Email	
Project Name	Midwest Generation
Site	
Sampler	
Phone	
Due Date Requested	1/17/2019
TAT Requested (days)	
PO #	
WO #	
Project #	18018377
SSOW#	
Lab PM	Gamber, Carrie L
E-Mail	carrie.gamber@testamericainc.com
Accreditations Required (See note)	NELAP - Illinois
Carrier Tracking No(s)	
State of Origin	Illinois
COC No	180-352603.2
Page	Page 2 of 2
Job #	180-85447-2

Preservation Codes:
A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA
M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
Other:

Analysis Requested

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	903.0/PrecSep_21 Standard Target List	904.0/PrecSep_0 Standard Target List	Total Number of containers	Special Instructions/Note:
			Preservation Code:							
ASB pH 7.0 (180-85447-41)	1/16/19	09:05 Central		Water			X	X	2	
ASB pH NATURAL (180-85447-45)	1/16/19	09:05 Central		Water			X	X	2	
MB NATURAL (180-85447-47)	1/16/19	09:05 Central		Water			X	X	2	
MB HIGH (180-85447-48)	1/16/19	09:05 Central		Water			X	X	2	

Note: Since laboratory accreditations are subject to change, TestAmerica Laboratories, Inc. places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody.

Possible Hazard Identification
Unconfirmed

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For* ______ *Months*

Deliverable Requested: I, II, III, IV, Other (specify)
Primary Deliverable Rank: 2
Special Instructions/QC Requirements:

Empty Kit Relinquished by: Date: Time: Method of Shipment:

Relinquished by	Date/Time	Company	Received by	Date/Time	Company
[signature]	1/16/19 1700	TAPIT	Michael Heem	1-17-19 0915	TA STL

Custody Seals Intact: Δ Yes Δ No
Custody Seal No.:
Cooler Temperature(s) °C and Other Remarks:

Ver: 09/20/2016

TestAmerica Pittsburgh
301 Alpha Drive RIDC Park
Pittsburgh, PA 15238
Phone (412) 963-7058 Fax (412) 963-2468

Chain of Custody Record

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Client Information (Sub Contract Lab)

Client Contact: Shipping/Receiving
Company: TestAmerica Laboratories, Inc.
Address: 13715 Rider Trail North,
City: Earth City
State, Zip: MO, 63045
Phone: 314-298-8566(Tel) 314-298-8757(Fax)
Email:
Project Name: Midwest Generation
Site:

Sampler:
Phone:
Due Date Requested: 1/17/2019
TAT Requested (days):
PO #:
WO #:
Project #: 18018377
SSOW#:

Lab PM: Gamber, Carrie L
E-Mail: carrie.gamber@testamericainc.com
Accreditations Required (See note): NELAP - Illinois
Carrier Tracking No(s):
State of Origin: Illinois
COC No: 180-352757.1
Page: Page 1 of 1
Job #: 180-85447-2

Preservation Codes:
A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA
M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
Other:

Analysis Requested

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	903.0/PrecSep_21 Standard Target List	904.0/PrecSep_0 Standard Target List	Total Number of containers	Special Instructions/Note:
			Preservation Code:							
ABB pH 10.5 (180-85447-28)	1/18/19	09:20 Central		Water			X	X	2	
ABB pH 5.5 (180-85447-32)	1/18/19	09:20 Central		Water			X	X	2	
ABB pH 4.0 (180-85447-33)	1/18/19	09:20 Central		Water			X	X	2	
ASB pH 5.5 (180-85447-42)	1/18/19	09:20 Central		Water			X	X	2	
MB LOW (180-85447-46)	1/18/19	09:20 Central		Water			X	X	2	

Note: Since laboratory accreditations are subject to change, TestAmerica Laboratories, Inc. places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody. If the laboratory does not currently maintain accreditation in the State of Origin listed above for analysis/tests/matrix being analyzed, the samples must be shipped back to the TestAmerica laboratory or other instructions will be provided. Any changes to accreditation status should be brought to TestAmerica Laboratories, Inc. attention immediately. If all requested accreditations are current to date, return the signed Chain of Custody attesting to said complicance to TestAmerica Laboratories, Inc.

Possible Hazard Identification
Unconfirmed
Deliverable Requested: I, II, III, IV, Other (specify) Primary Deliverable Rank: 2

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For* ______ *Months*
Special Instructions/QC Requirements:

Empty Kit Relinquished by: Date: Time: Method of Shipment:

Relinquished by	Date/Time	Company	Received by	Date/Time	Company
[signature]	1/18/19 1200	[illegible]	[signature]	1-19-19 0840	TASR

Custody Seals Intact: Δ Yes Δ No
Custody Seal No.:
Cooler Temperature(s) °C and Other Remarks:

Ver: 09/20/2016

1 2 3 4 5 6 7 8 9 10 11 12 13

1 2 3 4 5 6 7 8 9 10 11 12 13

TestAmerica Pittsburgh
301 Alpha Drive RIDC Park
Pittsburgh, PA 15238
Phone (412) 963-7058 Fax (412) 963-2468

Chain of Custody Record

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Client Information (Sub Contract Lab)

Client Contact: Shipping/Receiving
Company: TestAmerica Laboratories, Inc.
Address: 13715 Rider Trail North,
City: Earth City
State, Zip: MO, 63045
Phone: 314-298-8566(Tel) 314-298-8757(Fax)
Email:
Project Name: Midwest Generation
Site:

Sampler:
Phone:
Due Date Requested: 1/17/2019
TAT Requested (days):
PO #:
WO #:
Project #: 18018377
SSOW#:

Lab PM: Gamber, Carrie L
E-Mail: carrie.gamber@testamericainc.com
Carrier Tracking No(s):
State of Origin: Illinois
Accreditations Required (See note): NELAP - Illinois

COC No: 180-353110.1
Page: Page 1 of 1
Job #: 180-85447-2

Preservation Codes:
A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA
M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
Other:

Analysis Requested

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	903.0/PrecSep_21 Standard Target List	904.0/PrecSep_0 Standard Target List	Total Number of containers	Special Instructions/Note:
				Preservation Code:						
ASB pH 4.0 (180-85447-43)	1/23/19	07:40 Central		Water			X	X	2	
MB LOW 1 (180-85447-50)	1/23/19	07:40 Central		Water			X	X	2	

Note: Since laboratory accreditations are subject to change, TestAmerica Laboratories, Inc. places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody. If the laboratory does not currently maintain accreditation in the State of Origin listed above for analysis/tests/matrix being analyzed, the samples must be shipped back to the TestAmerica laboratory or other instructions will be provided. Any changes to accreditation status should be brought to TestAmerica Laboratories, Inc. attention immediately. If all requested accreditations are current to date, return the signed Chain of Custody attesting to said complicance to TestAmerica Laboratories, Inc.

Possible Hazard Identification
Unconfirmed
Deliverable Requested: I, II, III, IV, Other (specify) Primary Deliverable Rank: 2

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For* ____ *Months*
Special Instructions/QC Requirements:

Empty Kit Relinquished by: Date: Time: Method of Shipment:

Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
[signature]	1/23/19 1700	TA PITT	Michael Hum	1-24-19 0900	TA STL
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company

Custody Seals Intact: Δ Yes Δ No
Custody Seal No.:
Cooler Temperature(s) °C and Other Remarks:

Ver: 09/20/2016

TestAmerica Pittsburgh
301 Alpha Drive RIDC Park
Pittsburgh, PA 15238
Phone (412) 963-7058 Fax (412) 963-2468

Chain of Custody Record

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Client Information (Sub Contract Lab)	Sampler:	Lab PM: Gamber, Carrie L	Carrier Tracking No(s):	COC No: 180-354349.1
Client Contact: Shipping/Receiving	Phone:	E-Mail: carrie.gamber@testamericainc.com	State of Origin: Illinois	Page: Page 1 of 1
Company: TestAmerica Laboratories, Inc.		Accreditations Required (See note): NELAP - Illinois		Job #: 180-85447-2
Address: 13715 Rider Trail North,	Due Date Requested: 2/14/2019			
City: Earth City	TAT Requested (days):			
State, Zip: MO, 63045				
Phone: 314-298-8566(Tel) 314-298-8757(Fax)	PO #:			
Email:	WO #:			
Project Name: Midwest Generation	Project #: 18018377			
Site:	SSOW#:			

Analysis Requested

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	903.0/PrecSep_21 Standard Target List	904.0/PrecSep_0 Standard Target List	Total Number of containers	Special Instructions/Note:
			Preservation Code:							
ABB pH 2.0 (180-85447-34)	2/7/19	07:30 Central		Water			X	X	2	
ASB pH 2.0 (180-85447-44)	2/7/19	07:30 Central		Water			X	X	2	

Preservation Codes:

A - HCL	M - Hexane
B - NaOH	N - None
C - Zn Acetate	O - AsNaO2
D - Nitric Acid	P - Na2O4S
E - NaHSO4	Q - Na2SO3
F - MeOH	R - Na2S2O3
G - Amchlor	S - H2SO4
H - Ascorbic Acid	T - TSP Dodecahydrate
I - Ice	U - Acetone
J - DI Water	V - MCAA
K - EDTA	W - pH 4-5
L - EDA	Z - other (specify)

Other:

Note: Since laboratory accreditations are subject to change, TestAmerica Laboratories, Inc. places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody. If the laboratory does not currently maintain accreditation in the State of Origin listed above for analysis/tests/matrix being analyzed, the samples must be shipped back to the TestAmerica laboratory or other instructions will be provided. Any changes to accreditation status should be brought to TestAmerica Laboratories, Inc. attention immediately. If all requested accreditations are current to date, return the signed Chain of Custody attesting to said complicance to TestAmerica Laboratories, Inc.

Possible Hazard Identification
Unconfirmed

Deliverable Requested: I, II, III, IV, Other (specify) Primary Deliverable Rank: 2

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For* ____ *Months*

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:	Time:	Method of Shipment:		
Relinquished by: [signature]	Date/Time: 2/7/19 1700	Company: [illegible]	Received by: [signature]	Date/Time: 2-8-19 / 0800	Company: TASH
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Custody Seals Intact: Δ Yes Δ No	Custody Seal No.:		Cooler Temperature(s) °C and Other Remarks:		

Ver: 09/20/2016

TestAmerica Pittsburgh
301 Alpha Drive RIDC Park
Pittsburgh, PA 15238
Phone (412) 963-7058 Fax (412) 963-2468

Chain of Custody Record

TestAmerica — THE LEADER IN ENVIRONMENTAL TESTING

Client Information (Sub Contract Lab)	Sampler:	Lab PM: Gamber, Carrie L	Carrier Tracking No(s):	COC No: 180-354349.1
Client Contact: Shipping/Receiving	Phone:	E-Mail: carrie.gamber@testamericainc.com	State of Origin: Illinois	Page: Page 1 of 1
Company: TestAmerica Laboratories, Inc.		Accreditations Required (See note): NELAP - Illinois		Job #: 180-85447-1
Address: 13715 Rider Trail North,	Due Date Requested: 2/11/2019			
City: Earth City	TAT Requested (days):			
State, Zip: MO, 63045				
Phone: 314-298-8566(Tel) 314-298-8757(Fax)	PO #:			
Email:	WO #:			
Project Name: Midwest Generation	Project #: 18018377			
Site:	SSOW#:			

Analysis Requested

Preservation Codes:
A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA
M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
Other:

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	903.0/PrecSep_21 Standard Target List	904.0/PrecSep_0 Standard Target List	Total Number of containers	Special Instructions/Note:
			Preservation Code:							
MB LOW 2 (180-85447-52)	2/7/19	07:30 Central		Water			X	X	2	

Note: Since laboratory accreditations are subject to change, TestAmerica Laboratories, Inc. places the ownership of method, analyte & accreditation compliance upon out subcontract laboratories. This sample shipment is forwarded under chain-of-custody. If the laboratory does not currently maintain accreditation in the State of Origin listed above for analysis/tests/matrix being analyzed, the samples must be shipped back to the TestAmerica laboratory or other instructions will be provided. Any changes to accreditation status should be brought to TestAmerica Laboratories, Inc. attention immediately. If all requested accreditations are current to date, return the signed Chain of Custody attesting to said complicance to TestAmerica Laboratories, Inc.

Possible Hazard Identification
Unconfirmed

Deliverable Requested: I, II, III, IV, Other (specify) — Primary Deliverable Rank: 2

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For* ______ *Months*

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:		Time:	Method of Shipment:	
Relinquished by: [signature]	Date/Time: 2/7/19 1200	Company: TAPitt	Received by: [signature]	Date/Time: 2-9-19/0800	Company: TASTL
Relinquished by:	Date/Time:	Company:	Received by:	Date/Time:	Company:
Relinquished by:	Date/Time:	Company:	Received by:	Date/Time:	Company:
Custody Seals Intact: Δ Yes Δ No	Custody Seal No.:		Cooler Temperature(s) °C and Other Remarks:		

Ver: 09/20/2016

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc. | Job Number: 180-85447-2

Login Number: 85447 | **List Source: TestAmerica Pittsburgh**
List Number: 1
Creator: Watson, Debbie

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	False	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc.

Job Number: 180-85447-2

Login Number: 85447
List Number: 2
Creator: Hellm, Michael

List Source: TestAmerica St. Louis
List Creation: 01/17/19 02:44 PM

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	0.7, 0.8, 0.9, 2.6, 3.0, 3.2, 18.0
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	N/A	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	N/A	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	N/A	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc. Job Number: 180-85447-2

Login Number: 85447
List Number: 3
Creator: Hellm, Michael

List Source: TestAmerica St. Louis
List Creation: 01/19/19 01:36 PM

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	19.0
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	N/A	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	N/A	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc.

Job Number: 180-85447-2

Login Number: 85447
List Number: 4
Creator: Hellm, Michael

List Source: TestAmerica St. Louis
List Creation: 01/24/19 11:38 AM

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	False	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	17.0
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	N/A	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	N/A	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc. Job Number: 180-85447-2

Login Number: 85447
List Number: 5
Creator: Press, Nicholas B

List Source: TestAmerica St. Louis
List Creation: 02/08/19 08:27 PM

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	3.7
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Login Sample Receipt Checklist

Client: KPRG and Associates, Inc.

Job Number: 180-85447-2

Login Number: 85447
List Number: 6
Creator: Press, Nicholas B

List Source: TestAmerica St. Louis
List Creation: 02/08/19 08:28 PM

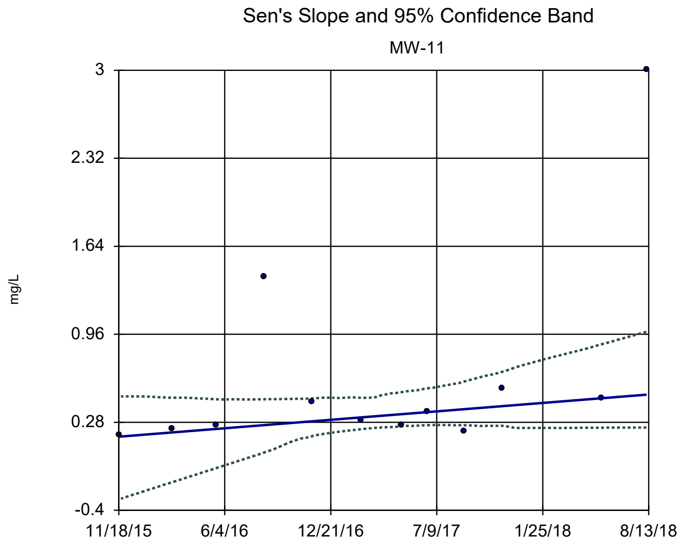
Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	3.7
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

ATTACHMENT 3
Sanitas™ Trend Analysis Results

Trend Test Linear Barium MW-11

Powerton Generating Station   Client: NRG   Data: Powerton   Printed 3/7/2019, 8:47 AM

Constituent	Well	Slope	Calc.	Critical	Sig.	N	%NDs	Normality	Xform	Alpha	Method
Barium (mg/L)	MW-11	0.1194	29	35	No	12	0	n/a	n/a	0.02	NP (Nor...



n = 12

Slope = 0.1194 units per year.

Mann-Kendall statistic = 29 critical = 35

Trend not significant at 98% confidence level (α = 0.01 per tail).
Sen's Slope/Mann-Kendall used in lieu of Linear Regression because the Shapiro Wilk normality test showed the residuals to be non-normal at the 0.05 alpha level, calculated = 0.8304, critical = 0.859.

Constituent: Barium Analysis Run 3/7/2019 8:46 AM

Powerton Generating Station Client: NRG Data: Powerton

Sen's Slope Estimator

Constituent: Barium (mg/L) Analysis Run 3/7/2019 8:47 AM

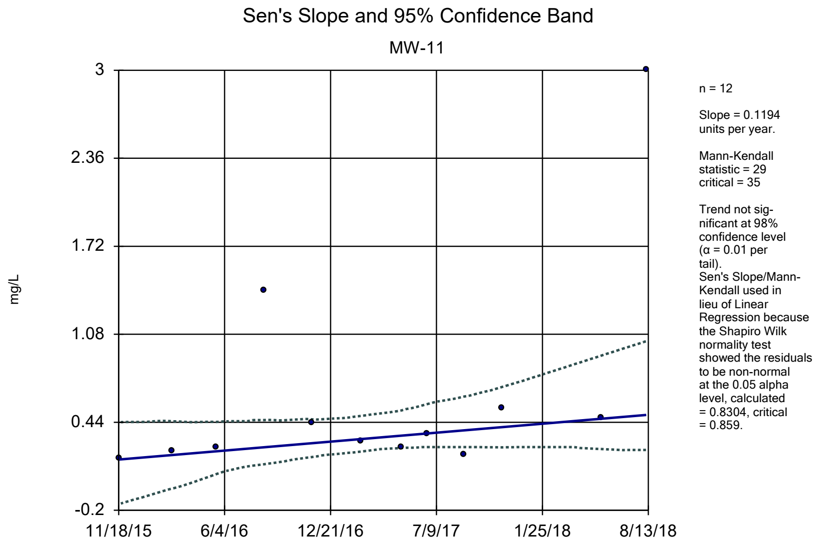
Powerton Generating Station Client: NRG Data: Powerton

	MW-11
11/18/2015	0.18
2/26/2016	0.23
5/20/2016	0.26
8/17/2016	1.4
11/17/2016	0.44
2/16/2017	0.3
5/3/2017	0.26
6/22/2017	0.36
8/29/2017	0.21
11/9/2017	0.54
5/16/2018	0.47
8/9/2018	3

Trend Test Sens Slope Barium MW-11

Powerton Generating Station   Client: NRG   Data: Powerton   Printed 3/7/2019, 8:57 AM

Constituent	Well	Slope	Calc.	Critical	Sig.	N	%NDs	Normality	Xform	Alpha	Method
Barium (mg/L)	MW-11	0.1194	29	35	No	12	0	n/a	n/a	0.02	NP (Nor...



Constituent: Barium Analysis Run 3/7/2019 8:49 AM

Powerton Generating Station Client: NRG Data: Powerton

Sen's Slope Estimator

Constituent: Barium (mg/L) Analysis Run 3/7/2019 8:51 AM

Powerton Generating Station Client: NRG Data: Powerton

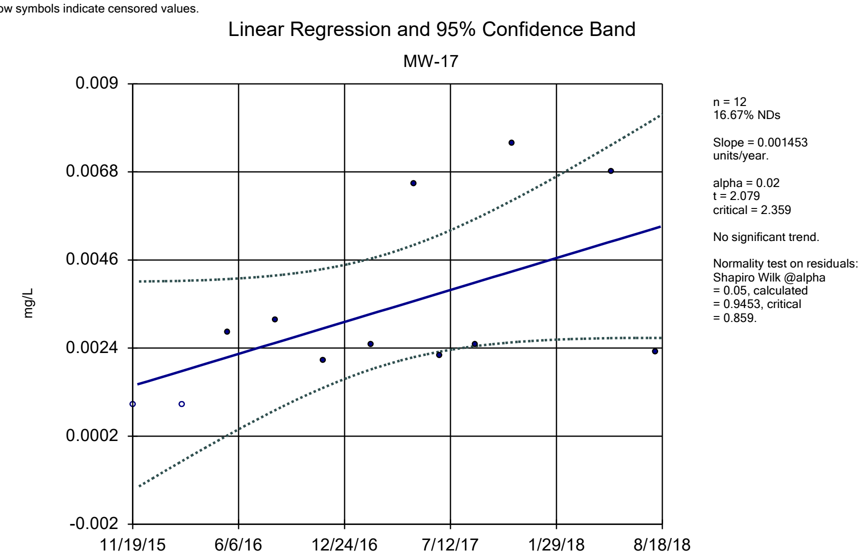
	MW-11
11/18/2015	0.18
2/26/2016	0.23
5/20/2016	0.26
8/17/2016	1.4
11/17/2016	0.44
2/16/2017	0.3
5/3/2017	0.26
6/22/2017	0.36
8/29/2017	0.21
11/9/2017	0.54
5/16/2018	0.47
8/9/2018	3

Trend Test Linear Thallium MW-17

Powerton Generating Station Client: NRG Data: Powerton Printed 3/7/2019, 9:17 AM

Constituent	Well	Slope	Calc.	Critical	Sig.	N	%NDs	Normality	Xform	Alpha	Method
Thallium (mg/L)	MW-17	0.001453	2.079	2.359	No	12	16.67	Yes	no	0.02	Param.

Sanitas™ v.9.6.09 Software licensed to KPRG and Associates, Inc. UG
Hollow symbols indicate censored values.



Constituent: Thallium   Analysis Run 3/7/2019 9:16 AM
Powerton Generating Station   Client: NRG   Data: Powerton

Linear Regression

Constituent: Thallium (mg/L) Analysis Run 3/7/2019 9:17 AM

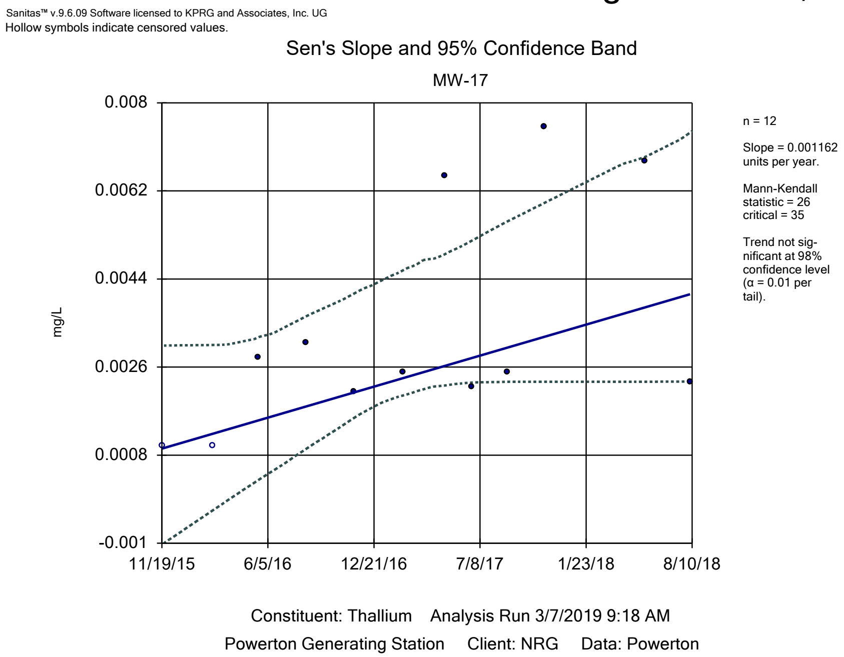
Powerton Generating Station Client: NRG Data: Powerton

	MW-17
11/19/2015	<0.002
2/22/2016	<0.002
5/18/2016	0.0028
8/15/2016	0.0031
11/14/2016	0.0021
2/13/2017	0.0025
5/4/2017	0.0065
6/22/2017	0.0022
8/29/2017	0.0025
11/6/2017	0.0075
5/14/2018	0.0068
8/6/2018	0.0023

Trend Test Sens Slope Thallium MW-17

Powerton Generating Station Client: NRG Data: Powerton Printed 3/7/2019, 9:19 AM

Constituent	Well	Slope	Calc.	Critical	Sig.	N	%NDs	Normality	Xform	Alpha	Method
Thallium (mg/L)	MW-17	0.001162	26	35	No	12	16.67	n/a	n/a	0.02	NP


Sanitas™ v.9.6.09 Software licensed to KPRG and Associates, Inc. UG
Hollow symbols indicate censored values.
Sen's Slope and 95% Confidence Band
MW-17
0.008
0.0062
0.0044
0.0026
0.0008
-0.001
mg/L
11/19/15
6/5/16
12/21/16
7/8/17
1/23/18
8/10/18
n = 12
Slope = 0.001162 units per year.
Mann-Kendall statistic = 26 critical = 35
Trend not significant at 98% confidence level (α = 0.01 per tail).
Constituent: Thallium Analysis Run 3/7/2019 9:18 AM
Powerton Generating Station Client: NRG Data: Powerton

Sen's Slope Estimator

Constituent: Thallium (mg/L)   Analysis Run 3/7/2019 9:19 AM

Powerton Generating Station   Client: NRG   Data: Powerton

	MW-17
11/19/2015	<0.002
2/22/2016	<0.002
5/18/2016	0.0028
8/15/2016	0.0031
11/14/2016	0.0021
2/13/2017	0.0025
5/4/2017	0.0065
6/22/2017	0.0022
8/29/2017	0.0025
11/6/2017	0.0075
5/14/2018	0.0068
8/6/2018	0.0023

EXHIBIT 18

November 30, 2020

Andrew Wheeler
Administrator
US EPA
One Potomac Yard
2777 S. Crystal Drive
Arlington, Virginia 22202-3553

RE: Powerton Generating Station, Midwest Generation, LLC
Alternate Closure Demonstration, 40 CFR Part 257.103

Administrator Wheeler,

The purpose of this correspondence is to submit to the United States Environmental Protection Agency (USEPA) a Demonstration for a Site-Specific Alternative Deadline to Initiate Closure documentation for the Powerton Generating Station, located on 13082 E. Manito Road, Pekin, Illinois 61554. Powerton Generating Station (the Station) is owned and operated by Midwest Generation, LLC (MWG).

The station is subject to 40 CFR Part 257 Subpart D "The Federal CCR Rule", effective April 17, 2015 and subsequent amendments including ***Hazardous and Solid Waste Management System: Disposal of Coal Combustion Residuals from Electric Utilities: A Holistic Approach to Closure Part A: Deadline to Initiate Closure, effective September 28, 2020***. The facility's Ash Surge Basin currently does not meet the liner design criteria as promulgated by 40 CFR Part 257.71 and by rule the station must cease placing the CCR and non-CCR wastestreams currently sent to the Ash Surge Basin and initiate closure as soon as technically feasible but no later than April 11, 2021, unless an alternative closure timeline is granted by the EPA in accordance with 40 CFR 257.103 based on a Site-Specific Demonstration for No Alternative Disposal Capacity.

MWG has concluded that no alternative disposal capacity is available and that it is technically infeasible to obtain alternative disposal capacity for these wastestreams on- or off-site by April 11, 2021. Accordingly, pursuant to 40 CFR 257.103(f)(1)(iv)(A), MWG has prepared the following demonstration and workplan detailing its proposed development of alternative disposal capacity and a timeline to replace the Ash Surge Basin.

We look forward to working with the USEPA on this request and proceeding with our project to establish alternative capacity. Please contact me at (302)-540-0327 or david.bacher@nrgenergy.com to address any questions or concerns regarding this submittal.

Sincerely,

David Bacher
Senior Regional Manager
Environmental Business, NRG Energy, Inc.
29416 Power Plant Road
Dagsboro, Delaware 19939

CC: Kirsten Hillyer (US EPA), Frank Behan (USEPA), Richard Huggins (USEPA)
W. Stone (NRG), S. Shealey (MWG), W. Shander (MWG)

MWG

Midwest Generation, LLC
Powerton Generating Station

Demonstration for a Site-Specific Alternative Deadline to Initiate Closure

Report SL-015574
Revision 0
November 30, 2020
Issue Purpose: Use
Project No.: 12661-097

55 East Monroe Street
Chicago, IL 60603-5780 USA
312-269-2000
www.sargentlundy.com

Sargent & Lundy

LEGAL NOTICE

This workplan was prepared by Sargent & Lundy, L.L.C. (S&L) expressly for the sole use of Midwest Generation, LLC (Client) in accordance with the contract agreement between S&L and Client. This workplan was prepared using the degree of skill and care ordinarily exercised by engineers practicing under similar circumstances. Client acknowledges: (1) S&L prepared this workplan subject to the particular scope limitations, budgetary and time constraints, and business objectives of Client; (2) information and data provided by others, including Client, may not have been independently verified by S&L; and (3) the information and data contained in this workplan are time-sensitive and changes in the data, applicable codes, standards, and acceptable engineering practices may invalidate the findings of this workplan. Any use or reliance upon this workplan by third parties shall be at their sole risk.

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EXECUTIVE SUMMARY

The Ash Surge Basin and Bypass Basin at the Powerton Generating Station (“Powerton” or the “Station”) in Pekin, Illinois do not meet the liner design criteria promulgated by 40 CFR Part 257 Subpart D (“the EPA CCR Rule”). Therefore, Powerton must cease placing the CCR and non-CCR wastestreams sent to the Ash Surge and Bypass Basins as soon as technically feasible but no later than April 11, 2021, unless an alternative deadline is granted by the EPA in accordance with 40 CFR 257.103. Because the Station does not need to have both of its CCR surface impoundments in service to generate power – and pursuant to the revised EPA CCR Rule – Powerton will not send CCR or non-CCR wastestreams to the Bypass Basin after April 11, 2021 and does not plan on sending any wastestreams to that basin in the interim. However, after evaluating several on- and off-site alternative disposal solutions for the wastestreams currently sent to the Ash Surge Basin – both permanent and temporary – Midwest Generation, LLC (MWG), the operator of the Station, has concluded that no alternative disposal capacity is available for these wastestreams, and that it is technically infeasible to obtain alternative disposal capacity for these wastestreams on- or off-site by April 11, 2021. Accordingly, pursuant to 40 CFR 257.103(f)(1)(iv)(A), MWG has prepared the following workplan detailing its proposed development of alternative disposal capacity to replace the Ash Surge Basin.

Powerton currently sends the following CCR and non-CCR wastestreams to the Ash Surge Basin: Unit 5 and 6 dewatering bin effluent (CCR), overflow from the Unit 5 and 6 slag tanks (non-CCR), overflow from the Station’s East Yard Runoff Basin (non-CCR), effluent from the Station’s Makeup Treatment Plant (non-CCR), and effluent from the Station’s Metal Cleaning Waste Treatment System (non-CCR). After evaluating several options for providing alternative disposal capacity to the Ash Surge Basin for these wastestreams, MWG elected to install a multiple technology system that will be developed in two phases. The first phase will bring Powerton into compliance with the EPA CCR Rule and will set up the second phase which will bring the Station into compliance with the EPA’s recently-revised effluent limitation guidelines for steam electric power generating stations (“ELG Rule”). When completed, the multiple technology solution selected to replace the Ash Surge Basin will feature four elements: refurbished dewatering bins, a new concrete ash-settling tank, a new Recycle Cooling Water Basin, and a new Low-Volume Waste Basin.

MWG will begin the development of this multiple technology solution by refurbishing Powerton’s existing dewatering bins, which are currently discharging effluent with relatively large ash particles remaining in suspension to the Ash Surge Basin. By refurbishing the dewatering bins, fewer and smaller ash particles will remain suspended in the effluent. In lieu of the Ash Surge Basin, MWG plans to manage this effluent with a new concrete ash-settling tank, which will feature two primary settling cells in parallel trains with a common surge cell. Treated wastewater in the surge cell will overflow into the new Recycle Cooling Water Basin, which will be constructed in the footprint of the Station’s Bypass Basin, which was recently taken out of service for routine cleaning. The Recycle Cooling Water Basin will be installed by first clean-closing the Bypass Basin and then installing a geomembrane liner over the basin’s storage area. Once the new concrete ash-settling tank and Recycle Cooling Water Basin are both operational, Powerton will divert all wastestreams from the Ash Surge Basin to these new facilities, marking the establishment of alternative disposal capacity. Finally, MWG will clean close and repurpose the Ash Surge Basin as the Station's Low-Volume Waste Basin. This will separate the CCR and non-CCR wastestreams currently being commingled in the Ash Surge Basin and will allow Powerton to strictly limit future discharges of bottom ash transport water in accordance with the EPA's recently-revised ELG Rule once a recirculation system is installed for the Station's bottom ash-handling system during the second phase of the project.

This proposed multiple technology solution to replace the Ash Surge Basin will be installed in accordance with the EPA CCR Rule and with the Illinois EPA's forthcoming regulations and permit program for CCR surface impoundments ("Final Illinois CCR Rule"), which is expected to be adopted by the Illinois Pollution Control Board into the Illinois Administrative Code in late March 2021. Pursuant to the Illinois Public Act authorizing the Illinois EPA to prepare and the Illinois Pollution Control Board to adopt the Final Illinois CCR Rule, MWG cannot "close any CCR surface impoundment without a permit granted by the [Illinois EPA]." Accordingly, both the design of and timeframes for the first phase of this proposed project is highly dependent on the future regulations and permitting requirements established by the Final Illinois CCR Rule.

Based on the anticipated timeframes for engineering/designing, permitting, constructing, and commissioning the refurbished dewatering bins, the new concrete ash-settling tank, and the new Recycle Water Cooling Basin, MWG is requesting the EPA allow the Ash Surge Basin to continue receiving the noted CCR and non-CCR wastestreams until August 11, 2023. Further details on the Ash Surge Basin, the wastestreams managed therein, the forthcoming Final Illinois CCR Rule, and MWG's development of alternative disposal capacity for the wastestreams currently being sent to the Ash Surge Basin are provided throughout this workplan. Finally, MWG's demonstration of Powerton's compliance with the EPA CCR Rule is also provided herein.

1.0 DEVELOPMENT OF ALTERNATIVE CAPACITY

This section presents the option selected by Midwest Generation, LLC (MWG) to provide alternative disposal capacity for the coal combustion residual (CCR) and non-CCR wastestreams currently sent to the Ash Surge and Bypass Basins at the Powerton Generating Station. This section also provides background information on the Powerton Generating Station, the routine operations of the Ash Surge and Bypass Basins and the wastestreams managed within the two CCR surface impoundments, and the adverse impact to plant operations if both the Ash Surge and Bypass Basins were both shut down by April 11, 2021. This section also describes the processes MWG undertook to select the alternative disposal capacity that is being proposed in this workplan and provides a narrative description of the alternative disposal capacity design. Finally, an explanation and justification for the time being requested to operate the Ash Surge Basin beyond April 11, 2021 is provided in this section.

1.1 BACKGROUND INFORMATION

1.1.1 POWERTON GENERATING STATION

MWG operates the Powerton Generating Station ("Powerton" or the "Station"), which is a coal-fired steam electric power generating station located in Pekin, Illinois and is adjacent to and south of the Illinois River. The Station's address is 13082 East Manito Rd, Pekin, IL 61554. The Station consists of two operating units, Units 5 and 6, which are cyclone boilers with an approximate nameplate capacity of 1,785 megawatts (MW). Drawing POW-CSK-001 in Appendix A shows the location of the plant and a general layout of the station facilities pertinent to this demonstration.

1.1.2 ASH SURGE BASIN & BYPASS BASIN

Powerton has two active CCR surface impoundments regulated by the EPA's CCR Rule (40 CFR Part 257 Subpart D, Ref. 1): the Ash Surge Basin and the Bypass Basin. As shown on drawing POW-CSK-001, these ponds are adjacent to each other and are located north of the Station's ash dewatering bins. Characteristics for both basins are listed in Table 1.

Table 1 – Ash Surge Basin & Bypass Basin Characteristics

Basin	Crest Elevation (ft)	Floor Elevation (ft)	Storage Area (acres)	Storage Capacity (cu. yd.)
Ash Surge Basin	467	452	8.4	162,000
Bypass Basin	467	457	0.83	9,000

Note: Listed elevations are referenced to the National Geodetic Vertical Datum of 1929.

1.1.2.1 BASIN OPERATIONS

The primary purpose of the Ash Surge and Bypass Basins is to treat the effluent from Powerton's dewatering bins prior to being discharged to the Illinois River in accordance with the Station's National Pollutant Discharge Elimination System (NPDES) permit (NPDES Permit No. IL0002232). Both Units 5 and 6 are equipped with an ash-handling system that sluices bottom ash and economizer ash to a set of two dewatering bins (one dedicated pair per unit) which promote sedimentation of the suspended ash particles in the sluice water. Effluent from each pair of dewatering bins overflows into a common concrete trench that directs the effluent into either the Ash Surge Basin or the Bypass Basin depending on which one is in service.

Only one basin operates at any given time, with the larger Ash Surge Basin functioning as the Station's primary ash-settling basin, which treats wastewater via sedimentation. Effluent from the dewatering bins enters the Ash Surge Basin through a distribution trough at the southern-most end of the basin. Upon entering the pond, the ash particles still suspended in the ash transport water settle to the pond floor as the wastewater migrates towards the basin outlet structure at the opposite end (*i.e.*, northern-most end of the basin). Treated water is then discharged through a reinforced concrete pipe into a sump underneath the pump station located north of the Ash Surge Basin. Water is then pumped to the Service Water Basin located northwest of the Ash Surge Basin and is then ultimately discharged to the Illinois River through NPDES-permitted Outfall 001. This process is illustrated on drawing POW-CSK-PFD-001, which is a process flow diagram (PFD) that shows how Powerton currently manages the wastestreams produced by its coal-fired steam electric generating process.

When the Ash Surge Basin is being cleaned to recover the ash particles stored therein, overflow from the dewatering bins is diverted to the smaller Bypass Basin. Like the Ash Surge Basin, the Bypass Basin is used to promote settling of the ash particles that remain in suspension in the dewatering bin effluent. Treated water from the Bypass Basin flows over a weir wall at the basin's southeastern corner into a reinforced concrete pipe that then conveys the water to the aforementioned pump station sump. After the Ash Surge Basin has been cleaned, the dewatering bin effluent is then redirected to the larger basin.

Both ash ponds are cleaned by first drawing down the water level in the subject pond. Powerton's existing "Ash Management Contractor" will then mobilize to the site and begin dewatering and then dredging/excavating the dry-to-moist ash out of the pond. The dredged/excavated ash is ultimately transported offsite to a beneficial-use or permitted-disposal facility.

1.1.2.2 BASIN INFLOWS

Per Powerton's NPDES permit (NPDES Permit No. IL0002232), bottom and economizer ash are sluiced to the Ash Surge or Bypass Basin (whichever is active) at an average rate of 10.9 million gallons per day (MGD). In addition to CCR wastestreams, several non-CCR, low-volume wastestreams are sent to these basins for treating the streams' concentrations of suspended solids prior to being discharged to the Illinois River. As illustrated on drawing POW-CSK-PFD-001, these wastestreams are:

- Overflow from the Unit 5 and 6 slag tanks,
- Overflow from the Station's East Yard Runoff Basin,
- Effluent from the Station's Makeup Treatment Plant, and
- Effluent from the Metal Cleaning Waste Treatment System.

Table 2 summarizes the Powerton wastestreams currently managed by the Ash Surge and Bypass Basins pursuant to the plant's NPDES permit. Of the five flows (CCR and non-CCR) listed in the table, three are continuously produced during power-generating operations (*i.e.*, "typical" flows): the effluent from the Unit 5 and 6 dewatering bins, the overflow water from the Unit 5 and 6 slag tanks, and the effluent from the Station's Makeup Treatment Plant. Based on the flow rates listed in the table, these wastestreams collectively account for 17.5 MGD of wastewater placed into the Ash Surge Basin.

In addition to the three aforementioned typical inflows, the Ash Surge Basin receives two intermittent wastestreams: overflow from the East Yard Runoff Basin and effluent from the Metal Cleaning Treatment System. The East Yard Runoff Basin collects stormwater run-off from various Powerton facilities on the east side of the Station's property (*i.e.*, "contact" stormwater). To prevent overtopping of the basin during significant storm events, water in the East Yard Runoff Basin will overflow into the Ash Surge Basin or Bypass Basin depending on which basin is in service at the time of the storm event. This intermittent flow has an average daily flow rate of approximately 1.3 MGD.

Powerton's Metal Cleaning Treatment System sends treated effluent from the Non-Chemical Cleaning Waste Basin to the Ash Surge Basin during scheduled boiler cleanings. Specifically, as shown in the PFD on drawing POW-CSK-PFD-001, Powerton sends the gas-side boiler cleaning wastewater to the Non-Chemical Cleaning Waste Basin which discharges into the Metal Cleaning Treatment System. The Station cleans each unit's boiler once per year over a 5-day period. During this period, gas-side boiler cleaning wastewater is pumped to the Non-Chemical Cleaning Waste Basin at an average rate of 1,200 gpm over 20 hours. Thus, each cleaning event produces approximately 7.2 million gallons of gas-side boiler cleaning wastewater. For the two units, this intermittent flow has an equivalent annual average continuous flow rate of approximately 0.04 MGD.

Table 2 – Inflows into Powerton Ash Surge Basin / Bypass Basin

Wastestream	Description	Average Flow, MGD (Type)
CCR Wastestreams		**10.9**
Unit 5 & 6 Dewatering Bin Effluent	Effluent from the Unit 5 and 6 dewatering bins containing suspended bottom and economizer ash particles.	10.9 (Typical)
Non-CCR Wastestreams		**7.9**
Unit 5 & 6 Slag Tank Overflow	Overflow water from the boiler slag tanks. Includes wastewater from: • Dust extractors in the coal tripper room, and • Washdown of the tail end and tripper rooms.	6.2 (Typical)
East Yard Runoff Basin Overflow	Overflow water from the Station's East Yard Runoff Basin. In addition to run-off from the eastern portion of the plant's property, includes water from: • Roof and yard drains in the areas of former Units 1 – 4; • Boiler room sumps, roof drains, and building drains; • Polymer building floor drains; • Scrubber and limestone building area drains; • Condensate storage tank overflow; • Washdown of the trona mill; and • Trona mill roof drains.	1.3 (Intermittent)
Makeup Treatment Plant Effluent	Wastewater generated by the Station for treating makeup water prior to use in station processes. Includes: • Demineralizer sand filter backwash, • Demineralizer regenerant, • Reverse osmosis (RO) reject wastewater, and • RO cleaning wastewater.	0.4 (Typical)
Metal Cleaning Waste Treatment System Effluent	Effluent from the Station's Metal Cleaning Waste Treatment System, which treats gas-side boiler cleaning waste overflow from the Non-Chemical Cleaning Waste Basin.	0.04 (Intermittent)

Source: Powerton NPDES Permit (NPDES Permit No. IL0002232)

1.1.2.3 APPLICABLE REGULATIONS

1.1.2.3.1 FEDERAL & STATE CCR REGULATIONS

Since the rule went into effect in October 2015, the Ash Surge and Bypass Basins have been regulated by the EPA CCR Rule. Per the 2016 Water Infrastructure Improvements for the Nation (WIIN) Act, the Ash Surge and Bypass Basins will continue to be subject to the requirements prescribed in the EPA CCR Rule until the EPA approves a CCR permit program developed and submitted by the Illinois EPA. On July 30, 2019, the governor of Illinois signed Illinois Public Act 101-0171 (Ref. 2, also formerly known as "Illinois Senate Bill 9") into law which instructed the Illinois EPA to prepare regulations for CCR surface impoundments owned and/or operated by the state's coal-fired power plants. In December 2019, the Illinois EPA published its draft regulations for CCR surface impoundments for public comment. The Illinois EPA accepted public comments on its draft regulations until mid-January 2020, after which the agency reviewed and considered these comments as it continued preparing a proposed rule to submit to the Illinois Pollution Control Board.

On March 30, 2020, the Illinois EPA submitted its final proposal for regulating CCR surface impoundments in the state of Illinois to the Illinois Pollution Control Board. These proposed regulations are hereafter referred to collectively as the "Proposed Illinois CCR Rule" and are provided in Appendix D. As required by Illinois Public Act 101-0171, the Illinois EPA proposed regulations that the agency considers to be at least as protective as the EPA CCR Rule and also proposed a corresponding statewide CCR surface impoundment permit program. Per Illinois Public Act 101-0171, the Illinois Pollution Control Board (IPCB) has a year to adopt the CCR surface impoundment regulations into Title 35 of the Illinois Administrative Code (35 Ill. Adm. Code). This timeline would establish a Final Illinois CCR Rule and corresponding CCR permit program by the end of March 2021. In the interim, the IPCB held several hearings with stakeholders and the general public on the Proposed Illinois CCR Rule. MWG was an active participant in this rulemaking process.

The Illinois EPA has yet to publish a timeline for submitting its proposed CCR permit program to the EPA for approval. Therefore, it is currently unknown when the EPA would accept the Illinois EPA's CCR surface impoundment regulations and permitting program to operate in lieu of the EPA CCR Rule. Consequently, Illinois is currently considered a Nonparticipating State per 40 CFR 257.53. However, the Proposed Illinois CCR Rule generally appears to be at least as comprehensive and protective as the EPA CCR Rule, with some specific design and closure criteria proposed in the rule seemingly being more protective. Therefore, it is anticipated that the EPA will accept the Final Illinois CCR Rule to operate in lieu of the federal version at some point during the development of alternative CCR disposal capacity at Powerton. However, until that time, Powerton's CCR surface impoundments will be subject to both the federal and state rules.

1.1.2.3.2 FEDERAL ELG RULE

In addition to the federal and state regulations for CCR surface impoundments, the operation of the Ash Surge and Bypass Basins – specifically discharges through NPDES-permitted Outfall 001 – is also subject to compliance with the EPA's effluent limitation guidelines for steam electric power plants ("ELG Rule"). The 2020 update to the ELG Rule (Ref. 3) sets new limits for discharging bottom ash transport water and other wastestreams generated by steam electric power plants to waters of the U.S. Pursuant to the new 40 CFR 423.13(k)(1)(i) and (k)(2)(i)(A), the ELG Rule establishes a zero-liquid discharge (ZLD) standard for Powerton's bottom ash transport water – including any low-volume wastestreams that come into contact with bottom ash transport water – except under the following conditions:

- To maintain the bottom ash system's water balance during:
  - Significant precipitation events (10-year, 24-hour storm event or longer), and
  - Situations where excessive quantities of other wastestreams regularly handled by the bottom ash system compromise the system's ability to handle recycled bottom ash transport water;
- To maintain the bottom ash system's water chemistry, and
- To conduct maintenance when water volumes cannot be managed by redundancies, tanks, etc.

In any of the preceding situations, the plant would not be permitted to purge more than 10% of the bottom ash system's maximum volumetric capacity for bottom ash transport water (calculated on a 30-day rolling average and excluding redundancies, maintenance systems, *etc*.).

Powerton will be subject to the ZLD standard for bottom ash transport water promulgated by the updated ELG Rule upon incorporation into the facility's NPDES permit by a date determined by the Illinois EPA, which is required by the new 40 CFR 423.13(k)(1)(i) to occur no later than December 31, 2025.

1.1.2.3.3 ILLINOIS EPA NPDES PERMIT

Powerton discharges wastestreams to surface waters adjacent to the site in accordance with its NPDES permit issued by the Illinois EPA (NPDES Permit No. IL0002232). The Station's existing permit was effective on June 1, 2015, was subsequently modified on April 10, 2017, and expired on May 31, 2020. In November 2019, more than 180 days before the permit's expiration date, MWG submitted an NPDES permit renewal application to the Illinois EPA. So, although the Station's existing NPDES permit has expired, it has been administratively continued until the permit renewal is issued by the Illinois EPA. To date, MWG has not received a draft NPDES permit renewal for Powerton.

1.1.2.4 FUTURE REPLACEMENT

While both ponds are lined with a high-density polyethylene (HDPE) geomembrane liner, the Ash Surge and Bypass Basins are not compliant with the liner design criteria promulgated by 40 CFR 257.71(a)(3). Thus, per 40 CFR 257.101(a)(1) and (a)(3), Powerton must cease placing the CCR and non-CCR wastestreams listed in Table 2 into these basins as soon as technically feasible and no later than April 11, 2021, unless an alternative deadline is granted by the EPA.

In early October 2020, Powerton took the Bypass Basin out of service for routine cleaning. Since the Station does not need to have both of its CCR surface impoundments in service to generate power and pursuant to the revised EPA CCR Rule, Powerton will not send CCR or non-CCR wastestreams to the Bypass Basin after April 11, 2021 and does not plan on sending any wastestreams to that basin in the interim. However, as detailed herein, MWG is requesting that the EPA allow Powerton to continue sending the CCR and non-CCR wastestreams listed in Table 2 to the Ash Surge Basin after April 11, 2021, while MWG develops alternative capacity to replace this basin because: (1) no existing alternative disposal capacity is available on- or off-site for these wastestreams, and (2) it was technically infeasible to develop the alternative capacity selected by April 11, 2021 for these wastestreams.

1.1.3 ADVERSE IMPACT TO PLANT OPERATIONS WITHOUT THE ASH SURGE BASIN

In order to generate power at Powerton, it is necessary to dispose of the bottom and economizer ash produced during the Station's coal-fired steam electric generating process. As demonstrated herein, the Ash Surge Basin is the only available site for Powerton's bottom and economizer ash disposal. There is currently no alternative on- or off-site disposal available for Powerton's bottom and economizer ash. Therefore, if Powerton was no longer able to use the Ash Surge Basin to dispose of its bottom and economizer ash, the Station could no longer generate power and would be forced to shut down until MWG develops alternative disposal capacity for the Station's ash, which is not expected to be completed until August 11, 2023.

There are three MWG facilities affected by the EPA CCR Rule – the Powerton, Waukegan, and Will County Generating Stations. None of these generating facilities have alternative options for ash disposal, and if they cannot dispose of their ash at existing locations they will also be forced to shut down. All three plants are located in the same subregion of the regional power market. Specifically, they are located in the ComEd zone of the PJM regional transmission organization. The ComEd zone consists of most of northern Illinois including the Chicago metropolitan area. These three MWG facilities provide 2,730 megawatts of installed capacity to electricity customers in PJM, or more than 10% of the total capacity needed in the ComEd zone. All three facilities have "cleared" in the PJM forward capacity auction to meet the region's reliability needs and therefore have an obligation to supply this capacity in future years. Ceasing use of the Ash Surge Basin at Powerton and the other CCR surface impoundments at the Waukegan and Will County Generating Stations would cause the loss of this substantial quantity of capacity beginning in April 2021. Shutdown would cause major financial harm and loss of jobs and could potentially increase the cost of capacity for ComEd zone customers. The financial impact could be so great as to cause the permanent shutdown of Powerton and the other two MWG power plants. The potential for substantial harm from loss of this capacity is disproportionate with the low risk of allowing operation of the Ash Surge Basin for the additional time needed to bring alternative disposal capacity into service without major disruptions to the company, its employees, and its customers.

1.2 GENERAL STRATEGY FOR COMPLIANCE WITH EPA REGULATIONS

MWG has evaluated several different handling and/or disposal alternatives for Powerton's CCR and non-CCR wastestreams since 2015, shortly after the EPA's new CCR Rule and the amendment to its ELG Rule were published. Given the ZLD standards established for bottom ash transport water in the 2015 ELG Rule (Ref. 4), wastestreams which included (and still include) non-CCR wastestreams that are commingled with bottom ash transport water, MWG evaluated alternatives that either eliminated Powerton's need for bottom ash transport water or allowed it to be recirculated back into the plant's bottom ash system. In options where bottom ash transport water would be recirculated, MWG sought to separate Powerton's CCR and non-CCR wastestreams to ensure the latter were not subject to the stricter ELGs for bottom ash transport water.

1.3 ALTERNATIVE DISPOSAL SOLUTIONS CONSIDERED

As discussed in more detail in Section 1.5.1, MWG has been evaluating different disposal alternatives to replace the Ash Surge and Bypass Basins in some capacity since 2015. In accordance with MWG's strategy for compliance with the EPA's CCR and ELG Rules, these evaluations assessed not only permanent disposal solutions for Powerton's bottom ash transport water (*i.e.*, dewatering bin effluent), but also the low-volume wastestreams managed by these basins as required by the amended EPA CCR Rule. After the August 2018 *Utility Solid Waste Activities Group* (*USWAG*) decision by the U.S. Court of Appeals for the D.C. Circuit (Ref. 5), in which the Court ordered the provisions in the EPA CCR Rule allowing unlined ash ponds to continue operating be vacated and remanded, MWG started refining the conceptual designs of the potential disposal alternatives identified in previous studies for the Ash Surge and Bypass Basins and started preparing budgetary cost estimates and implementation schedules. In addition, MWG has continued evaluating and refining these alternative disposal options throughout Illinois's rulemaking process towards a Final Illinois CCR Rule. The final assessment of alternative disposal solutions considered to replace Powerton's Ash Surge and Bypass Basins is summarized in Section 1.3.3.

Pursuant to the recently-revised alternative closure requirements for CCR surface impoundments in the EPA CCR Rule, MWG also evaluated whether existing capacity is available on- or off-site for each wastestream currently being sent to the Ash Surge Basin. For those wastestreams where existing capacity is not available, MWG evaluated whether it was technically feasible to obtain alternative disposal capacity – either temporary or permanent – by April 11, 2021. The following subsections discuss the alternative disposal solutions considered for each wastestream managed in the Ash Surge Basin and how these wastestreams were ultimately dispositioned.

1.3.1 EXISTING ON-SITE DISPOSAL SOLUTIONS

As shown in the PFD on drawing POW-CSK-PFD-001 in Appendix B, Powerton relies on several settling basins to treat the total suspended solids (TSS) in wastestreams produced during the Station's steam electric generating process and in contact stormwater from various plant facilities. These settling basins are shown on drawing POW-CSK-001 and are referred to as:

- Ash Surge Basin (CCR surface impoundment),
- Bypass Basin (CCR surface impoundment),
- Service Water Basin (non-CCR surface impoundment),
- Non-Chemical Metal Cleaning Waste Basin (non-CCR surface impoundment),
- East Yard Runoff Basin (non-CCR surface impoundment),
- West Yard Runoff Basin (non-CCR surface impoundment),
- Coal Pile Collection Basin (non-CCR surface impoundment),
- Primary Coal Pile Basin (non-CCR surface impoundment), and
- Secondary Coal Pile Basin (non-CCR surface impoundment).

1.3.1.1 CCR WASTESTREAMS

Because the overflow water from the dewatering bins contains suspended CCR particles, it is considered a CCR wastestream. Consequently, it must be disposed of in a CCR unit. Per the preceding list, the only two CCR units at Powerton are the Ash Surge Basin and the Bypass Basin. As previously stated, both basins are not compliant with the EPA CCR Rule's liner design criteria. Thus, there is no existing, compliant alternative disposal capacity to the Ash Surge Basin at Powerton for the station's dewatering bin effluent.

1.3.1.2 NON-CCR WASTESTREAMS

MWG evaluated two general scenarios for providing alternative disposal capacity for the non-CCR wastestreams currently sent to the Ash Surge Basin: (1) divert a given non-CCR wastestream to one of the Station's seven non-CCR surface impoundments, or (2) hold a given non-CCR wastestream in its existing temporary storage facility/unit upstream of the Ash Surge Basin.

1.3.1.2.1 DIVERT TO NON-CCR SURFACE IMPOUNDMENT

Powerton has seven non-CCR surface impoundments on site. Of these, the Service Water Basin would provide the Station with the fastest feasible means of diverting non-CCR wastestreams away from the Ash Surge Basin. The non-CCR wastestreams currently going into the Ash Surge Basin ultimately end up in the Service Water Basin prior to being discharged through NPDES-permitted Outfall 001. As such, the infrastructure sending the non-CCR wastestreams into the Ash Surge Basin is generally closer to the Service Water Basin on the east side of the Station's property than the West Yard Runoff Basin and the three coal pile basins. Moreover, given that the Station has historically been able to comply with its NPDES permit using the Bypass Basin as the primary or secondary settling pond for the subject non-CCR wastestreams, the larger Service Water Basin would likely provide adequate detention time to maintain the discharge limits in Powerton's NPDES permit.

To divert the subject non-CCR wastestreams to the Service Water Basin, MWG would need at least four to five months after initiating the project to perform the engineering and design work to determine the mechanical infrastructure required to convey these wastestreams directly to the Service Water Basin. This work would include routing and designing new pipes, evaluating existing pumps and designing necessary modifications, and verifying that the Service Water Basin indeed can adequately treat non-CCR wastestreams for TSS, pH, oil, and grease without an interim treatment facility like the Ash Surge and Bypass Basins upstream of it. Finally, the engineering and design work would include preparation of revised PFDs and other necessary documentation to be included in the NPDES permit application forms for this project.

Because the handling and treatment of these non-CCR wastestreams is being changed, MWG would need to apply for an NPDES construction permit to install the system and eventually modify its existing NPDES permit with the Illinois EPA to incorporate this new treatment method. MWG cannot currently modify Powerton's existing NPDES permit because, as discussed in Section 1.1.2.3.3, the Station's current permit expired in May 2020 and is administratively extended by MWG's timely permit renewal application that was submitted in November 2019. To date, MWG has not received a draft NPDES permit renewal from the Illinois EPA.

Based on recent experience in obtaining NPDES construction and renewal permits from the Illinois EPA, MWG anticipates an NPDES construction permit and the NPDES renewal permit would take approximately six and 18 months, respectively, given the time required for the agency to perform an initial review, accept public comments, review public comments, and draft the permits, not to mention the agency's current focus on establishing a CCR permit program. Finally, it would likely take another three to four months to install and commission this system, assuming a contractor has already been procured by the time the necessary permits are issued by the Illinois EPA.

Given the preceding timeframe, MWG expects that it would take at least 2.5 years (*i.e.*, summer 2023) to temporarily divert the non-CCR wastestreams from the Ash Surge Basin to the Service Water Basin while permanent alternative disposal capacity is being developed. As shown in the visual timeline representation in Section 2.0, MWG expects to develop new alternative disposal capacity for both the CCR and non-CCR wastestreams currently being sent to the Ash Surge Basin within a similar timeframe (August 11, 2023). Consequently, MWG does not consider the Service Water Basin or any of the Station's other non-CCR surface impoundments to be an appropriate alternative disposal solution for the non-CCR wastestreams currently going into the Ash Surge Basin.

Even if MWG could receive an NPDES construction permit and Powerton's NPDES renewal permit for this project sooner than forecasted (six and 18 months, respectively), MWG would be submitting at least one more permit application for the Illinois EPA to review for this site (the NPDES construction permit) in addition to the four CCR permit applications (two operating and two construction) that will need to be submitted to comply with the Final Illinois CCR Rule and to develop the alternative disposal capacity selected to replace the Ash Surge and Bypass Basins. (An NPDES permit renewal application will be required for either project.) Given the Illinois EPA's current focus on developing and implementing a new permit program for the 73 CCR surface impoundments the agency identified across 23 Illinois power plants (Ref. 6; Statement of Reasons, VI. Affected Facilities), MWG believes it is a more appropriate use of the agency's resources to submit only the permit applications necessary to develop the permanent alternative disposal solution proposed for Powerton rather than submitting additional permit applications for a temporary solution that may or may not be permitted faster than the permanent solution. Moreover, given that MWG's proposed alternative disposal capacity solution for Powerton includes closing the Ash Surge and Bypass Basins, and given Illinois's general focus on its current rulemaking process for regulating CCR surface impoundments, MWG expects that the Illinois EPA would prioritize the CCR surface impoundment closure construction permit applications included in the permanent solution than the NPDES construction permit application required for temporarily diverting wastestreams to a non-CCR surface impoundment at Powerton.

In conclusion, diverting the non-CCR wastestreams currently entering the Ash Surge Basin to one of Powerton's non-CCR surface impoundments would not be an appropriate solution given the longer path to compliance anticipated with the NPDES permitting timeframes.

1.3.1.2.2 HOLD IN EXISTING TEMPORARY STORAGE FACILITY

MWG also evaluated whether it would be possible to hold the non-CCR wastestreams at their sources in lieu of discharging them to the Ash Surge Basin. This evaluation is only appropriate for intermittent wastestreams, however, since the sources for the typical non-CCR wastestreams sent to the Ash Surge Basin (slag tank overflow and effluent from the Makeup Treatment Plant) were designed to discharge to the basin at regular intervals and would inherently not have sufficient capacity for long-term storage of these wastestreams. Conversely, the intermittent nature of overflow wastewater from the East Yard Runoff and Non-Chemical Metal Cleaning Water Basins may provide the opportunity of containing these flows in their respective basins until the Ash Surge Basin is replaced with alternative disposal capacity.

Based on MWG's projected date of obtaining alternative disposal capacity (August 11, 2023), both basins would need to be capable of providing approximately 2.5 years' worth of storage for their respective wastestreams. As demonstrated in the following paragraphs, neither the Non-Chemical Metal Cleaning Waste Basin nor the East Yard Runoff Basin have this much storage capacity.

The Non-Chemical Metal Cleaning Waste Basin only receives gas-side boiler cleaning wastewater during annual boiler cleanings. As previously stated, each boiler-clean produces 7.2 million gallons of gas-side boiler cleaning wastewater. However, the storage capacity of the Non-Chemical Metal Cleaning Waste Basin is only about 5.4 million gallons. Thus, this basin does not have adequate capacity to hold the volume of boiler cleaning wastewater generated during a single clean, let alone the volume that would be generated until alternative disposal capacity to the Ash Surge Basin becomes available in the summer of 2023. Thus, the Non-Chemical Metal Cleaning Waste Basin would not be capable of containing Powerton's gas-side boiler cleaning wastewater without discharging to the Ash Surge Basin.

Like the Metal Cleaning Treatment System, the East Yard Runoff Basin only discharges water to the Ash Surge Basin at irregular intervals, typically during significant storm events. Accordingly, MWG evaluated whether the East Yard Runoff Basin had sufficient storage capacity to hold the forecasted volume of stormwater it would receive until alternative disposal capacity to the Ash Surge Basin becomes available. The basin has an approximate storage capacity of 10.3 million gallons. Based on an average flow of 1.3 MGD of contact stormwater into the East Yard Runoff Basin (see Table 2), this basin would become full within eight days. Thus, the East Yard Runoff Basin would not be capable of retaining the stormwater sent to it until the summer of 2023 without discharging to the Ash Surge Basin.

1.3.2 OFF-SITE DISPOSAL

Although the EPA itself has acknowledged that it is not feasible to transport wet-generated CCR to an off-site disposal facility (Ref. 7), MWG performed its due diligence and evaluated the feasibility of temporarily transporting the average daily volume of CCR and non-CCR wastestreams currently sent to the Ash Surge Basin to an off-site disposal facility. Because the Illinois EPA generally prohibits solid waste landfills from receiving bulk or noncontainerized liquid wastes (Ref. 8), wastewater treatment plants (WWTP) are the only technically feasible alternative disposal facilities off-site for the CCR and non-CCR wastestreams currently being sent to the Ash Surge Basin. Per the average flow rates listed in Table 2, an average daily volume of 18.8 million gallons of CCR and non-CCR wastewater would need to be sent to a WWTP. Thus, to be a viable option, a WWTP would need to receive the full or significant portion of the 18.8 MGD of CCR and non-CCR wastewater generated by Powerton in addition to the daily volume of wastewater the WWTP currently manages.

Five WWTPs were identified within 20 miles of the Station, and four of these plants had listed design capacities less than 5 MGD. The other WWTP reported its average design capacity as just under 40 MGD and therefore may be a technically feasible solution for temporarily handling the CCR and non-CCR wastestreams currently going into the Ash Surge Basin. The technical feasibility of this temporary solution is contingent on MWG's ability to transport wastewater to this plant. Given the Station's existing infrastructure, trucks with tank trailers ("tankers") would likely be the only transportation method that could be established for the Station's CCR and non-CCR wastestreams prior to the April 11, 2021 deadline for ceasing all flows into the Ash Surge Basin. In this scenario, new infrastructure would be installed as necessary to pump a given wastestream from its interim holding facility (*e.g.*, dewatering bin) into a tanker.

Illinois state law limits the overall gross vehicle weight to 80,000 pounds (Ref. 9). Assuming the specific weight of suspended solids in the subject CCR and non-CCR wastestreams is equal to that of water (*i.e.*, 62.4 pounds per cubic foot (pcf)), and assuming an empty tanker weight of 12,000 pounds, an 8,200-gallon tank trailer would be the largest tank trailer that would be permitted to transport wastewater off-site. Therefore, it would take 2,300 truckloads to transport the 18.8 MGD of CCR and non-CCR wastewater currently being sent to the Ash Surge Basin. Even if trucks were operating 24 hours a day, 7 days a week ("24/7"), this would require a truck to enter the Powerton site, get cleared by security, load the wastewater, and leave the site travelling over City of Pekin roadways every 40 seconds on average. This is not technically feasible, especially during winter weather conditions (*i.e.*, snow and ice) which would only exacerbate the logistical issues of hauling this volume of waste to an off-site disposal facility.

Even if the Station could support the number of tankers required to keep up with its daily production of CCR and non-CCR wastewater, there would be significant logistics concerns in coordinating 2,300 trips to and from the Station's property. The only way trucks can enter the Powerton site is via Manito Road (Illinois State Route 16). Based on traffic data compiled by the Illinois Department of Transportation (Ref. 10), the average annual daily traffic (AADT) in 2018 for commercial trucks along this road near the entrance to the Powerton facility was 400 trucks. Therefore, the 2,300 truckloads required to transport the Ash Surge Basin's daily intake of CCR and non-CCR wastewater would be over five times the daily volume of truck traffic currently on Manito Road.

Based on the preceding estimates, transporting Powerton's daily generation of CCR and non-CCR wastestreams off-site would impose an increase in air pollution emissions, significant congestion issues on the two-lane Manito Road, and an increased potential for traffic accidents. These factors may pose short-term risks to human health and the environment that have not been present at the Ash Surge Basin, which is lined with a 60-mil HDPE geomembrane liner and has not caused any groundwater protection standard exceedances. Finally, it is also not technically feasible to route 2,300 trips' worth of trucks per day to an off-site disposal facility until alternative disposal capacity is available on-site.

1.3.3 NEW ON-SITE DISPOSAL SOLUTIONS

Based on the preceding evaluations, no alternative disposal capacity currently exists on- or off-site for the CCR and non-CCR wastestreams currently being sent to the Ash Surge Basin. Consequently, MWG is in the process of developing alternative disposal capacity at Powerton for these wastestreams. This subsection presents the alternatives MWG evaluated as potential replacements for the Ash Surge and Bypass Basins, the alternative disposal capacity option that MWG ultimately selected, and why MWG selected this solution.

1.3.3.1 EVALUATION OF BOTTOM ASH DISPOSAL METHODS

In the summer of 2015, shortly after the EPA finalized its new CCR Rule, MWG started developing and subsequently evaluating conceptual designs for different disposal alternatives for the bottom ash wastestreams at its Powerton, Waukegan, and Will County facilities. When the 2015 update to the EPA ELG Rule was published, MWG expanded the scopes of these studies to evaluate multiple technology solutions that would provide compliance with the revised ELGs. Then, following the Illinois EPA's publication of its draft regulations for CCR surface impoundments, MWG updated these conceptual designs and the corresponding analysis as needed to comply with the draft CCR regulations and align with the EPA's proposed ELG regulations. Finally, in the second quarter of 2020, MWG performed a final update to its conceptual alternative disposal solutions after the Illinois EPA published the Proposed Illinois CCR Rule at the end of March of 2020.

For Powerton, MWG evaluated the following options for managing the Station's dewatering bin effluent in lieu of the existing Ash Surge and Bypass Basins:

- Retrofitting the Ash Surge Basin,
- Installing geotextile filter tubes,
- Installing an under-boiler or remote submerged scraper conveyor, and
- Installing a concrete ash-settling tank.

1.3.3.1.1 RETROFITTED ASH SURGE BASIN

Given the Ash Surge Basin's compliance with all other parts of the Proposed Illinois CCR Rule, it would be suitable for future bottom ash disposal provided it was retrofitted with an Illinois EPA-compliant liner system. In this scenario, MWG would first divert all CCR and non-CCR wastestreams to the Bypass Basin, then draw down the water level in the pond, and finally dewater and remove the ash stored therein (including any impacted soils). Pursuant to the proposed 35 Ill. Adm. Code 845.770, the pond's existing liner would also be removed. Following the removal of these materials, the pond would be retrofitted with a composite liner consisting of a 60-mil HDPE geomembrane over a 2-ft-thick, compacted clay layer with a permeability no greater than 1×10^{-7} cm/sec.

In addition to the composite liner, the Proposed IL CCR Rule also requires a leachate collection and removal system (LCRS) be installed within retrofitted CCR surface impoundments. The proposed 35 Ill. Adm. Code 845.420 requires the LCRS to be placed above the composite liner; consist of highly permeable, granular drainage material; contain collection pipes; extend at least two feet above the collection pipes; have a filter layer placed above it; and have a slope of at least 3% towards the collection pipes. The LCRS conceptualized for this retrofit option would consist of, from bottom to top:

- A collection pipe network (4-in.-diameter, perforated polyvinyl-chloride (PVC) pipes) installed within a 6-in.-thick sand drainage layer,

- A 22-in.-thick gravel drainage layer, and
- A non-woven geotextile to filter out solids from the water to prevent fouling of the gravel drainage layer and clogging of the collection pipes.

In order to protect the geotextile and LCRS components from being damaged by equipment excavating CCR throughout the retrofitted pond's lifetime in accordance with historical Station cleaning practices, an 18-in.-thick protective soil layer would be installed over the engineered liner system. This protective layer would consist of six inches of crushed stone installed over 12 inches of sand.

1.3.3.1.2 GEOTEXTILE FILTER TUBES

Another option that was considered for replacing the Ash Surge Basin was installing a series of geotextile filter tubes, which are containers with oval-shaped cross sections that are composed of engineered fabric that can filter out fine particles within water. Thus, Powerton's dewatering bin effluent could be routed directly to these tubes to filter out the bottom and economizer ash particles still in suspension in the transport water. As the ash particles are consolidated within each tube, filtered sluice water would percolate out of each tube's outer fabric onto an impermeable pad with appropriate run-off control measures. Once a tube is full of ash particles, the dewatering bin effluent would be redirected to another tube while the full tube is dewatered. After the filtered ash has been sufficiently dewatered, the full tube would be cut open, loaded onto trucks, and transported off-site to a beneficial-use or permitted-disposal facility.

1.3.3.1.3 SUBMERGED SCRAPER CONVEYOR

MWG also considered replacing Powerton's ash ponds with a submerged scraper conveyor (SSC). Both under-boiler and remote SSCs were considered. Other than physical location, both SSC options operate similarly. An SSC contains a water-filled trough that promotes sedimentation of suspended ash particles in the transport water. As its name suggests, the trough in an under-boiler SSC is positioned directly under the boiler to catch and cool falling bottom ash. Conversely, piping is used to sluice ash to a remote SSC located elsewhere on the plant site. Chains and flight scrapers then move the ash along the trough to an inclined ramp. As the ash is conveyed up the ramp, gravity causes it to dewater. Water removed from the ash as it moves up the inclined ramp is ultimately drained down the ramp back into the trough. Once the ash reaches the top of the ramp, the ash is deposited into a temporary storage bunker where it is ultimately recovered and transported off-site to a beneficial-use or permitted-disposal facility.

1.3.3.1.4 CONCRETE ASH-SETTLING TANK

Finally, MWG evaluated replacing Powerton's two ash-settling surface impoundments with a concrete ash-settling tank. This self-supporting, reinforced concrete tank would operate similar to the Ash Surge and Bypass Basins. It would be comprised of two primary settling cells in parallel trains with a common surge cell. To limit the sizes of these cells (in both area and depth), MWG would refurbish both sets of dewatering bins to reduce the size and quantity of ash particles currently being conveyed to the Ash Surge and Bypass Basins. New piping would be installed to convey the dewatering bin effluent to the primary cells, which would settle out most of the suspended ash particles remaining. The wastewater would then overflow into the common surge cell where the remaining finer ash particles would settle. Effluent from the surge cell would then be discharged to the Bypass Basin, which would be clean closed and subsequently repurposed for this use.

1.3.3.2 OPTION SELECTED & JUSTIFICATION

Ultimately, MWG elected to replace the Ash Surge and Bypass Basins with a multiple technology solution:

- Installing a concrete ash-settling tank to manage the dewatering bin effluent, and
- Repurposing the Ash Surge Basin as the Station's new Low-Volume Waste Basin so that the pond can continue managing the non-CCR wastestreams currently managed therein.

Of the new, permanent on-site disposal alternatives considered to replace the Ash Surge and Bypass Basins, the multiple technology system selected is the alternative disposal capacity option that is technically feasible and expected to be implemented the fastest. MWG can and plans to refurbish Powerton's dewatering bins while going through the process of obtaining a construction permit under the Final Illinois CCR Rule to clean close and subsequently repurpose the Bypass Basin and to install a concrete ash-settling tank. Given its size and the need for a construction permit, MWG would not be able to retrofit the Ash Surge Basin in accordance with the Proposed Illinois CCR Rule faster than it is projected to take to clean close and repurpose the Bypass Basin while simultaneously constructing a new concrete ash-settling tank (approximately six months after awarding the construction contracts per the visual timeline representation of the project schedule in Section 2.0).

Given the Bypass Basin's small area (less than an acre) relative to the Ash Surge Basin (more than 8 acres), the former can be clean closed and repurposed faster than the latter. Moreover, the existing infrastructure at the plant – specifically the concrete trench that directs flows into either basin – allows for Powerton to immediately begin using the repurposed Bypass Basin for temporarily storing non-CCR wastestreams while the Ash Surge Basin is being clean closed. This is illustrated on drawing POW-CSK-PFD-002 in Appendix B. Therefore, even though it is not the permanent solution for managing Powerton's non-CCR wastestreams (repurposing the Ash Surge Basin as the Low-Volume Waste Basin as shown on drawing POW-CSK-PFD-003), MWG will effectively have access to alternative disposal capacity for the CCR and non-CCR wastestreams currently managed in the Ash Surge Basin once the Bypass Basin has been repurposed. Thus, the multiple technology solution selected provides alternative disposal capacity for the subject wastestreams faster than retrofitting the Ash Surge Basin in accordance with the Final Illinois CCR Rule.

Geotextile filter tubes have been successfully installed and operated to serve a variety of industrial purposes, including dewatering bottom ash ponds. These tubes could also be installed relatively quickly. However, this option could be considered a "first-of-a-kind" technology for dewatering a power plant's daily ash production. Moreover, limited information is available on the successful operation of geotextile filter tubes in winter conditions. Because Powerton operates under peak load conditions during the winter months, the reliable operation of geotextile tubes during this time would be crucial. Consequently, this option has significant uncertainties, especially as it pertains to dewatering and filtering out very fine economizer ash particles. Therefore, physical trials of geotextile tubes at the Powerton site would be warranted to determine filter aids that would be necessary to ensure the finer ash particles in Station's bottom ash transport water are captured by the geotextile filter tubes. Testing would also be required during the winter months to certify with a high degree of certainty that this option is a technically feasible replacement for the Ash Surge Basin. Given this schedule impact and concerns of technical feasibility, MWG opted for refurbishing its dewatering bins instead and relying on a concrete ash-settling tank to remove the remaining fines from the bottom ash transport water.

Finally, although an SSC is a proven CCR-handling technology, there is not enough space under the Unit 5 and 6 boilers to install an under-boiler SSC, and a remote SSC would not be an appropriate alternative CCR disposal option for Powerton given the Station's existing dewatering bins. These dewatering bins function like an SSC in that they dewater the ash and deposit it into a temporary storage area until it is loaded onto trucks and ultimately transported offsite.

1.4 CONCEPTUAL DESIGN OF MULTIPLE TECHNOLOGY SOLUTION

This section describes MWG's conceptual designs for the concrete ash-settling tank to manage Powerton's dewatering bin effluent and for the repurposed Ash Surge Basin to continue managing the low-volume wastestreams currently managed therein. The concrete ash-settling tank design is further illustrated on the drawings in Appendix A, and the modifications to Powerton's management of the CCR and non-CCR wastestreams impacted by this multiple technology solution are shown in the modified PFDs on drawings POW-CSK-PFD-002 and POW-CSK-PFD-003 in Appendix B. These PFDs reflect the interim and final conditions for the proposed multiple technology solution, with the interim condition representing the point at which Powerton has developed alternative disposal capacity for the CCR and non-CCR wastestreams currently entering the Ash Surge Basin. Given the planned operational changes to the Ash Surge Basin and the Bypass Basin, they will be hereafter referred to as the Low-Volume Waste Basin and the Recycle Water Cooling Basin, respectively.

1.4.1 CONCRETE ASH-SETTLING TANK

1.4.1.1 SETTLING & SURGE CELLS

As shown on drawing POW-CSK-200 in Appendix A, the new ash-settling tank will be a self-supporting, cast-in-place reinforced concrete structure with primary settling cells in two parallel trains and a common surge (secondary) cell. Overflow from the dewatering bins currently sent to the Ash Surge and Bypass Basins will be rerouted to one of the two primary concrete cells where most of the finer ash particles remaining in the dewatering bin effluent will settle. Water will then flow into the surge cell for final sedimentation of the ash particles. Treated effluent from this secondary cell will ultimately be discharged via gravity into the Bypass Basin, which will be clean closed and repurposed as the Station's new Recycle Water Cooling Basin. Given this planned operational change, the Bypass Basin will be hereafter referred to as the Recycle Water Cooling Basin.

Per drawing POW-CSK-200, the proposed site for the concrete ash-settling tank is a triangular area bordered by the new Recycle Water Cooling Basin to the north, a rail line to the east, the dewatering bins to the south, and the dewatering bin overflow trench to the west. The primary cell for each train will be approximately 75-ft long, 55-ft wide, and 10-ft deep. The common surge cell will be approximately 110-ft long, 30-ft wide, and 10-ft deep. In order for this proposed design to adequately handle and settle the ash particles remaining in the effluent from the Station's dewatering bins, however, the dewatering bins will need to be refurbished to reduce the size and quantity of ash particles currently suspended in the overflow water being sent to the Ash Surge Basin. It should be noted that the dimensions shown on drawing POW-CSK-200 are based on assumed settling characteristics of the effluent from the refurbished dewatering bins, which will need to be verified during the final engineering and design of the concrete settling and surge cells.

In accordance with EPA Office of Solid Waste and Emergency Response (OSWER) Directive No. 9483.01(83) (Ref. 11), the concrete ash-settling tank will be designed to ensure it can retain its structural integrity without the support of the adjacent earthen materials (*i.e.*, soils). The tank walls will be designed to provide sufficient structural support against the lateral pressures exerted by the ash and water stored in the tank's primary and surge cells like freestanding walls. Meanwhile, the combined weight of the tank and its contents will be supported by a cast-in-place, reinforced concrete mat foundation as shown on drawing POW-CSK-201.

1.4.1.2 RECYCLE WATER COOLING BASIN

Once the finer ash particles have settled out of the water in the concrete ash-settling tank's surge cell, the supernatant will drain through a gravity pipe into the Recycle Water Cooling Basin for heat dissipation. Cooled water leaving the Recycle Water Cooling Basin will then be conveyed to the pump station north of the existing Ash Surge Basin site via the existing outlet and discharge pipe. In accordance with current Station operations, this water will then be pumped to the Service Water Basin before ultimately being discharged to the Illinois River via NPDES-permitted Outfall 001.

In order to support the operation of the concrete ash-settling tank, the non-compliant Bypass Basin must first be clean closed in accordance with the Proposed Illinois CCR Rule. Specifically, the basin will be clean closed by removing the CCR and any impacted soils from the pond in accordance with the proposed 35 Ill. Adm. Code 845.740. As previously stated, Powerton has already taken the Bypass Basin out of service for routine cleaning. Consistent with the Station's current ash-handling operations, the Station will draw down the water level in the basin, and then the Station's Ash Management Contractor will begin dewatering and removing the ash therein. Ash will be removed down to the top of the existing liner, loaded onto trucks, and ultimately transported offsite to a beneficial-use or permitted-disposal facility.

Pursuant to the Proposed Illinois CCR Rule, the pond's existing liner will also be removed. Prior to removing the liner, however, MWG will submit a closure construction permit application to the Illinois EPA pursuant to the proposed 35 Ill. Adm. Code 845.220. After receiving a final permit from the agency, the contractor hired to execute the pond closure work will mobilize to the site and start excavating and/or dredging the existing liner materials and any underlying soils impacted by CCR. All materials removed from the basin will be transported offsite in accordance with the requirements stipulated in the proposed 35 Ill. Adm. Code 845.740(b)(1). Finally, after the Bypass Basin has been certified as closed in accordance with the proposed 35 Ill. Adm. Code 845.740(e), the area will be lined with an HDPE geomembrane and repurposed as the Recycle Cooling Water Basin for temporary storage of the treated effluent from the concrete ash-settling tank.

1.4.1.3 FABRIC ENCLOSURE

The concrete ash-settling tank will be incorporated into an enclosed structure to ensure reliability of the concrete ash-settling tank during winter, to preclude direct precipitation from falling into the cells, and to prevent fugitive dust emissions from the temporary ash piles on the dewatering slab (see Section 1.4.1.4). Currently, MWG intends to procure a fabric enclosure from a vendor specializing in these types of structures. As shown in Sections B and C on drawing POW-CSK-201, the fabric enclosure would be supported by an internal metal roof truss spanning between and supported by the external concrete walls of the ash-settling tank. Per Section C, the enclosure would have an access door for heavy equipment to access the concrete dewatering slab to recover reclaimed ash from the ash-settling tank's primary cells.

1.4.1.4 DEWATERING SLAB

Similar to Powerton's historical operation of the Ash Surge and Bypass Basins, the concrete ash-settling tank will be designed for continuous plant operation and will cycle between trains for filling and reclaiming ash. Once ash in one train reaches the cell's storage capacity, overflow from the dewatering bins will be diverted to the other train. Free water in the full cell will then be decanted into the empty cell to the top of the ash material. Afterwards, a front-end loader, backhoe, or similar equipment will remove the ash and stack it on a concrete slab for dewatering. Concrete curbs and pushwalls will contain the stacked ash and water therefrom within the dewatering area, and water from the stacked ash will ultimately drain back into the cells. Once the ash becomes dry enough to handle, it will be loaded onto trucks and hauled offsite to a beneficial-use or permitted-disposal facility.

The dewatering slab will be contained within the fabric enclosure discussed previously. In accordance with the proposed 35 Ill. Adm. Code 845.120, concrete pushwalls will be installed along the perimeter of this area to contain the CCR material as its handled by equipment loading in into trucks to be hauled offsite. The walls will be sufficiently designed to resist the impact forces from the equipment operating in this area (*e.g.*, front-end loader), and appropriate measures will be taken to ensure the walls are sufficiently durable to withstand repeated occurrences of these impact forces. Moreover, the concrete pushwalls will be designed to be freestanding pursuant to EPA OSWER Directive No. 9483.01(83) (Ref. 11). Finally, similar to the concrete cells, the concrete dewatering slab will be supported by a base mat foundation as shown on drawing POW-CSK-201.

1.4.1.5 LEAK PREVENTION / DETECTION

Because the concrete ash-settling tank will be managing CCR wastestreams, its structural components will be designed in accordance with the design requirements promulgated by the American Concrete Institute (ACI) Committee 350's *Code Requirements for Environmental Engineering Concrete Structures and Commentary*, also known as ACI 350 (Ref. 12). The structural concrete design requirements set forth in this code have been specifically developed for structures used for "conveying, storing, or treating liquid or other materials such as solid waste" (*e.g.*, CCR). These requirements also ensure the proper design, material specification, and construction of environmental engineering structures "to produce serviceable concrete that is dense, durable, nearly impermeable, and resistant to chemicals, with limited deflections and cracking." By designing to ACI 350, the concrete ash-settling tank design will protect the groundwater, the general environment, and human health from the non-hazardous chemical constituents in CCR.

In addition to a robust structural design, MWG will consider additional leak prevention / detection measures for the concrete ash-settling tank. Such measures will be evaluated during detailed engineering and design and in consultation with the Illinois EPA and may include waterproofing admixtures, impervious protective coatings or barriers, electronic leak detection (ELD), and/or groundwater monitoring wells. Any leak prevention / detection measure incorporated into the final design of the concrete ash-settling tank will be implemented in accordance with the appropriate regulatory requirements.

1.4.2 REFURBISHED DEWATERING BINS

Refurbishing the Station's four dewatering bins (two per unit) is a critical aspect for the design and future operation of the concrete ash-settling tank. As previously mentioned, the ash particles in the effluent currently being discharged from the dewatering bins will need to be reduced in both size and quantity. MWG plans to perform a condition assessment (including an evaluation of the structural support steel) to determine which parts need to be replaced and what improvements can be made in order to limit the ash particles sent to the concrete tanks, improve operability, and extend the operating lives of the dewatering bins. In addition to replacing degraded components, this work is expected to include installing new dewatering elements, low-leak sluice gate enclosures, and local control panels.

1.4.3 LOW-VOLUME WASTE BASIN

Once the concrete ash-settling tank is operational, Powerton will direct the dewatering bin effluent to the concrete tank and all non-CCR wastestreams to the Recycle Water Cooling Basin. The contractor who closed and repurposed the Bypass Basin would then start drawing down the water level in the Ash Surge Basin. Water may be removed by using temporary pumps to direct it to the Recycle Water Cooling Basin and/or Service Water Basin. Once the dewatering process is complete, the contractor will start excavating/dredging the ash stored in the Ash Surge Basin, the existing liner materials, and any underlying soils impacted by CCR in accordance with the Illinois EPA closure construction permit. All materials removed from the basin will be transported offsite in accordance with the requirements stipulated in the proposed 35 Ill. Adm. Code 845.740(b)(1). Finally, after the Ash Surge Basin has been certified as closed in accordance with the proposed 35 Ill. Adm. Code 845.740(e), the area will be lined with an HDPE geomembrane and repurposed as the Station's new Low-Volume Waste Basin for continued management of the non-CCR wastestreams currently sent to the existing Ash Surge Basin. Once the geomembrane liner has been installed, all non-CCR wastestreams will be diverted from the Recycle Water Cooling Basin to the Low-Volume Waste Basin.

1.5 EXPLANATION & JUSTIFICATION OF TIME REQUESTED

Per the visual timeline representation and narrative discussion of the project schedule presented in Sections 2.0 and 3.0, respectively, MWG is requesting the EPA allow the Ash Surge Basin to continue operating until construction of the multiple technology solution discussed in the previous section is completed, which is currently expected to be August 11, 2023. During this period, the following CCR and non-CCR wastestreams would be placed into the Ash Surge Basin since they do not currently have alternative disposal options at Powerton or offsite:

- Unit 5 and 6 dewatering bin effluent,
- Unit 5 and 6 slag tank overflow water,
- East Yard Runoff Basin overflow water,
- Makeup Treatment Plant effluent, and
- Metal Cleaning Waste Treatment System effluent.

MWG is requesting this additional time to continue operating the Ash Surge Basin because it is technically infeasible to refurbish Powerton's dewatering bins, construct a new concrete ash-settling tank, repurpose the Bypass Basin into the new Recycle Water Cooling Basin, and to repurpose the Ash Surge Basin into the new Low-Volume Waste Basin prior to April 11, 2021. This is primarily due to the ongoing Illinois rulemaking for regulating CCR surface impoundments. A detailed explanation and justification for the time required to refurbish the dewatering bins, install the concrete ash-settling tank, and repurpose the Bypass Basin are provided in the narrative of the project schedule in Section 3.0.

Finally, pursuant to the recently-revised alternative closure requirements in the EPA CCR Rule, MWG also evaluated whether temporary storage could be provided for the preceding CCR and non-CCR wastestreams that will be sent to the Ash Surge Basin until the concrete ash-settling tank is constructed and the Recycle Cooling Water Basin is operational. This evaluation is summarized in Section 1.5.3.

1.5.1 DEVELOPMENT & EVALUATION OF ALTERNATIVE DISPOSAL METHODS

The analysis of alternative disposal capacity options to replace Powerton's Ash Surge and Bypass Basins presented in Section 1.4 is the result of several years' worth of evaluations and studies performed by MWG. In the summer of 2015, shortly after the EPA finalized its new CCR Rule, MWG initiated a study of potential alternative bottom ash disposal options to replace the existing Ash Surge and Bypass Basins in case they were determined to violate the Rule's groundwater protection standards or uppermost aquifer location restriction and therefore be subject to the closure-for-cause provisions in 40 CFR 257.101. Following the 2015 update to the EPA ELG Rule, MWG expanded the scope of this study to evaluate multiple technology solutions that would provide compliance with both the EPA CCR and ELG Rules for the CCR and non-CCR wastestreams currently managed in the Ash Surge and Bypass Basins. Although there was no regulatory driver to replace the Ash Surge or Bypass Basins at the time as neither basin required corrective measures be implemented to remedy statistically significant exceedances of groundwater protection standards, MWG continued to evaluate and refine the conceptual designs for the multiple technology solutions proposed in this study through 2016 and 2017.

As shown in the visual timeline representation of the project schedule in Section 2.0, and as previously stated in Section 1.3, MWG commenced detailed assessments of the different alternative disposal methods for the CCR wastestreams at its Powerton, Waukegan, and Will County facilities shortly after the August 2018 *USWAG* decision since the active CCR surface impoundments at these three facilities were all determined to be non-compliant with the EPA CCR Rule's liner design criteria. These assessments expanded the studies performed between 2015 and 2017 and evaluated each option's technical feasibility and implementation requirements (*e.g.*, schedule and physical space). During this planning phase, MWG also prepared budgetary cost estimates and high-level implementation schedules for each option to determine forthcoming capital expenditures and asset retirement obligations.

1.5.2 ILLINOIS EPA RULEMAKING

While MWG was refining its conceptual designs for developing alternative bottom ash disposal capacity at Powerton, Illinois Senate Bill 9 was introduced in the Illinois Senate, which sought to establish state-specific regulations for constructing, operating, and closing CCR surface impoundments at Illinois power plants.

Illinois Senate Bill 9 was first introduced in the Illinois Senate in early January 2019 (Ref. 13) and ultimately passed by the Illinois General Assembly on May 27, 2019. On July 30, 2019, the governor signed the bill into law as Illinois Public Act 101-0171. A primary purpose of the Act was to authorize and instruct the Illinois EPA to propose rules regulating the construction, operation, and closure of CCR surface impoundments at Illinois power plants (Ref. 2, § 22.59(g)). Moreover, § 22.59(b)(2) of the Act prohibits the construction, installation, modification, operation, or closure of any CCR surface impoundment without a permit issued by the Illinois EPA. Thus, MWG cannot implement the multiple technology solution selected to replace the Ash Surge and Bypass Basins at Powerton or, in fact, any solution involving the construction of a new CCR surface impoundment and/or retrofit or closure of Powerton's existing CCR surface impoundments until a Final Illinois CCR Rule is adopted by the Illinois Pollution Control Board and the Illinois EPA issues the appropriate construction permits.

As discussed in Section 1.1.2, the Illinois EPA published its draft regulations for CCR surface impoundments in December of 2019 for public comment. At this time, MWG reviewed the draft regulations and updated its 2018-2019 evaluation of alternative bottom ash disposal options for Powerton based on the Illinois EPA's draft regulations. MWG performed a similar update after the Illinois EPA finalized its draft regulations and submitted the Proposed Illinois CCR Rule to the Illinois Pollution Control Board on March 30, 2020. Per § 22.59(g) of Illinois Public Act 101-0171, the Illinois Pollution Control Board has one year to adopt the Final Illinois CCR Rule into 35 Ill. Adm. Code. This timeline would establish a Final Illinois CCR Rule and corresponding permit program by the end of March 2021.

Given the statutory limitations on constructing, modifying, and closing CCR surface impoundments at Illinois power plants and the ongoing rulemaking and development of the Illinois EPA's permitting program, MWG is unable to initiate the work required to repurpose the Ash Surge and Bypass Basins to support the multiple technology solution selected to replace these non-compliant ash basins. Because a Final Illinois CCR Rule and corresponding permit program is not expected until the end of March 2021, it is technically infeasible for MWG to implement this solution – or any solution involving the modification of the Ash Surge and Bypass Basins and/or construction of a new CCR surface impoundment – by April 11, 2021. Further, MWG is unable to complete final engineering and initiate any procurement activity until the Final Illinois CCR Rule is published, the Illinois EPA's requirements are known, and planning is approved by the Illinois EPA within the agency's permit process. However, as previously discussed, planning components of the multiple technology solution that could be initiated without a Final Illinois CCR Rule are indeed ongoing. Accordingly, MWG has developed a plan for implementing the option selected that minimizes the schedule impacts of the Illinois EPA's current rulemaking and future permitting processes, thereby providing alternative disposal capacity for the CCR and non-CCR wastestreams currently being sent to the Ash Surge Basin as soon as technically feasible. This plan is illustrated in the visual representation of the project schedule and corresponding narrative discussion in Sections 2.0 and 3.0, respectively.

1.5.3 TEMPORARY ON-SITE DISPOSAL OF WASTESTREAMS

MWG considered two temporary disposal solutions for the CCR and non-CCR wastestreams that will continue to be sent to the Ash Surge Basin until the concrete ash-settling tank and Recycle Water Cooling Basin are operational on August 11, 2023: storage tanks and water treatment trailers.

1.5.3.1 STORAGE TANKS

Based on MWG's current forecast of obtaining permanent alternative disposal capacity to replace the Ash Surge Basin, enough tanks would need to be procured and installed at the site to provide storage of wastewater produced by the plant for approximately 2.5 years. As shown in the PFD on drawing POW-CSK-PFD-001, Powerton currently uses frac tanks to temporarily dispose of water-side boiler cleaning water before it is transported offsite for final disposal. A frac tank is a heavy gauge steel storage tank with a typical capacity of about 20,000 gallons. The effluent from Powerton's Metal Cleaning Waste Treatment System, which is treated gas-side boiler cleaning wastewater, is the smallest wastestream (based on flow) currently managed by the Ash Surge Basin (0.04 MGD per Table 2). To provide 2.5 years' worth of temporary storage for just this wastestream, over 1,800 frac tanks would need to be furnished and installed on Powerton's property. This is not a technically feasible solution for the smallest wastestream currently managed by the Ash Surge Basin, let alone all of the CCR and non-CCR wastestreams currently entering the basin.

In lieu of procuring and installing thousands of frac tanks to temporarily store the CCR and non-CCR wastestreams currently going into the Ash Surge Basin, a more appropriate solution would be to install a network of large modular tanks on the Station's available property. The largest modular tank identified during MWG's review of tanks available on the market for temporary wastewater storage was a 1.7-million-gallon tank (Ref. 14). For the 0.04-MGD wastestream identified earlier, approximately 22 of these modular tanks would need to be installed to provide adequate storage for just this wastestream. Assuming 22 of these tanks are available on the market, approximately 20 acres of land would need to be identified at the Powerton site to support this many tanks (each tank occupies approximately 0.90 of an acre).

Of Powerton's property, only approximately 10 acres of land are currently undeveloped that are not otherwise in the 100-year floodplain of the Illinois River and/or contain a potential wetland (Refs. 15 and 16, respectively). This is only about half of the area that would be required to install enough modular tanks to store Powerton's gas-side boiler cleaning wastewater for the next 2.5 years. Consequently, modular tanks are not a technically feasible solution for this wastestream or the other CCR and non-CCR wastestreams currently being sent to the Ash Surge Basin.

1.5.3.2 WASTEWATER TREATMENT TRAILERS

While it is technically infeasible to use tanks to temporarily store and/or treat the large CCR and non-CCR flows currently going into the Ash Surge Basin, wastewater treatment trailers from a vendor that specializes in such technology could provide a temporary solution for these wastestreams. These trailers can remove TSS, oil, and grease from and neutralize the pH of the CCR and non-CCR wastestreams currently going into the Ash Surge Basin (all of which are required under Powerton's existing NPDES permit), among other treatment capabilities. These trailers can also remove heavy metals from the CCR wastestreams. The amount of wastewater a trailer can treat is dependent on the water chemistry, but 1 MGD is generally achievable.

Per Table 2, approximately 18.8 MGD of CCR and non-CCR wastestreams are currently being managed by the Ash Surge Basin. Therefore, it would take about 19 wastewater treatment trailers to handle and treat the wastestreams currently going into the Ash Surge Basin. While it may be feasible to find space on the plant site for 19 trailers, the implementation of this temporary system would require time to perform the engineering and design of piping to and from the trailers, obtain an NPDES construction permit, and installation of the system itself. Moreover, it should be recognized that there is a limited number of these wastewater treatment trailers available on the market, which is an important consideration given the number of power plants that may need to implement temporary treatment solutions to comply with the alternative closure standards in the EPA CCR Rule.

Assuming Powerton is able to procure and find space for 19 wastewater treatment trailers, it would take a similar timeframe to implement this temporary solution as it would to divert the non-CCR wastestreams from the Ash Surge Basin to the Service Water Basin (2.5 years). Based on the discussion in Section 1.3.1.2.1 about temporarily utilizing the existing Service Water Basin for the subject non-CCR wastestreams, MWG does not consider wastewater treatment trailers to be an appropriate alternative solution for the wastestreams currently being sent to the Ash Surge Basin because (1) the permanent alternative disposal capacity solution system proposed herein will be operational within a similar timeframe, and (2) the Illinois EPA will likely prioritize the closure construction permit applications for the Ash Surge and Bypass Basins incorporated into the modified bottom ash treatment system proposed herein over the permit applications required to construct a temporary treatment system.

2.0 PROJECT SCHEDULE: VISUAL TIMELINE

This section presents a visual timeline representation of MWG's schedule for refurbishing Powerton's existing ash dewatering bins, constructing a new concrete ash-settling tank, and repurposing the Bypass Basin as a cooling pond. Pursuant to 40 CFR 257.103(f)(iv)(1)(A)(*2*), the following visual timeline representation of the project schedule shows:

- How each phase and the steps within that phase interact with or are dependent on each other and the other phases,
- All of the steps and phases that can be completed concurrently,
- The total time needed to refurbish the dewatering bins, construct a new concrete ash-settling tank, and repurpose the Bypass Basin as a cooling pond.

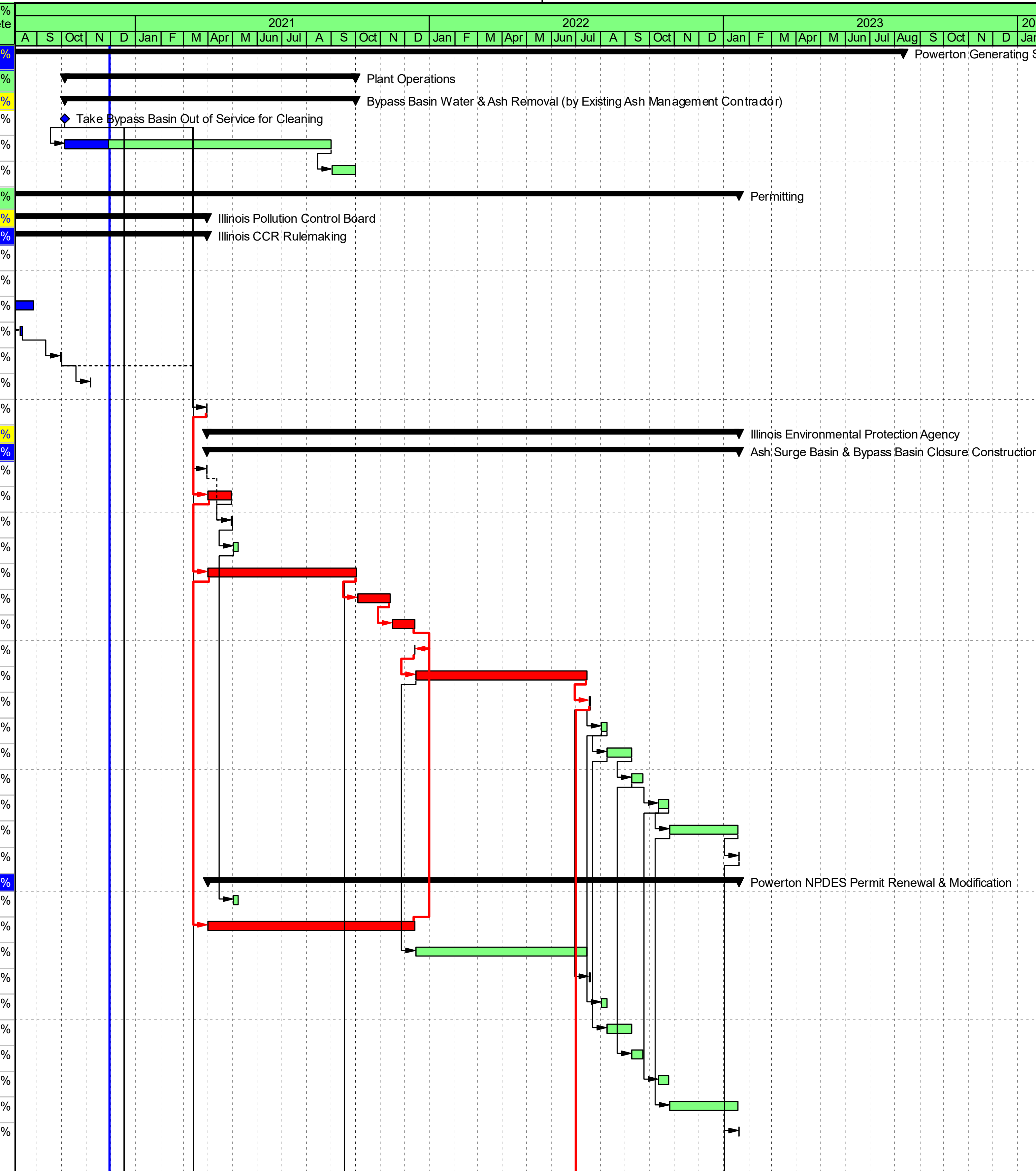
As shown in its visual timeline representation, the project schedule is divided into the following phases:

- Plant Operations,
- Permitting,
- Engineering & Design,
- Contractor Selection,
- Equipment Fabrication & Delivery,
- Construction, and
- Start-Up & Implementation.

See Section 3.0 for the corresponding narrative discussion of the project schedule.

Engineering, Procurement and Construction Schedule

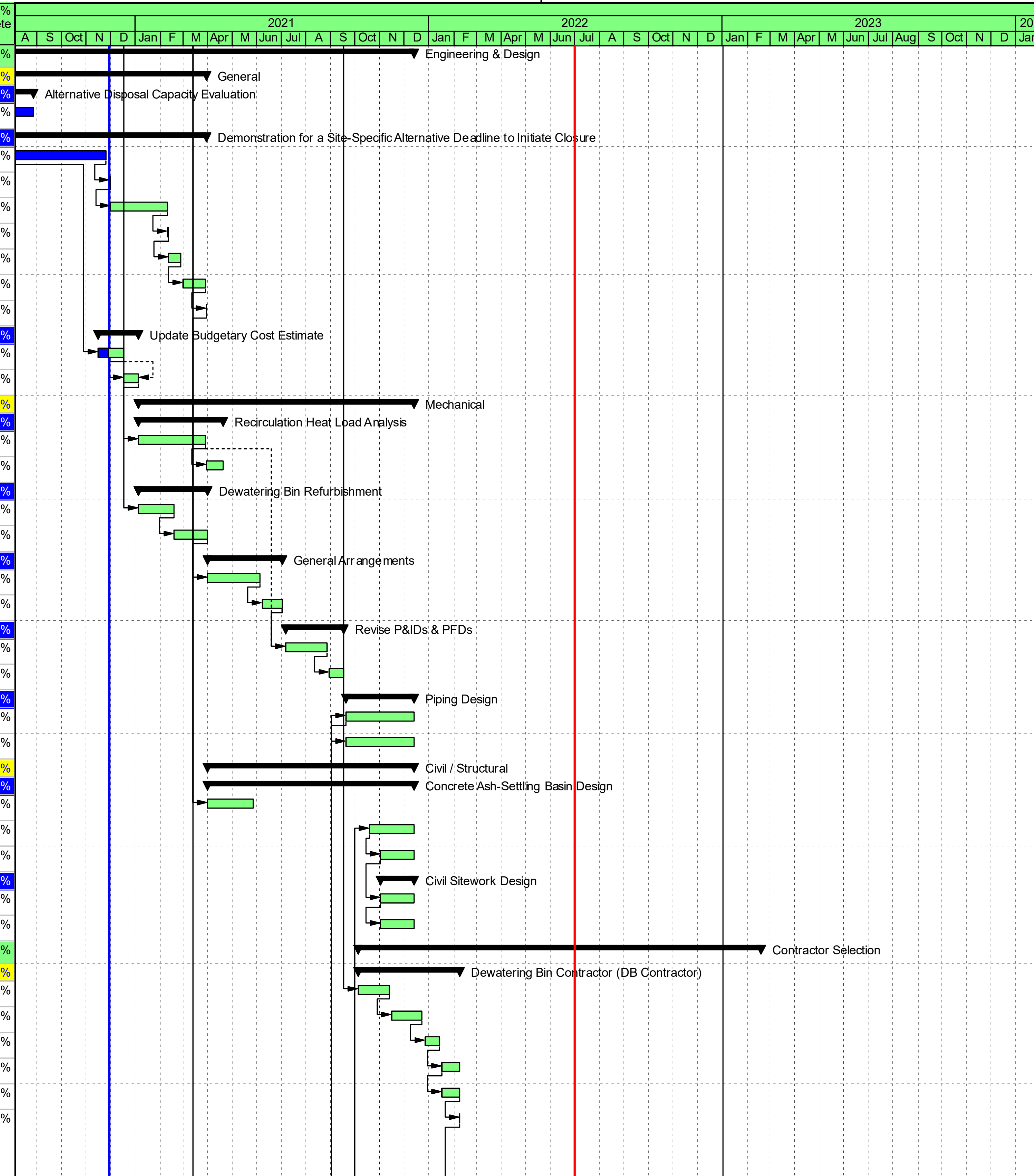
Activity ID	Activity Name	Ori Dur	Start	Finish	% Complete
Powerton Generating Station - Concrete Ash Settling Basin		731	19-Sep-18 A	11-Aug-23	5.2%
Plant Operations		251	05-Oct-20 A	30-Sep-21	15.14%
Bypass Basin Water & Ash Removal (by Existing Ash Management Contractor)		251	05-Oct-20 A	30-Sep-21	15.14%
1.1.1	Take Bypass Basin Out of Service for Cleaning	0	05-Oct-20 A		100%
1.1.2	Draw Down Water & Dewater Impounded Ash	230	05-Oct-20 A	31-Aug-21	16.52%
1.1.3	Excavate Ash & Transport to Offsite Facility	21	01-Sep-21	30-Sep-21	0%
Permitting		585	30-Mar-20 A	19-Jan-23	20.68%
Illinois Pollution Control Board		181	30-Mar-20 A	30-Mar-21	99.45%
Illinois CCR Rulemaking		181	30-Mar-20 A	30-Mar-21	99.45%
2.1.1.1	Illinois EPA Submits Proposed Illinois CCR Rule to IPCB	1	30-Mar-20 A	30-Mar-20 A	100%
2.1.1.2	Prepare & Submit Pre-Filed Questions to Illinois EPA	59	31-Mar-20 A	23-Jun-20 A	100%
2.1.1.3	Prepare & Submit Pre-Filed Testimonies to IPCB	45	24-Jun-20 A	27-Aug-20 A	100%
2.1.1.4	Participate in First IPCB Hearing on Proposed Illinois CCR Rule	2	11-Aug-20 A	13-Aug-20 A	100%
2.1.1.5	Participate in Second IPCB Hearing on Proposed Illinois CCR Rule	2	29-Sep-20 A	01-Oct-20 A	100%
2.1.1.6	IPCB Closes Record on Proposed Illinois CCR Rulemaking	1	06-Nov-20 A	06-Nov-20 A	100%
2.1.1.7	IPCB Adopts CCR Regulations into Title 35 of Illinois Admin. Code	1	30-Mar-21	30-Mar-21	0%
Illinois Environmental Protection Agency		464	30-Mar-21	19-Jan-23	0%
Ash Surge Basin & Bypass Basin Closure Construction Permits		464	30-Mar-21	19-Jan-23	0%
2.2.1.01	Illinois EPA Publishes Permit Application Forms	1	30-Mar-21	30-Mar-21	0%
2.2.1.02	Determine Closure Category Designation (845.700(c))	22	31-Mar-21	29-Apr-21	0%
2.2.1.03	Submit Closure Category Designation (845.700(c))	1	30-Apr-21	30-Apr-21	0%
2.2.1.04	Pre-Application Meeting with Illinois EPA	5	03-May-21	07-May-21	0%
2.2.1.05	Perform Closure Alternatives Analysis (845.710(b))	130	31-Mar-21	01-Oct-21	0%
2.2.1.06	Schedule & Hold Public Meetings (845.710(e) & 845.240(a))	30	04-Oct-21	12-Nov-21	0%
2.2.1.07	Finalize Closure Plan (845.710(f) & 845.720(b))	19	15-Nov-21	13-Dec-21	0%
2.2.1.08	Submit Closure Construction Permit Applications	1	13-Dec-21	13-Dec-21	0%
2.2.1.09	Illinois EPA Reviews Permit Applications	150	14-Dec-21	15-Jul-22	0%
2.2.1.10	Illinois EPA Issues Draft Permit (845.250)	1	18-Jul-22	18-Jul-22	0%
2.2.1.11	Illinois EPA Publishes Public Notice of Draft Permit (845.260(b))	5	02-Aug-22	08-Aug-22	0%
2.2.1.12	Illinois EPA Accepts Public Comments (845.260(c))	23	09-Aug-22	08-Sep-22	0%
2.2.1.13	Illinois EPA Issues Notice of Public Hearing (845.260(e))	10	09-Sep-22	22-Sep-22	0%
2.2.1.14	Illinois EPA Holds Public Hearing (845.260(d))	10	11-Oct-22	24-Oct-22	0%
2.2.1.15	Illinois EPA Reviews Public Comments (845.270(a))	62	25-Oct-22	18-Jan-23	0%
2.2.1.16	Illinois EPA Issues Final Permit (845.270(b))	1	19-Jan-23	19-Jan-23	0%
Powerton NPDES Permit Renewal & Modification		463	31-Mar-21	19-Jan-23	0%
2.2.2.01	Pre-Application Meeting with Illinois EPA	5	03-May-21	07-May-21	0%
2.2.2.02	Prepare & Submit Permit Application	179	31-Mar-21	13-Dec-21	0%
2.2.2.03	Illinois EPA Reviews Permit Application	150	14-Dec-21	15-Jul-22	0%
2.2.2.04	Illinois EPA Issues Draft Permit	1	18-Jul-22	18-Jul-22	0%
2.2.2.05	Illinois EPA Publishes Public Notice of Draft Permit	5	02-Aug-22	08-Aug-22	0%
2.2.2.06	Illinois EPA Accepts Public Comments	23	09-Aug-22	08-Sep-22	0%
2.2.2.07	Illinois EPA Issues Notice of Public Hearing	10	09-Sep-22	22-Sep-22	0%
2.2.2.08	Illinois EPA Holds Public Hearing	10	11-Oct-22	24-Oct-22	0%
2.2.2.09	Illinois EPA Reviews Public Comments	62	25-Oct-22	18-Jan-23	0%
2.2.2.10	Illinois EPA Issues Final Permit	1	19-Jan-23	19-Jan-23	0%



Remaining Work | Actual Work | Actual Milestone | Summary
Critical Remaining Work | Forecast Milestone | Summary | LOE

Sargent & Lundy

Activity ID	Activity Name	Ori Dur	Start	Finish	% Complete
Engineering & Design		492	19-Sep-18 A	13-Dec-21	46.54%
General		492	19-Sep-18 A	30-Mar-21	82.93%
Alternative Disposal Capacity Evaluation		492	19-Sep-18 A	28-Aug-20 A	100%
3.1.1.1	Develop & Evaluate Alternative Disposal Capacity Solutions	492	19-Sep-18 A	28-Aug-20 A	100%
Demonstration for a Site-Specific Alternative Deadline to Initiate Closure		236	26-Dec-19 A	30-Mar-21	64.41%
3.1.2.1	Prepare & Review	236	26-Dec-19 A	25-Nov-20 A	100%
3.1.2.2	Submit to U.S. EPA	1	30-Nov-20	30-Nov-20	0%
3.1.2.3	U.S. EPA Reviews Demonstration	48	01-Dec-20	09-Feb-21	0%
3.1.2.4	U.S. EPA Publishes Proposed Decision	1	10-Feb-21	10-Feb-21	0%
3.1.2.5	Public Comment Period on U.S. EPA Proposed Decision	12	11-Feb-21	26-Feb-21	0%
3.1.2.6	U.S. EPA Reviews Public Comments	21	01-Mar-21	29-Mar-21	0%
3.1.2.7	U.S. EPA Publishes Final Decision	1	30-Mar-21	30-Mar-21	0%
Update Budgetary Cost Estimate		31	16-Nov-20 A	04-Jan-21	25.81%
3.1.3.1	Prepare & Review	22	16-Nov-20 A	17-Dec-20	36.36%
3.1.3.2	Issue for Use	9	18-Dec-20	04-Jan-21	0%
Mechanical		240	05-Jan-21	13-Dec-21	0%
Recirculation Heat Load Analysis		75	05-Jan-21	19-Apr-21	0%
3.2.1.1	Prepare & Review	60	05-Jan-21	29-Mar-21	0%
3.2.1.2	Issue for Use	15	30-Mar-21	19-Apr-21	0%
Dewatering Bin Refurbishment		62	05-Jan-21	31-Mar-21	0%
3.2.2.1	Perform Condition Assessment	32	05-Jan-21	17-Feb-21	0%
3.2.2.2	Determine Target Ash Particle Size	30	18-Feb-21	31-Mar-21	0%
General Arrangements		67	31-Mar-21	02-Jul-21	0%
3.2.3.1	Prepare & Review	47	31-Mar-21	04-Jun-21	0%
3.2.3.2	Issue for Design	20	07-Jun-21	02-Jul-21	0%
Revise P&IDs & PFDs		53	06-Jul-21	17-Sep-21	0%
3.2.4.1	Prepare & Review	39	06-Jul-21	27-Aug-21	0%
3.2.4.2	Issue for Design	14	30-Aug-21	17-Sep-21	0%
Piping Design		59	20-Sep-21	13-Dec-21	0%
3.2.5.1	Design Dewatering Bin Effluent Piping	59	20-Sep-21	13-Dec-21	0%
3.2.5.2	Design Concrete Ash-Settling Basin Effluent Piping	59	20-Sep-21	13-Dec-21	0%
Civil / Structural		178	01-Apr-21	13-Dec-21	0%
Concrete Ash-Settling Basin Design		178	01-Apr-21	13-Dec-21	0%
3.3.1.1	Determine Preliminary Settling & Surge Tank Sizes	41	01-Apr-21	27-May-21	0%
3.3.1.2	Finalize Settling & Surge Tank Sizes	39	18-Oct-21	13-Dec-21	0%
3.3.1.3	Concrete Wall & Slab Design	29	01-Nov-21	13-Dec-21	0%
Civil Sitework Design		29	01-Nov-21	13-Dec-21	0%
3.3.2.1	Design Site Grading	29	01-Nov-21	13-Dec-21	0%
3.3.2.2	Design Access Roads	29	01-Nov-21	13-Dec-21	0%
Contractor Selection		353	05-Oct-21	17-Feb-23	0%
Dewatering Bin Contractor (DB Contractor)		86	05-Oct-21	08-Feb-22	0%
4.1.1	Prepare & Issue Technical Specification & Commerical Terms	29	05-Oct-21	12-Nov-21	0%
4.1.2	Bid Period	27	15-Nov-21	23-Dec-21	0%
4.1.3	Bid Evaluation	13	27-Dec-21	14-Jan-22	0%
4.1.4	Contract Negotiation	16	17-Jan-22	07-Feb-22	0%
4.1.5	Conform Technical Specification for Contract	16	17-Jan-22	07-Feb-22	0%
4.1.6	Contract Award	1	08-Feb-22	08-Feb-22	0%



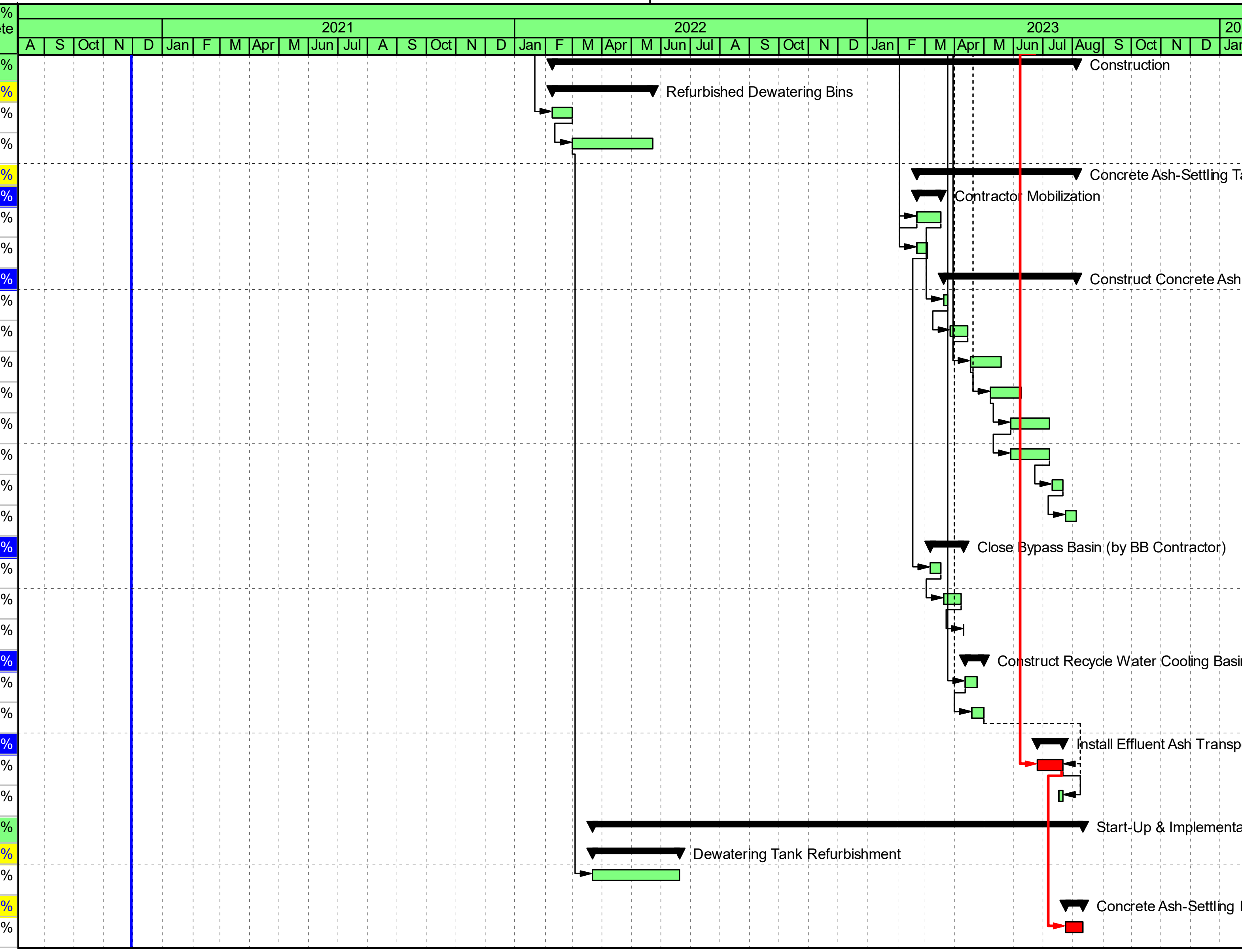
Remaining Work | Actual Work | Actual Milestone | Summary
Critical Remaining Work | Forecast Milestone | Summary | LOE

Sargent & Lundy

Activity ID	Activity Name	Ori Dur	Start	Finish	% Complete
Concrete Ash-Settling Tank Contractor (CT Contractor)		154	19-Jul-22	17-Feb-23	0%
4.2.1	Prepare & Issue Technical Specification & Commerical Terms	74	19-Jul-22	28-Oct-22	0%
4.2.2	Bid Period	30	31-Oct-22	09-Dec-22	0%
4.2.3	Bid Evaluation	29	12-Dec-22	19-Jan-23	0%
4.2.4	Contract Negotiation	20	20-Jan-23	16-Feb-23	0%
4.2.5	Conform Technical Specification for Contract	20	20-Jan-23	16-Feb-23	0%
4.2.6	Contract Award	1	17-Feb-23	17-Feb-23	0%
Bypass Basin Closure Contractor (BB Contractor)		154	19-Jul-22	17-Feb-23	0%
4.3.1	Prepare & Issue Technical Specification & Commerical Terms	74	19-Jul-22	28-Oct-22	0%
4.3.2	Bid Period	30	31-Oct-22	09-Dec-22	0%
4.3.3	Bid Evaluation	29	12-Dec-22	19-Jan-23	0%
4.3.4	Contract Negotiation	20	20-Jan-23	16-Feb-23	0%
4.3.5	Conform Technical Specification for Contract	20	20-Jan-23	16-Feb-23	0%
4.3.6	Contract Award	1	17-Feb-23	17-Feb-23	0%
Equipment Fabrication & Delivery		583	01-Apr-21	07-Jul-23	0%
Dewatering Bin Components		226	01-Apr-21	22-Feb-22	0%
Dewatering Bin Vendor Procurement		100	01-Apr-21	20-Aug-21	0%
5.1.1.1	Prepare & Issue Technical Specification & Commercial Terms	36	01-Apr-21	20-May-21	0%
5.1.1.2	Bid Period	29	21-May-21	01-Jul-21	0%
5.1.1.3	Bid Evaluation	14	02-Jul-21	22-Jul-21	0%
5.1.1.4	Contract Negotiation	20	23-Jul-21	19-Aug-21	0%
5.1.1.5	Conform Technical Specification for Contract	20	23-Jul-21	19-Aug-21	0%
5.1.1.6	Contract Award	1	20-Aug-21	20-Aug-21	0%
Material Procurement (by Dewatering Bin Vendor)		126	23-Aug-21	22-Feb-22	0%
5.1.2.1	Design Modifications for Existing Dewatering Bins	78	23-Aug-21	13-Dec-21	0%
5.1.2.2	Material Order	51	18-Oct-21	30-Dec-21	0%
5.1.2.3	Fabrication	61	25-Oct-21	24-Jan-22	0%
5.1.2.4	Delivery	21	25-Jan-22	22-Feb-22	0%
Concrete Materials		40	20-Feb-23	14-Apr-23	0%
5.2.1	Material Order	5	20-Feb-23	24-Feb-23	0%
5.2.2	Fabrication (Detailing, Shop Drawing Approval)	30	27-Feb-23	07-Apr-23	0%
5.2.3	Delivery	5	10-Apr-23	14-Apr-23	0%
Ash Transport Water Piping		90	20-Feb-23	23-Jun-23	0%
5.3.1	Material Order	5	20-Feb-23	24-Feb-23	0%
5.3.2	Fabrication	74	27-Feb-23	08-Jun-23	0%
5.3.3	Delivery	11	09-Jun-23	23-Jun-23	0%
Geomembrane		36	20-Feb-23	10-Apr-23	0%
5.4.1	Material Order	5	20-Feb-23	24-Feb-23	0%
5.4.2	Fabrication	26	27-Feb-23	03-Apr-23	0%
5.4.3	Delivery	5	04-Apr-23	10-Apr-23	0%
Fabric Enclosure		121	20-Jan-23	07-Jul-23	0%
5.5.1	Material Order	41	20-Jan-23	17-Mar-23	0%
5.5.2	Fabrication	60	20-Mar-23	09-Jun-23	0%
5.5.3	Delivery	20	12-Jun-23	07-Jul-23	0%

Remaining Work | Actual Work | Actual Milestone | Summary
Critical Remaining Work | Forecast Milestone | Summary | LOE

Activity ID	Activity Name	Ori Dur	Start	Finish	% Complete
Construction		388	08-Feb-22	04-Aug-23	0%
Refurbished Dewatering Bins		75	08-Feb-22	23-May-22	0%
6.1.1	DB Contractor Mobilizes to Project Site	15	08-Feb-22	28-Feb-22	0%
6.1.2	Refurbish Dewatering Bins	60	01-Mar-22	23-May-22	0%
Concrete Ash-Settling Tank & Repurposed Bypass Basin		120	20-Feb-23	04-Aug-23	0%
Contractor Mobilization		20	20-Feb-23	17-Mar-23	0%
6.2.1.1	CT Contractor Mobilizes	20	20-Feb-23	17-Mar-23	0%
6.2.1.2	BB Contractor Mobilizes	10	20-Feb-23	03-Mar-23	0%
Construct Concrete Ash-Settling Tank (by CT Contractor)		100	20-Mar-23	04-Aug-23	0%
6.2.2.1	Install Erosion & Sediment Control Measures	5	20-Mar-23	24-Mar-23	0%
6.2.2.2	Excavate Basin Area & Prepare Subgrade	15	27-Mar-23	14-Apr-23	0%
6.2.2.3	Install Base Mat Foundations	25	17-Apr-23	19-May-23	0%
6.2.2.4	Install Concrete Slabs for Basins & Dewatering Area	25	08-May-23	09-Jun-23	0%
6.2.2.5	Install Basin Walls	30	29-May-23	07-Jul-23	0%
6.2.2.6	Install Pushwalls & Curbs for Dewatering Area	30	29-May-23	07-Jul-23	0%
6.2.2.7	Erect Fabric Enclosure	10	10-Jul-23	21-Jul-23	0%
6.2.2.8	Construct New Access Roads	10	24-Jul-23	04-Aug-23	0%
Close Bypass Basin (by BB Contractor)		26	06-Mar-23	10-Apr-23	0%
6.2.3.1	Excavate Existing Liner & CCR-Impacted Soils (if Any)	10	06-Mar-23	17-Mar-23	0%
6.2.3.2	Decontaminate Pond Floor & Appurtenances	15	20-Mar-23	07-Apr-23	0%
6.2.3.3	Certify Bypass Basin Closure	1	10-Apr-23	10-Apr-23	0%
Construct Recycle Water Cooling Basin (by BB Contractor)		15	11-Apr-23	01-May-23	0%
6.2.4.1	Prepare Subgrade	10	11-Apr-23	24-Apr-23	0%
6.2.4.2	Place Geomembrane Liner	10	18-Apr-23	01-May-23	0%
Install Effluent Ash Transport Water Piping (by CT Contractor)		20	26-Jun-23	21-Jul-23	0%
6.2.5.1	Install Effluent Piping from Dewatering Bins	20	26-Jun-23	21-Jul-23	0%
6.2.5.2	Install Effluent Piping from Concrete Ash-Settling Tank	5	17-Jul-23	21-Jul-23	0%
Start-Up & Implementation		363	22-Mar-22	11-Aug-23	0%
Dewatering Tank Refurbishment		65	22-Mar-22	20-Jun-22	0%
7.1.1	Commission Refurbished Dewatering Bins	65	22-Mar-22	20-Jun-22	0%
Concrete Ash-Settling Basin		15	24-Jul-23	11-Aug-23	0%
7.2.1	Commission Concrete Ash-Settling Tank	15	24-Jul-23	11-Aug-23	0%



3.0 PROJECT SCHEDULE: NARRATIVE DISCUSSION

This section presents a narrative of the project steps and sequencing necessary to develop the alternative disposal capacity selected to replace the Ash Surge and Bypass Basins. This narrative follows and supplements the visual timeline representation of the project schedule provided in Section 2.0.

Section 3.1 presents the steps MWG will take to refurbish Powerton's dewatering bins, construct a new concrete ash-settling tank, and repurpose the Bypass Basin, and the general sequence in which these steps will occur. This workflow is based on the steps necessary to execute the project and is considered to be the fastest feasible timeline in which MWG can establish an EPA CCR Rule-compliant system at Powerton for addressing the CCR and non-CCR wastestreams currently managed in the Ash Surge and Bypass Basins. The subsequent sections discuss the steps that occur within each phase of the project (as shown in the visual timeline representation), including the tasks that occur during each of those steps.

See Section 4.0 for a narrative discussion of the progress MWG has made to date in developing this alternative disposal capacity for the Ash Surge and Bypass Basins.

3.1 INSTALLATION ACTIVITIES & PROJECTED WORKFLOW

As currently designed, a new, EPA CCR Rule-compliant ash management system will be installed at Powerton by executing the following sequence of activities:

- Cleaning the Bypass Basin;
- Refurbishing the existing ash dewatering bins, which will include:
    - Performing a condition assessment,
    - Procuring a specialty vendor to design and procure new/modified dewatering bin components,
    - Procuring a contractor to install the new/modified dewatering bin components,
    - Installing the new/modified dewatering bin components, and
    - Commissioning the refurbished dewatering bins;
- Preparing and permitting the final closure plan for the Bypass Basin;
- Designing the new concrete ash-settling tank;
- Procuring contractors to construct the concrete ash-settling tank and to close the Bypass Basin;
- Constructing the concrete ash-settling tank, which will include:
    - Excavating the area to install the tank,
    - Constructing the primary cells, surge cell, ramps, and dewatering slab, and
    - Installing mechanical components within the tank (*e.g.*, mud valves);

- Closing and repurposing the Bypass Basin, which will include:
  - Removing the existing liner and excavating CCR-impacted soils (if any),
  - Certifying the basin's closure in accordance with the Illinois EPA closure construction permit, and
  - Installing a geomembrane liner;
- Installing the dewatering bin effluent piping to the concrete ash-settling tank;
- Installing the concrete ash-settling tank effluent piping to the Recycle Water Cooling Basin;
- Constructing new access roads to and around the concrete ash-settling tank; and
- Commissioning the new concrete ash-settling tank.

3.2 PLANT OPERATIONS

Although the Bypass Basin cannot be closed until MWG receives a closure construction permit from the Illinois EPA, Powerton can remove the ash currently stored in the pond in accordance with historical Station cleaning practices (see Section 1.1.2). This work will expedite the future closure of the Bypass Basin. Once a closure construction permit is received, the only work left to clean close the Bypass Basin will be to remove the existing liner and to decontaminate the pond area and pond appurtenances.

Before any water or ash can be removed from the Bypass Basin, Powerton must first cease sending all CCR and non-CCR wastestreams to the pond. Indeed, the Station recently took the Bypass Basin out of service after it finished recovering ash in the Ash Surge Basin for beneficial use by third parties. The Station will now draw down the water in the Bypass Basin and then dewater the ash currently stored therein.

Powerton intends to remove the initial volume of free surface water from the Bypass Basin by natural means (*e.g.*, evaporation) and by allowing the water to drain towards the existing outlet structure in the southeast corner of the pond. Once the water level falls below the overflow weir elevation, the Station's Ash Management Contractor may excavate sumps and trenches within the impounded material to promote additional drainage and dewatering. The contractor may also use portable pumps to remove additional water by pumping water over the weir into the pond's discharge pipe. Finally, the contractor may utilize earthmoving equipment to move the ash within the pond to promote additional drainage and dewatering.

Once it has been dewatered enough to handle, the ash in the Bypass Basin will be dredged and removed from the pond, loaded onto trucks, and transported offsite to a beneficial-use or permitted disposal facility. Fugitive dust control measures (*e.g.*, water spray, dust suppressants) will be implemented to minimize airborne CCR particulates while the CCR is being handled.

Drawdown of the free surface water in the Bypass Basin is expected to continue through the winter of 2020 and into the summer of 2021. Powerton's Ash Management Contractor is expected to mobilize to the site in the third quarter of 2021 and implement the necessary procedures to remove the remaining free water in the pond as well as to dewater the ash. It is currently anticipated that the contractor will start removing ash from the Bypass Basin by the end of summer 2021. Given the small size of the Bypass Basin, it is expected that Powerton's Ash Management Contractor can remove the CCR stored in the pond within a month. Therefore, the Bypass Basin is currently scheduled to be emptied (*i.e.*, only small amounts of CCR and the liner remaining) by the end of September 2021.

It should be noted that the removal of ash in the Bypass Basin is not on the critical path of the overall project schedule so long as the ash is removed before the final closure work can start on the Bypass Basin (*i.e.*, Illinois EPA issues final permit and contractor mobilizes to the site). Given that contractor responsible for closing the Bypass Basin is not expected to mobilize to the site until the appropriate permits have been issued, this work by Powerton's Ash Management Contractor is expected to be completed more than a year in advance of the final closure activities for the pond. As previously stated, removing the water and ash currently stored in the Bypass Basin in 2021 will expedite the pond's final closure and subsequent refurbishment in 2023.

3.3 PERMITTING

MWG will need two permits from the Illinois EPA to implement the planned modifications to the bottom-ash handling operations at Powerton. First, MWG will need construction permits under the forthcoming Final Illinois CCR Rule to close the Ash Surge and Bypass Basins so that they can then be repurposed for other uses (Recycle Water Cooling Basin and Low-Volume Waste Basin, respectively) and to install the new concrete ash-settling tank. Second, MWG will need to renew Powerton's NPDES permit since the existing permit has expired and the current treatment methods are being modified for the Station's CCR wastestreams prior to being discharged to the Illinois River via permitted Outfall 001. Since both permits will be issued by the Illinois EPA and are based on the same project, MWG intends to prepare both the CCR construction permit and NPDES permit renewal/modification applications concurrently and submit them at the same time. Imbedded in this strategy is MWG's hope that a renewed Powerton NPDES permit can be obtained sooner than previous modifications, which have historically taken six to 12 months to receive after closure of the public comment period (*i.e.*, not including the Illinois EPA's initial review time or the time of the public comment period itself).

3.3.1 ILLINOIS CCR RULEMAKING

To better understand the Illinois EPA's intentions for regulating CCR surface impoundments at Illinois power plants, MWG has actively participated in the corresponding rulemaking process. After the Illinois EPA submitted its Proposed Illinois CCR Rule to the IPCB in late March 2020, stakeholders began preparing questions for the Illinois EPA to answer prior to the first IPCB hearing on the new rule in mid-August 2020. These questions were filed in late June 2020, and MWG received responses in early August 2020. MWG reviewed these responses and asked follow-up questions during the first IPCB hearing in which the Illinois

EPA responded to questions from other stakeholders. As discussed later in Section 3.4.1, the Illinois EPA's responses to MWG's and the other stakeholders' questions were used to finalize MWG's selection of alternative disposal capacity for Powerton's Ash Surge and Bypass Basins.

In addition to asking the Illinois EPA questions on its Proposed Illinois CCR Rule, MWG also prepared expert testimonies on the proposed regulations and suggested changes. MWG started preparing these testimonies after submitting its pre-filed questions to the Illinois EPA with the IPCB in late June 2020. These testimonies were the focus of the second IPCB hearing in late September 2020 and were filed with the IPCB in late August 2020, one month prior to the hearing.

3.3.2 ASH SURGE & BYPASS BASIN CLOSURE CONSTRUCTION PERMITS

3.3.2.1 PERMIT APPLICATIONS

Prior to closing the Ash Surge and Bypass Basins, MWG must first receive closure construction permits from the Illinois EPA to perform the work. Indeed, per Illinois Public Act 101-0171, MWG cannot "close any CCR surface impoundment without a permit granted by the [Illinois EPA]." Preparation of the closure construction permit applications for these two CCR surface impoundments is also contingent on when the Illinois EPA publishes the corresponding application form. Per the Illinois EPA's answers to pre-filed questions it received ahead of the August 2020 Illinois Pollution Control Board hearings on the Proposed Illinois CCR Rule, the agency will be making "every effort to have CCR permit specific application forms available by March 31, 2021" (Ref. 17). Accordingly, MWG expects to start preparing the closure construction permit application form for closing the Bypass Basin in early April 2021, which is when MWG expects to start preparing the final written closure plan for the Bypass Basin and the required closure alternatives analysis. Since both documents are required in the permit application, MWG intends to prepare the closure construction permit application form for closing the Bypass Basin concurrently with the basin's final written closure plan and the closure alternatives analysis.

Early in the permit application preparation process, MWG will seek to hold a pre-application meeting with the Illinois EPA to discuss the overall project, the preliminary closure method for the Ash Surge and Bypass Basins, and the agency's requirements and expectations. This meeting will likely occur in early May 2021 after MWG has submitted the closure category designations for the Ash Surge and Bypass Basins and has performed some preliminary engineering and design work.

Although not required to develop alternative disposal capacity for the Ash Surge and Bypass Basins, it is important to note that MWG will also need to prepare and submit operating permit applications for both basins while simultaneously preparing the closure construction permit applications. Per the proposed 35 Ill. Adm. Code 845.230(d), MWG expects to have the initial operating permit applications for the Ash Surge and

Bypass Basins completed and submitted to the Illinois EPA by September 30, 2021. Pursuant to the proposed 35 Ill. Adm. Code 845.230(d)(2), this application must contain, at a minimum:

- The basins' histories of construction;
- An analysis of the chemical constituents found within the CCR and non-CCR wastestreams placed in both basins (including all chemical additives and sorbent materials);
- Demonstrations that the basins comply with the Proposed Illinois CCR Rule's location standards;
- Evidence that the permanent name markers for the basins have been installed;
- Documentation that both basins will be operated and maintained with a form of slope protection specified by the Proposed Illinois CCR Rule (*e.g.*, vegetative cover);
- Certifications of the basins' Emergency Action Plans and fugitive dust control plans;
- Information on the basins' groundwater monitoring program;
- Preliminary written closure plan;
- Initial written post-closure plan;
- Documentation on whether the basins' liners comply with the proposed rule's liner design criteria; and
- Documentation of known groundwater protection standard exceedances and any corrective action taken.

In order to develop alternative disposal capacity for the Ash Surge and Bypass Basins as soon as technically feasible, MWG intends to prepare the closure construction and operating permit applications for both basins at the same time once the Final Illinois CCR Rule is published. Accordingly, many of MWG's resources will be relied on to prepare both sets of applications for not only the Ash Surge and Bypass Basins but also for their CCR surface impoundments at Waukegan, Will County, and Joliet. While many of the preceding documents are expected to be similar if not equivalent to the EPA CCR Rule compliance documentation already prepared for the Ash Surge and Bypass Basins, some documents may require more information to comply with the Final Illinois CCR Rule's requirements relative to those of the EPA CCR Rule. In the case of the chemical constituent analysis, MWG will need to sample the wastestreams currently going into the Ash Surge and Bypass Basins and have each sample analyzed for its chemical constituents.

3.3.2.2 CLOSURE PRIORITIZATION CATEGORY

The first step in the closing the Ash Surge and Bypass Basins will be determining each basin's closure prioritization category pursuant to the proposed 35 Ill. Adm. Code 845.700(g). The closure prioritization categories range from Category 1 (highest priority) to Category 7 (lowest priority) and will ultimately influence the permitting timeframe for closing the Bypass Basin. The Illinois EPA will prioritize issuing construction permits for Category 1 closures, then Category 2 closures, then Category 3 closures, and so forth. In accordance with the proposed 35 Ill. Adm. Code 845.700(c), MWG will assign and submit the closure category designations for the Ash Surge and Bypass Basins to the Illinois EPA within 30 days after the effective date of the Final Illinois CCR Rule. Based on an effective rule date of March 30, 2021, MWG therefore expects to submit a closure category designation for the Bypass Basin to the Illinois EPA by the end of April 2021.

As its name indicates, the closure prioritization category establishes the Illinois EPA's priority for reviewing and processing closure construction permit applications. Accordingly, pursuant to 845.700(h), owners or operators of CCR surface impoundments with the highest closure priorities (Categories 1 through 4) are required to submit a closure construction permit application to the Illinois EPA no later than January 1, 2022. Conversely, closure construction permit applications for Category 5 CCR surface impoundments are not due to the Illinois EPA until July 1, 2022. Finally, Category 6 and 7 CCR surface impoundments do not require a closure construction permit application be submitted to the Illinois EPA until July 1, 2023.

It should be noted that MWG does not expect the Ash Surge or Bypass Basin to have a high priority for closure given that they have not impacted a potable water supply, are in compliance with the safety factors and location restrictions promulgated by the Proposed Illinois CCR Rule, are not in an area of environmental justice concern, and have not caused an exceedance of groundwater protection standards. Per the proposed 35 Ill. Adm. Code 845.700(g)(1), MWG anticipates both basins will be considered Category 7 CCR surface impoundments (*i.e.*, the lowest closure priority for the Illinois EPA). Conversely, MWG expects the Illinois EPA to have a higher closure priority for the East and West Ash Ponds at the Waukegan Generating Station in Waukegan, Illinois given that those ash ponds are located in an area of environmental justice concern (Category 3 per the proposed 35 Ill. Adm. Code 845.700(g)(1)).

Upon submission of the closure prioritization category for the Bypass Basin to the Illinois EPA, MWG will have initiated closure of the Bypass Basin in accordance with the federal standard promulgated by 40 CFR 257.102(e)(3)(iii). Since MWG will complete this prerequisite to closing the Bypass Basin in accordance with the Proposed Illinois CCR Rule by the end of April 2021, this action will have taken place within 30 days of the April 11, 2021 cessation-of-waste deadline promulgated by the EPA CCR Rule in compliance with 40 CFR 257.102(e)(1).

3.3.2.3 CLOSURE ALTERNATIVES ANALYSIS

Concurrent with determining the Illinois EPA closure prioritization categories for the Ash Surge and Bypass Basins, MWG will also commence an analysis of closure alternatives for both basins. As stipulated in the proposed 35 Ill. Adm. Code 845.710(b), this analysis – which is also required by Illinois Public Act 101-0171 to be in the Final Illinois CCR Rule – must be performed before MWG can formally select a method for closing the Bypass Basin and thus before MWG can finalize the written closure plan for the pond. Pursuant to the proposed 35 Ill. Adm. Code 845.710(c), MWG must evaluate the following criteria for each closure method considered in the analysis:

- Level of effectiveness and protectiveness in the short- and long-terms;

- Ability to control future releases to the environment;
- Degree of difficulty to implement the closure method; and
- Extent to which concerns of residents impacted by the closure method are addressed, including CCR handling, transportation, and final disposal.

In addition to the preceding criteria, MWG must also:

- Evaluate whether a landfill can be constructed at the Powerton site to dispose of the CCR removed from the Ash Surge and/or Bypass Basins,
- Prepare a Class 4 cost estimate per the Association for the Advancement of Cost Engineering's (AACE) classification standards,
- Perform groundwater contaminant transport modeling and corresponding calculations to demonstrate how each closure alternative will achieve compliance with the site's groundwater protection standards,
- Describe the fate and transport of contaminants in each closure method over time, and
- Evaluate each closure method's impact to waters in Illinois.

While the tasks required for the closure alternatives analysis can generally be performed concurrently, the overall analysis requires a thorough and exhaustive evaluation of potential methods for closing the Ash Surge and Bypass Basins and of the CCR contaminants therein. Moreover, MWG will also be preparing the written closure plans and the operating permit application forms (see Section 3.3.2.1) for both basins concurrent with this closure alternatives analysis. Accordingly, this analysis is expected to take approximately six months to complete. Based on the IPCB publishing the Final Illinois CCR Rule by the end of March 2021, which will include the final requirements for the closure alternatives analysis, MWG plans to have the analysis completed and a preliminary closure method selected by the beginning of October 2021.

3.3.2.4 PUBLIC MEETINGS ON PROPOSED CLOSURE METHOD

Once MWG has completed the closure alternatives analysis required by the Proposed IL CCR Rule for the Ash Surge and Bypass Basins and has selected a preliminary closure method, MWG can then hold the public meetings with parties interested and/or affected by the basins' future closures. Per the proposed 35 Ill. Adm. Code 845.240 and 845.710(e), MWG must hold at least two public meetings to discuss the proposed closure activities and the results from the closure alternatives analysis at least 30 days before submitting the corresponding closure construction permit application. It is anticipated that these meetings will take place approximately 40 days after MWG completes the closure alternatives analysis. The proposed 35 Ill. Adm. Code 845.240 would require MWG to secure an accessible facility (14 days), mail and post notices of the proposed project and meeting dates (10 days), and conduct the meetings (at least 14 days after anticipated last notice receipt date). This time is also necessary for MWG to adequately prepare for these meetings, which will include coordinating with their consultants and preparing presentation materials. Therefore, based on the closure alternatives analysis being completed by the beginning of October 2021, it is anticipated that MWG will hold these public meetings in early to mid-November 2021.

3.3.2.5 FINAL WRITTEN CLOSURE PLANS

After conducting the public meetings on the proposed method for closing the Ash Surge and Bypass Basins, MWG will select a final closure method pursuant to the proposed 35. Ill. Adm. Code 845.710(f). This final closure method will be described in each basin's final written closure plan, which will include the results of MWG's alternatives closure analysis and will address comments received during the public meetings as necessary. Although most of the written closure plan can and will be prepared as MWG performs the closure alternatives analysis, it cannot be finalized until after the public meetings. Pursuant to the proposed 35 Ill. Adm. Code 845.240(a), MWG will submit the final written closure plans, closure alternatives analysis, and closure construction permit applications for the Ash Surge and Bypass Basins no sooner than 30 days after holding the last public meeting. During these 30 days, MWG will review public comments, finalize the written closure plans, and finish preparing the closure construction permit application forms (see Section 3.3 for permitting requirements). Therefore, MWG expects to have the final written closure plans for the Ash Surge and Bypass Basins prepared and ready to submit to the Illinois EPA by mid-December 2021.

3.3.2.6 ILLINOIS EPA REVIEW & PERMIT ISSUANCE

Based on a mid-December 2021 submittal, it is expected the Illinois EPA will begin reviewing the closure construction permit application for closing the Bypass Basin in late December 2021 or early January 2022. The time required for the agency to perform its review and make a tentative determination on issuing a closure construction permit is unknown. However, MWG expects the initial Illinois EPA review to take at least seven months because:

- The agency will likely receive a large volume of operating and closure construction permit applications for the 73 CCR surface impoundments the Illinois EPA has identified across 23 Illinois power plants;
- Closure construction permit applications for CCR surface impoundments closing due to groundwater protection standard exceedances will be prioritized over Powerton's Ash Surge and Bypass Basins (Ref. 6, § 845.700(g));
- Closure construction permit applications for CCR surface impoundments located in area of environmental justice concern (like the East and West Ash Ponds at MWG's Waukegan Generating Station) will be prioritized over Powerton's Ash Surge and Bypass Basins (Ref. 6, § 845.700(g));
- The agency will need to review the substantial amount of information required to be in the closure alternatives analysis (Ref. 6, § 845.710), which may also require reviews by other state agencies (*e.g.*, Illinois Department of Natural Resources); and

- The agency will need to efficiently allocate its resources to simultaneously cover NPDES permit modifications and renewals, ELG Rule assessments, and its new permit program for CCR surface impoundments.

Based on the preceding factors, it is assumed that the earliest the Illinois EPA will be able to issue draft closure construction permits for the Ash Surge and Bypass Basin would be seven months from the date MWG submits the corresponding application. Therefore, MWG expects the Illinois EPA to issue draft permits for closing the Ash Surge and Bypass Basins by mid-July 2022.

It should be noted that the assumed timeframe for receiving a draft permit from the Illinois EPA is significantly shorter than MWG's recent experience in renewing/modifying an NPDES permit with the agency. MWG submitted a renewal permit application for Powerton's NPDES permit in November 2019 and has yet to receive the draft permit. However, given the recent focus by the Illinois EPA, the IPCB, the Illinois General Assembly, and the public on regulating CCR surface impoundments, MWG assumes that draft permits for operating, modifying, and closing ash ponds in Illinois will be issued in a more expeditious manner than previous experience with the Illinois EPA NPDES permitting program.

Upon issuing the draft closure construction permit for the Bypass Basin, the Illinois EPA will prepare and distribute a public notice of its tentative decision to issue the permit. Per the proposed 35 Ill. Adm. Code 845.260(b), the Illinois EPA would distribute this notice at least 15 days after issuing the draft permit in mid-July 2022. Once the public notice is distributed, a 30-day public comment period on the draft permit would commence in accordance with the proposed 35 Ill. Adm. Code 845.260(c). Therefore, it is expected that the public comment period on the draft construction permits for closing the Ash Surge and Bypass Basins will span from early August 2022 to early September 2022.

During the public comment period, any person may submit a request for the Illinois EPA to hold a public hearing on the draft closure construction permits. Per the proposed 35 Ill. Adm. Code 845.260(d)(1), the Illinois EPA may hold this public hearing if "there exists a significant degree of public interest in the proposed permit." During the August 12, 2020 IPCB hearing on the Proposed Illinois CCR Rule, a representative from the Illinois EPA stated that the agency has historically held a public hearing for NDPES draft permits if anyone requests such a hearing (Ref. 18). The representative added, "I can't think of a recent example where we have denied anyone." Given this agency precedent; the statutory mandate in Illinois Public Act 101-0171 that the IPCB adopt final CCR regulations that "specify meaningful public participation procedures for the issuance of CCR surface impoundment construction and operating permits, including, but not limited to…an opportunity for a public hearing prior to permit issuance" (Ref. 2, § 22.59(g)(6)); and the general level of public participation made throughout Illinois's rulemaking process, MWG presumes that a public hearing will be requested during the 30-day public comment period on the Ash Surge and Bypass Basin closure construction permits and that the Illinois EPA will grant the public hearing.

Pursuant to the proposed 35 Ill. Adm. Code 845.260(e)(1), the Illinois EPA cannot hold a public hearing sooner than 30 days after notifying the public of the hearing date. Assuming it takes the agency approximately two weeks to schedule the hearing (reserving a location, notifying the public, *etc*.), the public hearing cannot not occur until at least 45 days after the Illinois EPA agrees to hold one. Presuming a public hearing will be called near the end of the public comment period in late August or early September of 2022, it is anticipated that the public hearing will be held in mid- to late October 2022.

After consideration of the public comments the agency receives on the draft closure construction permit, including those submitted during the public hearing, the Illinois EPA will then make a final permit determination. During this time, the Illinois EPA will consider all timely comments submitted by the public and will prepare written responses to these comments. In MWG's experience with renewing its NPDES permits with the Illinois EPA for its power plants, it has generally taken the Illinois EPA several months to issue final permits after the completion of the public comment period. Moreover, the Illinois EPA has often extended the public comment period beyond the public hearing date (typically 30 days), which would be permitted under the proposed 35 Ill. Adm. Code 845.260(c)(4). In its response to pre-filed questions ahead of the August 2020 Illinois Pollution Control Board hearings (Ref. 17), the Illinois EPA states, "The proposed permitting process was modeled after the existing NPDES permit program, which also does not include a time frame for a final Agency decision. The complex nature of these applications, public notice requirements, and the opportunity for a public hearing, make it difficult to complete the process within a defined timeframe. Like the NPDES program, robust public participation is an essential part of this proposal. Not having a specific deadline allows for the maximum flexibility during the public notice and hearing processes."

Given the Illinois EPA's lack of a decision deadline for a final permit, MWG's experience in receiving final NPDES permits from the agency, and the precedence of the agency extending the public comment period beyond a public hearing, MWG presumes the Illinois EPA will require a few months after the public hearing to respond to public comments and finalize the closure construction permits for the Ash Surge and Bypass Basins. However, MWG also expects the Illinois EPA to prioritize issuing final permits for closing non-compliant CCR surface impoundments like the Ash Surge and Bypass Basins given the state's recent focus on establishing regulations and a corresponding permitting program for CCR surface impoundments in general and the public participation throughout the rulemaking process. Thus, MWG assumes the agency will finish reviewing public comments approximately three months after the public hearing is held. This timeline would result in MWG receiving the final closure construction permits for the Ash Surge and Bypass Basins from the Illinois EPA by mid-January 2023, approximately 11 months after submitting the corresponding permit application to the agency.

As previously stated, this overall permitting timeline is based on MWG's experience with obtaining other permits from the Illinois EPA; the agency's need to allocate its resources to implement its new CCR permit program and to renew or modify the NPDES permits at power plants in Illinois in accordance with the EPA's revised ELG Rule; and the closure prioritization categories in the proposed 35 Ill. Adm. Code 845.700(g). A delay in this permitting timeframe may result in a delay in implementing the alternative disposal capacity selected for the Ash Surge and Bypass Basins within the requested timeframe.

3.3.3 POWERTON NPDES PERMIT RENEWAL & MODIFICATION

Because this project will modify the treatment methods used for Powerton's CCR wastestreams prior to being discharged to the Illinois River via permitted Outfall 001 and because the Station's NPDES permit has expired, MWG will need to renew Powerton's NPDES permit and modify the current treatment methods historically implemented in accordance with the permit. Since this permit renewal is related to the same project for which the Ash Surge and Bypass Basin closure construction permit applications are being submitted, MWG intends to prepare the application for modifying Powerton's NPDES permit concurrently with its preparation of the Ash Surge and Bypass Basin closure construction permits. By submitting the NPDES and CCR permit applications together, MWG expects that both permits can be processed together and will follow the same (or at least similar) review and public participation timeframes. Thus, MWG anticipates submitting the application for renewing Powerton's NPDES permit to the Illinois EPA by mid-December 2021 and expects to have the final permit by mid-January 2023.

3.4 ENGINEERING & DESIGN

As Powerton works to draw down the water level in the Bypass Basin, MWG will commence the final engineering and design work for the project. Based on the design activities required for this project and the dependence of some activities on vendor design inputs and Illinois EPA regulatory timeframes, the engineering and design work is expected to be completed in the following three phases:

1. General Engineering & Design,
2. Dewatering Bin Refurbishment, and
3. Concrete Ash-Settling Tank Design.

3.4.1 GENERAL

General engineering and design commenced in September 2018, approximately one month after the *USWAG* decision, and focused on developing permanent alternative disposal capacity solutions for the Powerton CCR and non-CCR wastestreams sent to the Ash Surge and Bypass Basins. As previously discussed, this work focused on refining and adding to conceptual alternative disposal capacity designs developed in 2015 in addition to evaluating each design's technical feasibility, physical space requirements, implementation schedule, and capital cost. MWG also assessed the potential impacts of the EPA's forthcoming (at the time) revision to the ELG Rule to each potential solution.

After the Illinois EPA published its draft CCR surface impoundment regulations for comment in December of 2019, MWG reviewed the draft regulations and incorporated them into its alternative disposal capacity evaluation. MWG has continued updating its evaluation of alternative disposal capacity options for the Ash Surge and Bypass Basins throughout Illinois's CCR rulemaking and has actively participated in this rulemaking to better understand the Illinois EPA's intentions, including future permitting priorities and timeframes (see Section 3.3.1). Shortly after the IPCB's first hearing on the Proposed Illinois CCR Rule in mid-August 2020, during which the Illinois EPA responded to stakeholder questions on the proposed regulations (including MWG questions), MWG finalized its evaluation of alternative disposal capacity solutions for Powerton's two CCR surface impoundments and selected the multiple technology solution described herein.

Shortly after the EPA published its proposed revisions to the alternative closure requirements in 40 CFR 257.103 in early December 2019, MWG began preparing this demonstration for a site-specific alternative deadline to initiate closure. MWG updated this demonstration concurrent with updates to its evaluation of alternative disposal capacity solutions for the bottom ash transport water sent to the Ash Surge and Bypass Basins in response to the Illinois rulemaking process for CCR surface impoundments. Pursuant to the final amendment to 40 CFR 257.103 published in late August 2020, MWG incorporated its evaluation of alternative disposal capacity solutions for the non-CCR wastestreams sent to both CCR surface impoundments at Powerton. In accordance with 40 CFR 257.103(f)(3)(i), MWG has submitted this demonstration to the EPA for approval by November 30, 2020.

Upon completing this demonstration, MWG will begin updating the budgetary cost estimate prepared in 2019 for the multiple technology solution described in this demonstration in accordance with the revisions and refinements that have since been made to this alternative disposal capacity solution. MWG will then use this updated cost estimate to ensure adequate funding is allocated for this project. This work will include acquiring and/or confirming budgetary cost estimates and lead times from vendors (*e.g.*, fabric enclosure), revising and adding material quantities as necessary, and updating labor rates as necessary. Given that a budgetary cost estimate has already been prepared for this solution and only requires updating, it is expected the updated estimate will be prepared by mid-December of 2020 and subsequently finalized in early January 2021 at the onset of the mechanical and civil engineering tasks for the project.

3.4.2 DEWATERING BIN REFURBISHMENT

The initial phase of engineering and design will focus on designing the components required to refurbish the Station's dewatering bins. These modifications need to be designed first since they will influence the size of the concrete ash-settling tank required to settle the quantity and size of ash particles in the effluent from the modified dewatering bins. Ultimately, MWG will seek an optimal engineering solution that balances the modifications made to the dewatering bins and the sizes of the tanks within the concrete ash-settling tank, so some design iterations are expected.

To determine what modifications are required to reduce the quantity and size of ash particles sent to the future concrete ash-settling tank, MWG must first perform a condition assessment of the dewatering bins, including their supporting structures. MWG started this assessment in September 2019 as part of its evaluation of alternative disposal capacity solutions by engaging in discussions with Powerton personnel on their observations and recommendations for repairing the dewatering bins. In recent discussions, Station personnel noted the relatively large sizes of ash particles that were removed from the Ash Surge Basin during the recent beneficial-use recovery work. MWG has also contacted a vendor specializing in ash-handling equipment and discussed various options for refurbishing the dewatering bins.

MWG intends to follow up these preliminary assessments with a formal condition assessment of the Powerton dewatering bins, which would be performed by an ash-handling vendor (evaluation of equipment and components) and an engineering design firm (evaluation of supporting structures). These evaluations are expected to start in January 2021 and will likely take the ash-handling vendor and engineering design firm approximately six weeks to perform their respective assessments and document their findings for all four dewatering bins. Therefore, the dewatering bin condition assessment is expected to be finished by mid-February 2021.

Based on the findings from the condition assessment, MWG will identify the components that need to be replaced and new equipment and components that should be installed to improve the operability of Powerton's dewatering bins and to extend their operating lives. Part of this work will include determining an appropriate size distribution of ash particles that can remain suspended in the dewatering bin overflow, which will influence the sizes of the tanks within the concrete ash-settling tank. As previously stated, MWG plans to identify a target ash particle size distribution that balances the required modifications to the dewatering bins and the size of the concrete ash-settling tank. This work will include performing calculations to determine the areas and depths required for the tanks within the ash-settling tank to remove the suspended ash particles in the dewatering bin effluent. An evaluation of chemical additives to facilitate flocculation of ash particles to promote settlement may also occur during this time.

Given the design activities and likely iterations required to determine preliminary tank sizes for the concrete ash-settling tank and to finalize the modifications required for the dewatering bins, it is expected that this engineering and design work will take approximately six weeks to complete following the condition assessment. Based on the scheduled end date for the condition assessment (mid-February 2021), it is expected that MWG will be able to finalize the dewatering bin refurbishment scope of work by the end of March 2021.

MWG also plans on conducting heat load analysis of the future bottom ash recirculation system while the dewatering bins are being evaluated. This analysis will verify that the proposed Recycle Water Cooling Basin can indeed adequately cool treated effluent from the future concrete ash-settling tank before the water is recirculated back into the Station's bottom ash system. Although the recirculation system will not be installed during this project, this design concept needs to be validated to ensure the appropriate segregation of CCR and non-CCR wastestreams to facilitate future compliance with the EPA ELG Rule. Should it be determined that the existing Bypass Basin footprint is too small to function as a cooling pond, MWG would likely modify the proposed design to turn the Ash Surge Basin into the cooling pond for bottom ash transport water and the Bypass Basin into a low-volume waste basin. Doing this analysis at the onset of the project will minimize the risks of delays to the overall project schedule should it be determined that the existing Bypass Basin footprint would be incapable of fulfilling MWG's need to provide a means of adequately cooling the bottom ash transport water prior to recirculation. Based on this analysis being performed concurrently with the dewatering bin refurbishment work, it is expected to be completed by mid-April 2021.

Finally, once the recirculation heat load analysis validates the repurposing of the Bypass Basin as a cooling pond and after preliminary sizes for the tanks in the concrete ash-settling tank are determined, then MWG will begin preparing general arrangement drawings for the project and revising the Station's piping and instrumentation diagrams (P&IDs) and PFDs for the modified bottom ash-handling process. These tasks are therefore expected to start in early February 2021. MWG plans on having the general arrangement drawings, P&IDs, and PFDs for the project ready for design/use by the time the Illinois Pollution Control Board adopts the Final Illinois CCR Rule at the end of March 2021. This will facilitate use of these documents during MWG's planned pre-application meeting with the Illinois EPA once the final state rule has been promulgated.

3.4.3 CONCRETE ASH-SETTLING TANK DESIGN

The third and final design phase for this project will be the engineering and design of the concrete ash-settling tank and its appurtenances. The preliminary tank sizes shown on drawing POW-CSK-200 in Appendix A will be verified or updated as necessary after the target ash particle size is finalized at the end of March 2021. As previously discussed, some design iterations will likely be performed to determine an optimal combination of tank area and depth to ensure the ash particles in the dewatering bin effluent are settled out of the transport water prior to being discharged into the Recycle Water Cooling Basin. This work will also include preliminary engineering and design of the concrete ash-settling tank appurtenances (*i.e.*, building enclosure, site grading, and access roads). Accordingly, this task is expected to take approximately two months to complete, from early April to late May 2021.

The subsequent detailed design for the concrete ash-settling tank can commence once the dewatering bin vendor has progressed far enough into the final design modifications for the dewatering bins to provide certainty that the target ash particle size distribution determined in the first engineering and design phase can and will be met. This is expected to occur approximately two months into the dewatering bin vendor's design efforts, which corresponds to when the vendor will begin placing material orders for equipment and components (see Section 3.6.1). At this time, MWG can begin finalizing the sizes of the primary and surge cells for the concrete ash-settling tank. Thus, the detailed engineering and design for this phase is expected to start in mid-October 2021.

While the sizes of the tanks within the concrete ash-settling tank are being finalized to provide adequate detention time to promote sedimentation of the ash particles in the dewatering bin effluent, the structural designs of the tank walls and slabs will also be finalized. Specifically, the required thicknesses of these structural elements will be determined as well as the required reinforcement (*i.e.*, rebar). Some design iterations will likely occur to obtain an efficient structural design. The site grading required to construct the concrete ash-settling tank and the roads necessary to access the tank to periodically dewater and remove ash stored therein will also be designed at this time. Finally, the effluent pipes from the dewatering bins to the concrete ash-settling tank and from the tank to the Recycle Water Cooling Basin will be designed (routing, sizing, designing of supports) while the aforementioned structural and civil engineering is being performed.

The preceding concrete ash-settling tank design tasks are expected to be performed concurrently and are anticipated to take approximately two months to complete. It is expected that the structural and mechanical engineering design tasks will start in mid-October 2021 once necessary design inputs are received from the dewatering bin vendor, particularly the expected size distribution of ash particles in the dewatering bin effluent. The internal design of the concrete ash-settling tank and the design of access roads thereto are expected to commence a few weeks after MWG starts determining the final sizes for the primary and surge cells within the concrete tank. Overall, these tasks are expected to take between 1.5 and 2 months to complete. Thus, MWG expects to have the designs for the concrete ash-settling tank and its appurtenances by mid-December 2021.

3.5 CONTRACTOR SELECTION

MWG intends to hire three separate contractors to execute this project. The first contractor will be responsible for refurbishing Powerton's existing dewatering bins. The second contractor will be charged with installing the concrete ash-settling tank, the dewatering bin and tank effluent piping, and the access roads and general site grading. Finally, the third contractor will be responsible for clean closing the Bypass Basin and repurposing it as a cooling pond for the treated effluent from the concrete ash-settling tank. This contracting strategy will allow MWG to hire contractors specialized in the different scopes of work specified within this project. This strategy will also allow MWG to expedite construction of the project given the anticipated permitting timeline for closing the Bypass Basin and constructing the concrete ash-settling tank, because the dewatering bin refurbishment can start before receiving the closure construction and NPDES modification permits from the Illinois EPA.

3.5.1 DEWATERING BIN CONTRACTOR (DB CONTRACTOR)

MWG intends to prepare, bid, and award the contract for installing the new equipment and components for Powerton's dewatering bins to a contractor experienced in installing mechanical systems. MWG plans to award this contract by the time the dewatering bin vendor has furnished the required components and equipment for refurbishing the dewatering bins and is ready to ship the materials to the project site. Per Section 3.6.1, it is currently anticipated that the dewatering bin vendor will begin delivering these materials to Powerton in late January 2022. Therefore, MWG plans on hiring the Dewatering Bin Contractor ("DB Contractor") by early February 2022.

To facilitate the DB Contractor mobilizing to the Powerton site by March 2022, MWG plans to start preparing the technical specification and commercial terms and conditions for the dewatering bin refurbishment work in early October 2021. The bid package is expected to be completed approximately six weeks later and subsequently issued to prospective contractors in mid-November 2021. The corresponding bid period is expected to last about six weeks, after which MWG will evaluate the bids and ultimately select the DB Contractor. After a three-week bid evaluation phase, MWG will begin negotiating the installation contract with the DB Contractor, which will include conformance of the technical specification with the commercial terms and conditions outlined in the contract. The contract negotiation phase is expected to take approximately three weeks, which would conclude with MWG awarding the dewatering bin refurbishment work to the DB Contractor in early February 2022.

3.5.2 BYPASS BASIN CLOSURE CONTRACTOR (BB CONTRACTOR)

MWG plans to start clean closing the Bypass Basin as soon as possible after receiving a final closure construction permit from the Illinois EPA. Given that the permit will establish the agency's requirements and expectations for closing the basin, MWG will begin preparing the technical requirements and commercial terms and conditions upon receipt of the draft permit from the Illinois EPA. Per Section 3.3.1, this is currently anticipated to be completed in mid-July 2022.

Given the public comment period and likely public hearing that will be held between the Illinois EPA's issuance of the draft and final permits for the Bypass Basin closure work, MWG does not plan on issuing the corresponding bid package until after the public hearing, at which time MWG will have some reasonable certainty that the project will be approved as proposed or will require some modifications. Bidding the work beforehand would leave MWG susceptible to potential material changes required by the Illinois EPA to MWG's closure plan which would then require MWG to rebid the work, causing unavoidable delays to the project. Thus, MWG does not anticipate issuing the Bypass Basin closure work for bids until after the public hearing on Illinois EPA's draft permit is held in mid-October 2022.

MWG intends to provide the prospective Bypass Basin contractors ("BB Contractor") approximately six weeks to review the bid package materials, including the draft closure construction permit from the Illinois

EPA. After the bid period concludes in early December 2022, MWG will review the submitted bids. MWG expects to take approximately six weeks to thoroughly review the submitted bids before ultimately selecting the BB Contractor with the intention of having a final closure construction permit from the Illinois EPA before beginning contract negotiations with the selected contractor (expected mid-January 2023 per Section 3.3.1). This final permit will be incorporated into the final contract documents and conformed technical specification. Ultimately, MWG expects to award the Bypass Basin closure work to the BB Contractor by mid-February 2023 following a month-long contract negotiation phase.

3.5.3 CONCRETE ASH-SETTLING TANK CONTRACTOR (CT CONTRACTOR)

Because the concrete ash-settling tank work will be on the same permitting timeline as the Bypass Basin closure work, MWG will procure the contractor responsible for installing the concrete ash-settling tank and its appurtenances ("CT Contractor") coincident with procuring the BB Contractor. Therefore, the activities and corresponding timeframes for procuring the CT Contractor are expected to follow the same sequence as that for the BB Contractor described in the preceding section. Accordingly, MWG expects to have the CT Contractor hired by mid-February 2023.

3.6 EQUIPMENT FABRICATION & DELIVERY

The major equipment and materials being fabricated for this bottom ash-handling modification project at Powerton are the components and equipment for refurbishing the Station's four dewatering bins, the structural materials to construct the concrete ash-settling tank, piping for the dewatering bin overflow and for the treated effluent from the concrete ash-settling tank, and geomembrane liner for the Recycle Water Cooling Basin. The following subsections discuss how MWG anticipates these various materials will be procured for the project.

3.6.1 DEWATERING BIN COMPONENTS

3.6.1.1 DEWATERING BIN VENDOR PROCUREMENT

After MWG finalizes the dewatering bin refurbishment scope of work in late March 2021 (as detailed in Section 3.4.1), MWG will begin preparing the technical specification and commercial terms to procure a vendor specialized in ash-handling equipment to design, furnish, manufacture, and deliver the components and equipment required to refurbish Powerton's dewatering bins. MWG plans to issue this scope of work a couple weeks after meeting with the Illinois EPA in early May 2021 (see Section 3.3.1) to discuss the project with the Illinois EPA. This will ensure MWG meets the agency's requirements and expectations for the handling and treatment of the dewatering bin effluent, which will allow MWG to accurately convey the scope of work and schedule requirements to potential vendors.

Following a six-week period for vendors to evaluate the scope of work, to develop design and manufacturing strategies, and to ultimately submit bids, MWG will start evaluating the bids and ultimately select a vendor. Immediately after selecting the winning bidder, MWG will work with the selected vendor to conform the commercial terms and technical specification before ultimately awarding the contract. These bid evaluation and contract negotiation phases are expected to collectively take about seven weeks to complete, which would have the dewatering bin vendor receiving its contract to perform the dewatering bin refurbishment design work by mid-August 2021.

3.6.1.2 MATERIAL PROCUREMENT

Upon receiving the contract in mid-August 2021, the dewatering bin vendor will begin designing the equipment and components to refurbish Powerton's dewatering bins to obtain the specified performance standards (*e.g.*, size distribution of ash particles in the dewatering bin effluent). It is expected that the vendor will take approximately four months to complete the engineering and design work associated with the new equipment and components for refurbishing the four Powerton dewatering bins. This work may include, but not be limited to, preparing, reviewing, and/or designing:

- General arrangement drawings;
- Piping and Instrumentation Diagrams (P&IDs);
- Mechanical equipment, valve, and line lists;
- Equipment supplier drawings; and
- Mechanical equipment data sheets.

As an individual component or piece of equipment is designed and/or specified for the dewatering bins, the vendor would submit the pertinent design document to MWG for review. After receiving MWG's approval, the vendor would then place a material order for the subject equipment, component, or set of equipment and/or components. It is expected that the first such material order will be placed in mid-October 2021 – approximately two months after the vendor starts the engineering and design work for refurbishing the dewatering bins – following the initial engineering and design work by the vendor and initial review by MWG.

It is expected that the dewatering bin vendor will work with third-party suppliers to procure and/or fabricate the equipment and components required for refurbishing Powerton's four dewatering bins consistent with the vendor's engineering and design. Once the vendor submits a material release and purchase order to its supplier(s), the supplier(s) would first prepare and submit shop drawings to the dewatering bin vendor to review and approve. Once approved, the equipment and/or components would be fabricated and inspected for conformance with the shop drawings and/or the vendor's design. Fabrication is expected to occur throughout the fourth quarter of 2021, concurrent with the last few months of the dewatering bin vendor's engineering and design work. Thus, the equipment and components for refurbishing Powerton's four dewatering bins are expected to be ready for delivery to the project site by the end of January 2022. This would allow for the dewatering bin materials to be delivered to the project site by the end of February 2022 as the DB Contractor is mobilizing to the site to install the fabricated components and equipment (see Section 3.5.1).

3.6.2 CONCRETE MATERIALS

Immediately after being awarded the contract to install the concrete ash-settling tank in mid-February 2023, the CT Contractor will begin contacting concrete and rebar suppliers to furnish and deliver the materials required to construct the ash-settling tank and its foundations.

Once the rebar supplier receives the tank and foundation design drawings from the CT Contractor, the supplier will begin preparing rebar shop drawings for the tank and its base mat foundations. Given the tank's small profile relative to most other concrete construction projects, it is expected that the supplier can have the shop drawings prepared within two weeks and submitted to the CT Contractor and MWG for review. After a two-week review period and ultimate approval of the shop drawings, the rebar supplier will begin fabricating the steel reinforcement. Fabrication is also expected to take approximately two weeks to complete, after which the rebar supplier will start delivering the rebar to the project site. Based on these timeframes and given the concrete ash-settling tank contract being awarded in mid-February 2023, it is expected that the rebar supplier will furnish and deliver the reinforcement for the concrete ash-settling tank and its base mat foundations to the project site by mid-April 2023.

Several potential ready-mix concrete suppliers are located within a 20-mile radius of the Powerton site, which includes the cities of Peoria and East Peoria, Illinois. Therefore, it is expected that concrete for the ash-settling tank and its base mat foundations will be prepared at one of these plants and delivered to the site via ready-mix trucks. Given the proximity of these plants, ready-mix trucks should have adequate time to deliver and discharge the concrete in accordance with ASTM C94, "Standard Specification for Ready-Mixed Concrete," which requires concrete be discharged within 90 minutes after hydration commences.

3.6.3 EFFLUENT PIPING

Like the concrete materials, the CT Contractor will begin ordering the effluent piping for the dewatering bin and ash-settling tank shortly after being awarded the installation contract. However, since this piping will not be needed until late June 2023 (see Section 3.7.2), these materials are not expected to be fabricated and delivered to the project site until mid-to-late June 2023. This schedule should provide adequate lead time for a pipe supplier to fulfill the CT Contractor's order. It is currently anticipated that the CT Contractor will arrange to have all piping delivered to the site just as the contractor begins installing the dewatering bin effluent pipes in late June 2023.

3.6.4 GEOMEMBRANE

Once the BB Contractor is awarded the contract for closing and repurposing the Bypass Basin, the contractor will place the material order for the geomembrane panels required to line the basin after it has been clean-closed. Although geomembrane can be a long-lead time component for solid waste facility construction projects, the relatively small size of the Bypass Basin (less than an acre) should facilitate a shorter lead time and thus timely delivery of the geomembrane panels. Therefore, MWG expects the geomembrane panels for the new Recycle Water Cooling Basin to be delivered to the project site shortly after the BB Contractor has finished closing the existing Bypass Basin in mid-April 2023 (see Section 3.7.2).

3.6.5 FABRIC ENCLOSURE

After receiving a final construction permit from the Illinois EPA, MWG will order the fabric enclosure for the concrete ash-settling tank. Based on a budgetary cost estimate from a vendor specializing in these enclosures, MWG expects a 60- to 90-day lead time for this enclosure. Given that the concrete ash-settling tank walls are expected to be installed by early July 2023, ordering the enclosure between late January 2023 and mid-March 2023 should provide plenty of time for the selected vendor to fabricate and deliver the fabric enclosure to the Powerton site in time for the CT Contractor to erect it over the new concrete ash-settling tank.

3.7 CONSTRUCTION

Like the engineering and design work for this project, construction of this modified bottom ash-handling system for Powerton is expected to occur in three phases. A fourth phase of construction will implement the segregation of CCR and non-CCR wastestreams currently managed in the Ash Surge Basin. This phased approach will allow MWG to install the different components of the project as soon as technically feasible while accommodating the different regulatory and procurement timeframes discussed earlier. Accordingly, construction of the alternative disposal capacity to replace the Ash Surge Basin is expected to be executed in the following three phases:

1. Refurbish Dewatering Bins (by DB Contractor),
2. Close and Repurpose Bypass Basin (by BB Contractor), and
3. Construct Concrete Ash-Settling Tank (by CT Contractor).

Although not discussed herein since alternative disposal capacity for all wastestreams will be developed following the third phase of construction, the BB Contractor will also execute the fourth phase of construction for this project: Close and Repurpose the Ash Surge Basin.

The following construction schedule assumes that each of the three contractors hired to execute this project and their respective subcontractors (if any) will normally work five days per week at 10 hours per day.

3.7.1 PHASE 1: REFURBISH DEWATERING BINS

The DB Contractor will begin refurbishing the dewatering bins after mobilizing to the site and upon delivery of the components and equipment designed and furnished by the dewatering bin vendor. Per Section 3.5.1, MWG expects to award the installation contract for this work by mid-February 2022. Similarly, per Section 3.6.1, the dewatering bin vendor is expected to start delivering the new components and equipment to Powerton throughout February 2022. Thus, the DB Contractor should be able to fully mobilize to the site by the end of February 2022 and begin refurbishing Powerton's four dewatering bins by the beginning of March 2022.

Because each unit has two dedicated dewatering bins, it is expected that the DB Contractor can perform the refurbishment work without a given unit being taken offline (*i.e.*, during a scheduled outage). To execute this work, it is anticipated that the DB Contractor will refurbish one dewatering bin at a time. When one of the dewatering bins at a given unit is being refurbished, it will be taken out of service to perform the specified modifications while all bottom and economizer ash sluice water generated by the unit during this time is directed to the other dewatering bin. As the DB Contractor finishes its work at one dewatering, that dewatering bin will be commissioned (see Section 3.8.1), and the DB Contractor will begin refurbishing the next dewatering bin. Refurbishing and subsequently commissioning multiple dewatering bins at once would be logistically challenging without a unit outage, as the DB Contractor could not start refurbishing the second pair of dewatering bins until the first pair of dewatering bins are commissioned and placed back into service. Thus, the proposed sequencing is expected to provide the fastest technically feasible schedule for refurbishing the dewatering bins, especially since the work can be performed while Powerton Units 5 and 6 remain online.

In general, the DB Contractor's scope of work is expected to include replacing degraded components; installing new dewatering elements, new low-leak sluice gate enclosures, and new local control panels; and performing general maintenance tasks (*e.g.*, painting). This work is expected to take the DB Contractor approximately three weeks to complete at each dewatering bin. Based on the expected maintenance sequencing (one dewatering bin at a time), it is expected that all four dewatering bins will be refurbished within three months of the DB Contractor mobilizing to the site in late February 2022. Thus, it is currently anticipated that all four dewatering bins at Powerton will be refurbished by the end of May 2022.

3.7.2 PHASE 2: CLOSE & REPURPOSE BYPASS BASIN

3.7.2.1 BYPASS BASIN CLOSURE

Closure activities for the Bypass Basin are expected to commence within a couple weeks of the BB Contractor being awarded the closure contract in mid-February 2023 (see Section 3.5.2). All closure work will be performed in accordance with the final closure construction permit issued by the Illinois EPA (expected mid-January 2023).

Upon mobilizing to the site in early March 2023, the BB Contractor will begin removing any CCR remaining on the Bypass Basin liner from the initial cleaning performed by Powerton's Ash Management Contractor (see Section 3.2) and will then remove the 60-mil HDPE geomembrane liner itself. In addition to removing the liner, the BB Contractor will also be responsible for removing all CCR and CCR-impacted soils beneath the liner (if any). All liner, CCR, and CCR-impacted materials will be removed by excavating them out of the pond, loading them onto trucks, and transporting them offsite to a permitted disposal facility. As the existing liner is removed, the subgrade will be visually inspected to ensure all CCR constituents have been removed from the pond area. Finally, after all the excavation work is complete, the BB Contractor will begin decontaminating the pond's appurtenances (including the outlet structure) for re-use or removing them.

Given the relatively small size of the Bypass Basin, it is expected that the BB Contractor will be able to remove any CCR remaining on the pond's liner, remove the liner, and excavate any CCR-impacted soils within two weeks of mobilizing to the site. It is anticipated that the subsequent decontamination of the area and the appurtenant structures can be completed within three weeks after the pond's liner has been removed. Therefore, it is expected that the Bypass Basin will be clean closed and certified as such by mid-April 2023.

3.7.2.2 RECYCLE WATER COOLING BASIN CONSTRUCTION

Once the Bypass Basin has been closed, the BB Contractor will begin repurposing the area into the new Recycle Water Cooling Basin. First, the BB Contractor will prepare the subgrade to receive a new geomembrane liner. This work will include any re-grading necessary to restore the basin floor to a relatively smooth surface after the existing liner and underlying soils have been excavated during the Bypass Basin closure work. As the floor is being re-graded, it will be compacted and/or rolled smooth and then lined with new geomembrane panels. Given the pond's small area, this work is expected to be completed within three weeks. Thus, it is currently anticipated that the Recycle Water Cooling Basin will be lined by the beginning of May 2023.

3.7.3 PHASE 3: CONSTRUCT CONCRETE ASH-SETTLING TANK

Based on being awarded the contract in mid-February 2023 (see Section 3.5.3), the CT Contractor is expected to start mobilizing to the site shortly thereafter and be fully mobilized about one month later in mid-March 2023. Once fully mobilized, the CT Contractor will likely spend the first week installing appropriate erosion and sediment control measures around the area(s) to be disturbed by construction activities. Once these environmental protection measures are established, the CT Contractor will then begin excavating the area to install the base mat foundations for the concrete ash-settling tank's cells and dewatering slab. Excavation work will include compacting and rolling smooth the subgrade to ensure it can adequately support the base mat foundations. By the time the excavation work is completed in mid-April 2023, the CT

Contractor can begin forming out the base mats and placing rebar, which is expected to be delivered to the site around this time (see Section 3.6.2).

The base mat foundations will be constructed by first forming out the area, then installing the specified rebar, and finally placing the concrete. As previously mentioned, the concrete is expected to be installed via ready-mix trucks from a nearby concrete supplier. Because the base mat foundations for the concrete cells and the dewatering slab will be structurally isolated, it is anticipated that they will be installed around the same time. After the base mats have reached their design strengths – within 28 days per standard practice – the CT Contractor can begin constructing the concrete ash-settling tank and dewatering slab on top of their respective foundations.

Like the base mat foundations, the concrete cells for the ash-settling tank will be constructed by first forming out the area, then installing the specified rebar for the slabs and dowels for the walls, and finally placing the concrete. As previously mentioned, the concrete is expected to be installed via ready-mix trucks from a nearby concrete supplier. A similar process will be followed for placing the concrete walls and curbs. After the concrete has reached sufficient strength (within 28 days per standard practice), the CT Contractor will strip the formwork and backfill the tank. Each set of concrete pours (slabs then walls and curbs) are expected to take approximately four to six weeks to form, install the appropriate rebar, place the concrete, and verify the concrete strength. However, it is expected that CT Contractor can begin installing the vertical concrete elements (walls/curbs) approximately three weeks after starting work on the horizontal concrete elements (slabs) so that the walls and curbs can be placed once the concrete strengths of the slabs have been verified. Consequently, it is currently anticipated that all concrete work will be completed by early July 2023, approximately two months after completing the excavation.

Once the concrete walls have been constructed and have achieved their specified design strength, the CT Contractor can begin erecting the fabric structure. Based on a budgetary cost estimate from a vendor specializing in these enclosures, MWG expects the structure to be erected within two weeks. Thus, MWG currently anticipates the concrete ash-settling tank structure to be constructed by late July 2023.

Installation of the effluent piping to and from the new concrete ash-settling tank is expected to be timed with the erection of the fabric enclosure. Given the longer distance between the dewatering bins and the new ash-settling tank relative to that between the tank and the Recycle Water Cooling Basin, it is expected that the CT Contractor will begin installing the dewatering bin effluent piping first. This work is expected to take approximately one month to complete, so it is expected that the CT Contractor will begin installing the dewatering bin effluent piping in late June 2023 so that the piping can be fully installed by the time the fabric enclosure is erected. Given the proximity of the new ash-settling tank to the Recycle Water Cooling Basin, the gravity effluent pipe between the two units is expected to be installed within a week. After these new effluent lines have been installed, the concrete ash-settling tank will be ready for commissioning.

After both effluent lines have been installed, the CT Contractor will start constructing the new roads around the ash-settling tank to allow trucks to access the site for reclaiming the dewatered ash for beneficial use or disposal in a permitted solid waste facility. This work is expected to be performed as MWG is commissioning the new concrete ash-settling tank, and the CT Contractor is expected to finish this work about two weeks later as Powerton prepares to start using the concrete ash-settling tank to manage its CCR wastestreams and the Recycle Water Cooling Basin to temporarily manage its non-CCR wastestreams.

3.8 START-UP & IMPLEMENTATION

Given the preceding construction schedules, commissioning of Powerton's new bottom ash treatment system is expected to occur in two phases: first the dewatering bins, then the new concrete ash-settling tank.

3.8.1 COMMISSION DEWATERING BINS

Once the DB Contractor completes the modifications at a given dewatering bin, MWG can beginning commissioning it to ensure it operates as intended. Specifically, MWG will verify that the effluent from each modified dewatering bin meets the specified standards for the size distribution and quantity of ash particles remaining in suspension.

In general, the commissioning process will be performed by first ensuring each piece of equipment is operational and functional. The dewatering bin will then be commissioned as a system, during which MWG will optimize and tune the system as necessary to ensure it operates at maximum efficiency in accordance with the design specifications. Modifications will be made as necessary in order to meet the performance requirements.

It is expected that each dewatering bin will take approximately one month to commission. Based on the anticipated construction sequence presented in Section 3.7.1 (*i.e.*, refurbish one dewatering bin at a time), approximately three months will be needed to commission all four dewatering bins. Given that the last dewatering bin is expected to be refurbished by late May 2022, it is currently anticipated that all four modified dewatering bins will be commissioned and operational by late June 2022.

3.8.2 COMMISSION CONCRETE ASH-SETTLING TANK

Upon installation of the dewatering bin and ash-settling tank effluent lines, MWG can begin commissioning Powerton's new bottom ash treatment system. This work will include inspecting and testing the new effluent pipelines and concrete ash-settling tank to ensure they are functional, operate as designed, and are reliable. In particular, MWG will verify that the settling tank operates as intended by removing the suspended ash particles remaining in the effluent from the refurbished dewatering bins. During this time, Powerton will need to continue sending CCR and non-CCR wastestreams to the Ash Surge Basin until the new bottom ash treatment system components are commissioned and accepted by MWG. Should issues arise during commissioning, appropriate modifications will be made to ensure the system performance requirements are met.

After the new bottom ash treatment system has been commissioned and MWG has accepted the contractors' work, Powerton may start using the new system for managing the CCR and non-CCR wastestreams currently being sent to the Ash Surge Basin. Given that the dewatering bins will have been commissioned by this time and given the relative simplicity of this new system, commissioning the new concrete ash-settling tank is expected to take three weeks to ensure it has been installed in accordance with the design specifications, operates in accordance with the applicable permits, and is reliable. Thus, it is expected that Powerton will have alternative disposal capacity for the CCR and non-CCR wastestreams currently being sent to the Ash Surge Basin by August 11, 2023.

4.0 PROJECT SCHEDULE: PROGRESS TO DATE

This section presents a narrative of the progress MWG has made in installing a new bottom ash treatment system at Powerton to replace the non-compliant Ash Surge and Bypass Basins. The project commenced in the fall of 2018 with the development of conceptual engineering solutions for the non-compliant ash ponds at MWG's Powerton, Waukegan, and Will County stations. Per the project schedule presented and discussed in Sections 2.0 and 3.0, detailed engineering and design work is set to commence in January 2021.

To date, MWG has completed the following steps to develop the new bottom ash treatment system that will replace the Ash Surge and Bypass Basins at Powerton:

- Took the Bypass Basin out of service for routine cleaning,
- Evaluated several options for obtaining alternative disposal capacity to replace the non-compliant Ash Surge and Bypass Basins,
- Developed a conceptual design for the new bottom ash treatment system to be installed at Powerton,
- Actively participated in Illinois's rulemaking for CCR surface impoundments, and
- Engaged in preliminary discussions with vendors for dewatering bin components and for a fabric enclosure for the new concrete ash-settling tank.

5.0 DEMONSTRATION OF COMPLIANCE

Pursuant to criteria listed in 40 CFR 257.103(f)(1)(iv)(B), the following information demonstrates that Powerton's Ash Surge Basin, Bypass Basin, and the Former Ash Basin are in compliance with the EPA CCR Rule.

5.1 SIGNED CERTIFICATION OF COMPLIANCE

In accordance with 40 CFR 257.103(f)(1)(iv)(B)(*1*), a certification of compliance signed by Powerton's plant manager is included with this demonstration in Appendix C.1.

5.2 VISUAL REPRESENTATION OF SITE HYDROGEOLOGY

In accordance with 40 CFR 257.103(f)(1)(iv)(B)(*2*), the following information is provided in Appendix C.2 to provide a visual representation of hydrogeology at and around the Ash Surge Basin, Bypass Basin, and the Former Ash Basin that supports the design, construction, and installation of the unit's groundwater monitoring system:

- Maps showing the locations of the groundwater monitoring wells,
- Well construction diagrams and drilling logs for the groundwater monitoring wells, and
- Maps characterizing the direction of groundwater flow under the Ash Surge Basin, Bypass Basin, and the Former Ash Basin (including seasonal variations).

5.3 GROUNDWATER MONITORING CONSTITUENT CONCENTRATIONS

In accordance with 40 CFR 257.103(f)(1)(iv)(B)(*3*), a table summarizing the constituent concentrations recorded during each sampling event through the second quarter of 2020 at each groundwater monitoring well around the Ash Surge Basin, Bypass Basin, and the Former Ash Basin is provided in Appendix C.3.

5.4 NARRATIVE OF SITE HYDROGEOLOGY

In accordance with 40 CFR 257.103(f)(1)(iv)(B)(*4*), a narrative description of the Powerton site's hydrogeology and stratigraphic cross sections are provided in Appendix C.2.

5.5 CORRECTIVE MEASURES ASSESSMENTS

To date, Powerton has not had to perform a corrective measures assessment required by 40 CFR 257.96 for the Ash Surge Basin, Bypass Basin, and the Former Ash Basin. Accordingly, no corrective measures assessment is included in this demonstration.

5.6 CORRECTIVE ACTION REMEDY REPORTS

To date, Powerton has not had to perform any corrective action remedies required by 40 CFR 257.97 for the Ash Surge Basin, Bypass Basin, and the Former Ash Basin. Accordingly, no corrective action remedy reports are included in this demonstration.

5.7 STRUCTURAL STABILITY ASSESSMENT

In accordance with 40 CFR 257.103(f)(1)(iv)(B)(*7*), the most recent structural stability assessment demonstrating the Ash Surge and Bypass Basin's' compliance with 40 CFR 257.73(d), dated October 2016, is provided in Appendix C.4-1. Similarly, the most recent structural stability assessment demonstrating the Former Ash Basin's compliance with 40 CFR 257.73(d), dated April 2018, is provided in Appendix C.4-2.

5.8 SAFETY FACTOR ASSESSMENT

In accordance with 40 CFR 257.103(f)(1)(iv)(B)(*8*), the most recent safety factor assessment demonstrating the Ash Surge and Bypass Basin's' compliance with 40 CFR 257.73(e), dated October 2016, is provided in Appendix C.4-1. Similarly, the most recent safety factor assessment demonstrating the Former Ash Basin's compliance with 40 CFR 257.73(e), dated April 2018, is provided in Appendix C.4-2.

6.0 REFERENCES

1. 40 CFR Part 257 Subpart D, "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments."
2. Illinois Public Act 101-0171, "Coal Ash Pollution Prevention," Effective 07/30/2019, http://www.ilga.gov/legislation/publicacts/101/PDF/101-0171.pdf, Accessed 10/28/2020.
3. U.S. Environmental Protection Agency, "Steam Electric Reconsideration Rule," 85 Fed. Reg. 198, pp. 64650–64723, 10/13/2020.
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5. U.S. Court of Appeals, District of Columbia Circuit, *Utility Solid Waste Activities Group et al. v. Environmental Protection Agency*, No. 15-1219, 08/21/2018.
6. Proposed 35 Ill. Adm. Code Part 845, "Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments." Published 03/30/2020.
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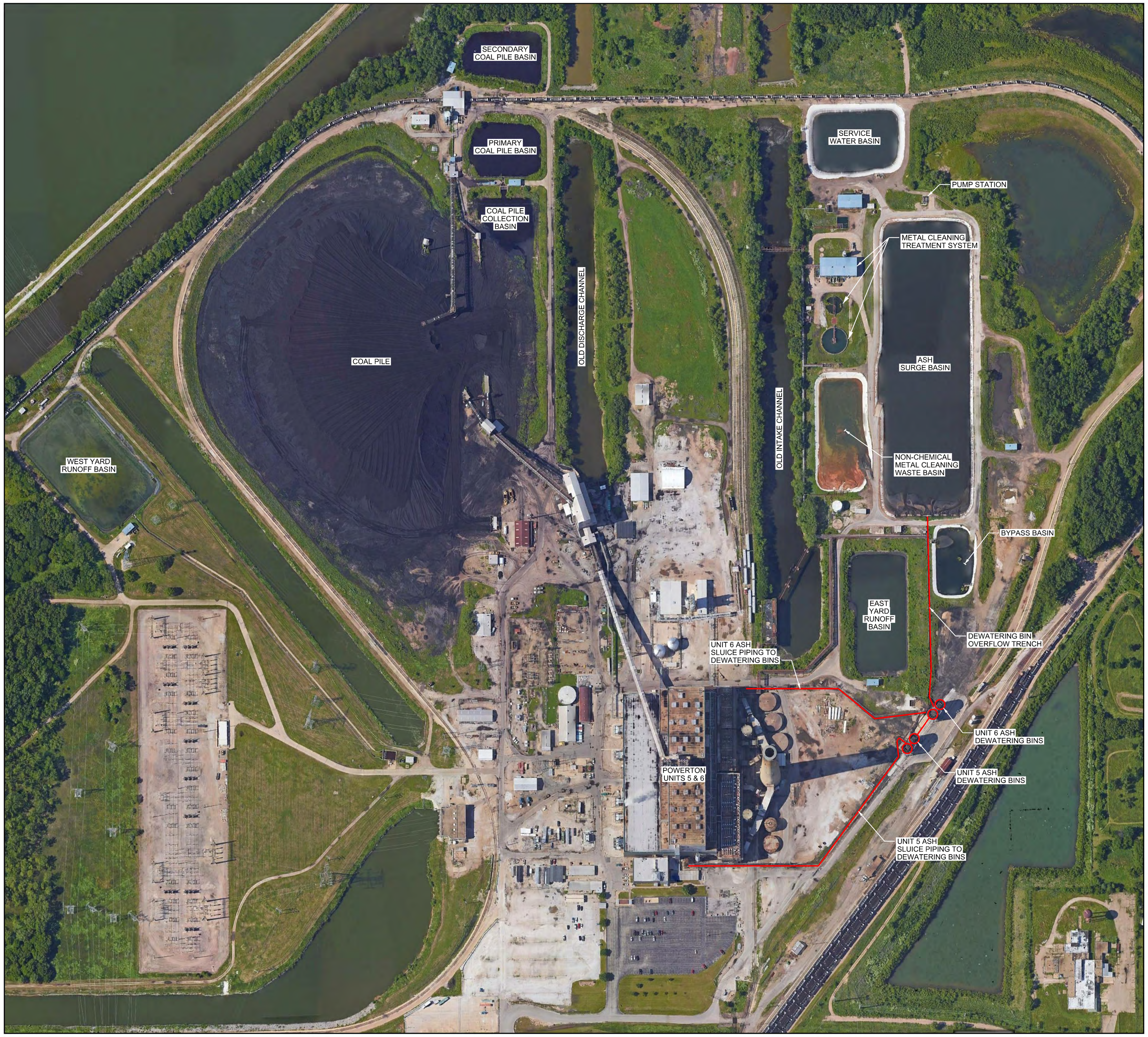
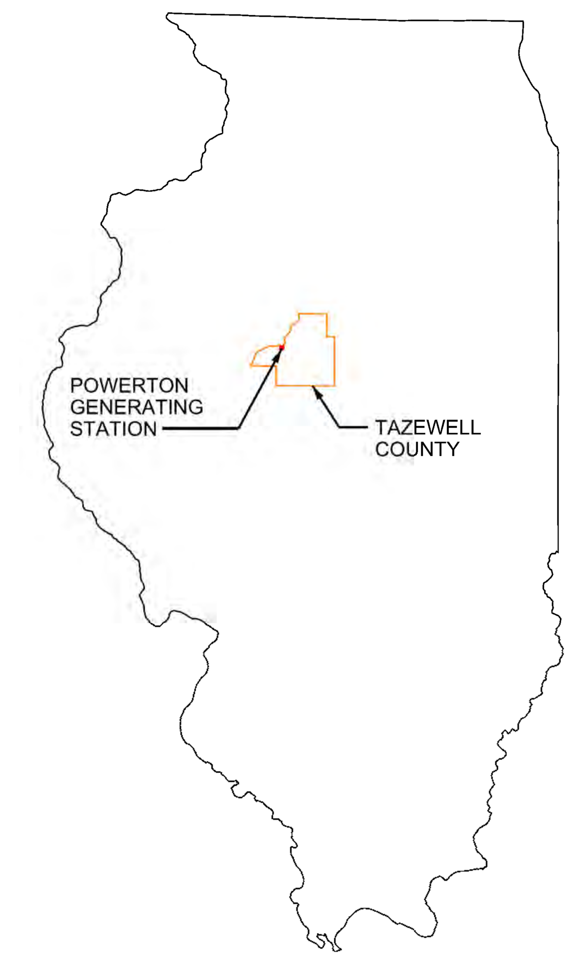
15. Federal Emergency Management Agency, "Flood Insurance Rate Map, Tazewell County, Illinois, Panel 175 of 500," Map No. 17179C0175E, Effective 02/17/2017.
16. Fish and Wildlife Service, "National Wetlands Inventory, Wetlands Mapper," https:// https://www.fws.gov/wetlands/data/Mapper.html, Accessed 10/28/2020.
17. "Illinois EPA's Pre-Filed Answers." Illinois Pollution Control Board Case No. R2020-019. 08/03/2020.
18. "Transcript of August 12, 2020 Hearing." Illinois Pollution Control Board Case No. R20-19. 08/12/2020.

APPENDIX A — CONCEPTUAL DESIGN DRAWINGS

Drawing No.	Drawing Title	Rev.	Date
POW-CSK-001	Site Plan	0	11-25-2020
POW-CSK-200	Concrete Ash-Settling Tank, Plan	0	11-25-2020
POW-CSK-201	Concrete Ash-Settling Tank, Sections and Details	0	11-25-2020





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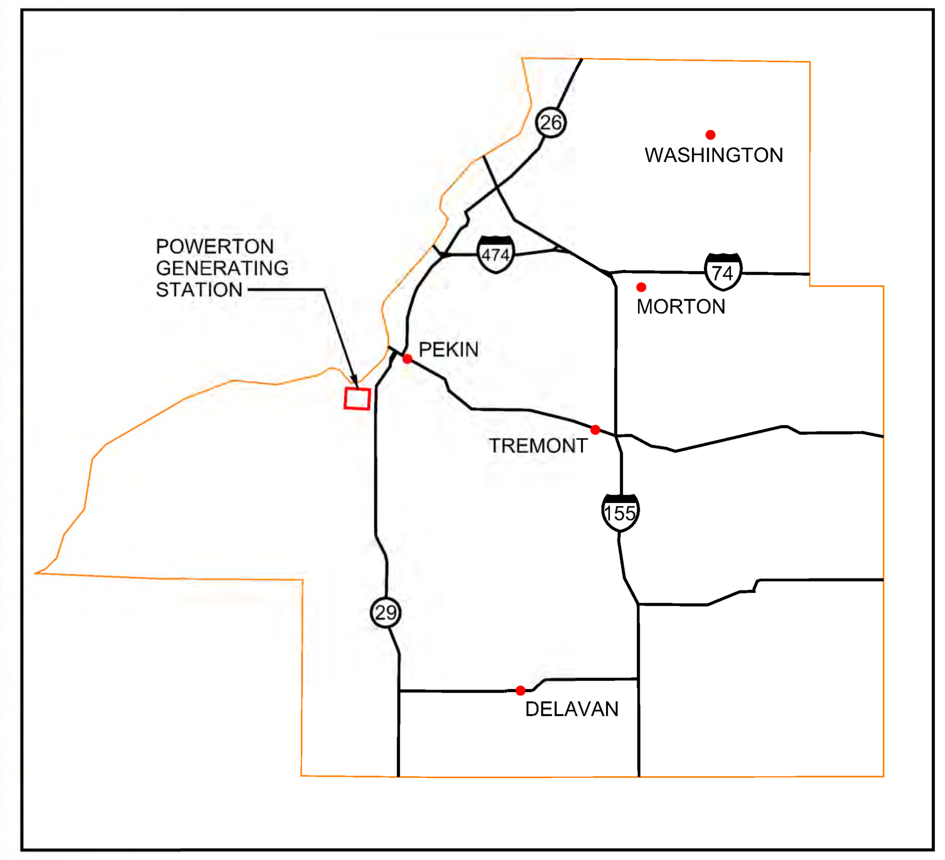
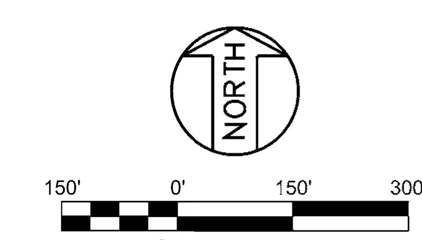


TAZEWELL COUNTY PLAN
SCALE: N.T.S



NOTES

1. AERIAL IMAGE IS FROM GOOGLE EARTH PRO V.7.3 AND IS DATED 09/14/2017.

REFERENCE DRAWINGS

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ISSUE PURPOSE: FOR USE
SPECIFICATION: ---
PROJECT NO.: 12661-097

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REVIEWED BY: T. DEHLIN
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POWERTON
GENERATING STATION
UNITS 5 & 6

DRAWING TITLE

SITE PLAN

DRAWING NUMBER	REVISION
POW-CSK-001	0

SHEET 1 OF 1

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Revision 11A. Revision Date: 04-30-2010

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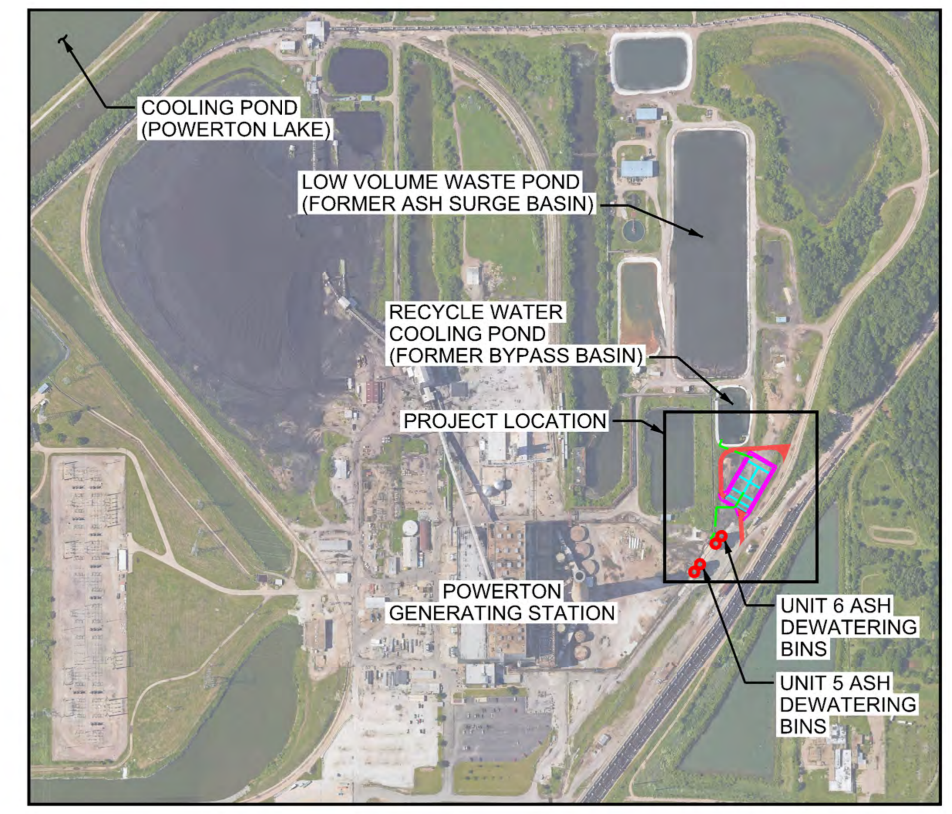

KEY PLAN
SCALE: 1"=500'

NORTH

30' 0' 30' 60'
GRAPHIC SCALE

NOTES

1. AERIAL IMAGE IS FROM GOOGLE EARTH PRO V7.3 AND IS DATED 09/14/2017.
2. FOR SECTIONS AND DETAILS SEE DRAWING POW-CSK-201.
3. ASH REMOVED FROM CONCRETE SETTLING TANK WILL BE TEMPORARILY STORED ON THE CONCRETE DEWATERING SLAB FOR DEWATERING PRIOR TO BEING HAULED OFFSITE FOR FINAL DISPOSAL OR BENEFICIAL USE.
4. BYPASS BASIN WILL BE CLEAN CLOSED AND REPURPOSED FOR COOLING AND TEMPORARY STORAGE OF RETURN WATER.

REFERENCE DRAWINGS

POW-CSK-001	SITE PLAN
POW-CSK-201	CONCRETE ASH-SETTLING TANK SECTIONS AND DETAILS.

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DRAWING TITLE
CONCRETE ASH-SETTLING TANK
PLAN

DRAWING NUMBER	REVISION
POW-CSK-200	0

SHEET 1 OF 1

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Revision 11A, Revision Date: 04-30-2010

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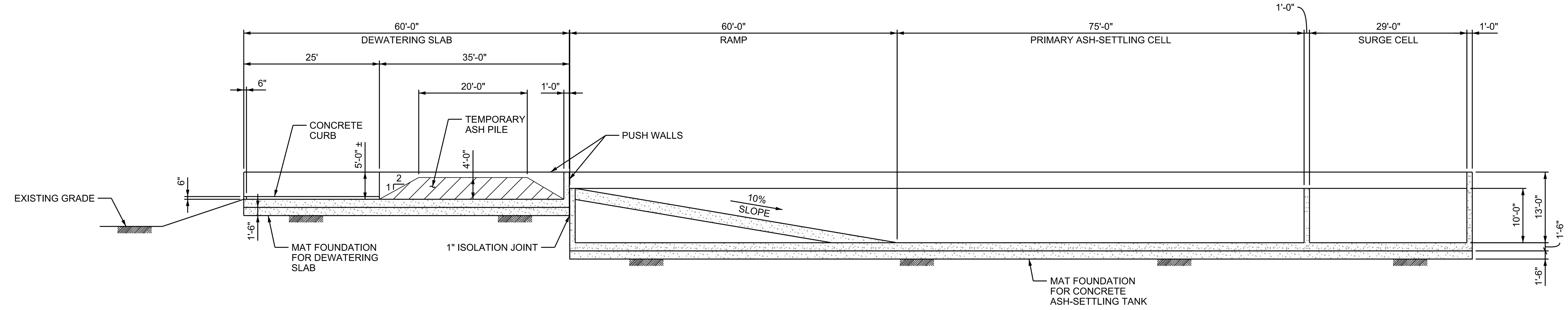

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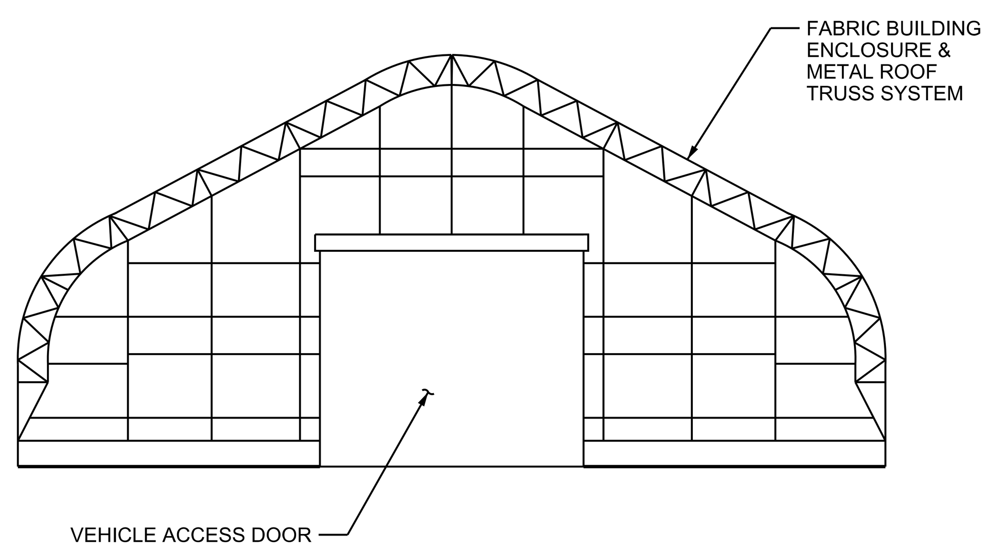

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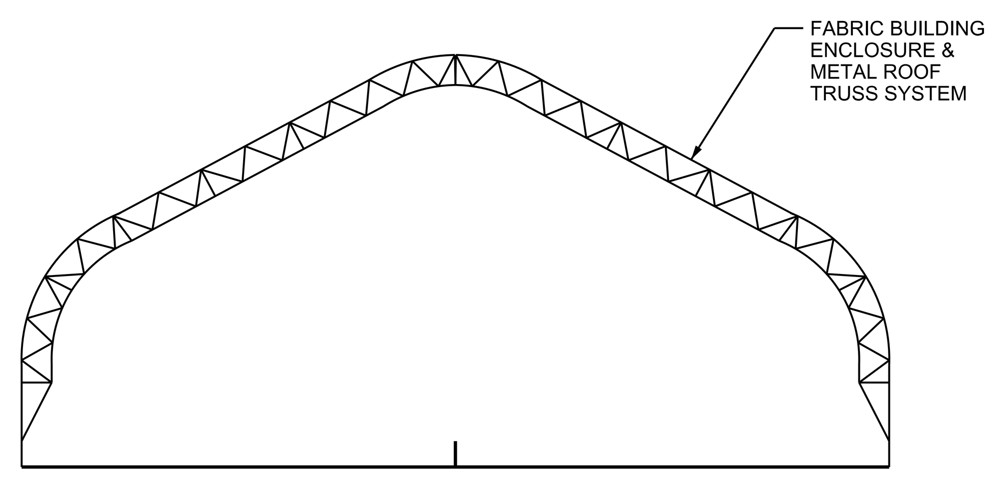

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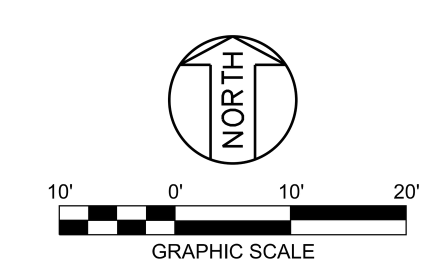

PRELIMINARY
NOT FOR CONSTRUCTION

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1.	FOR PLAN SEE DRAWING POW-CSK-200.

REFERENCE DRAWINGS	
POW-CSK-001	SITE PLAN
POW-CSK-200	CONCRETE ASH-SETTLING TANK PLAN

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DRAWING TITLE

CONCRETE ASH-SETTLING TANK
SECTIONS AND DETAILS

DRAWING NUMBER	REVISION
POW-CSK-201	0
SHEET 1 OF 1	

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Revision 11A, Revision Date: 04-30-2010

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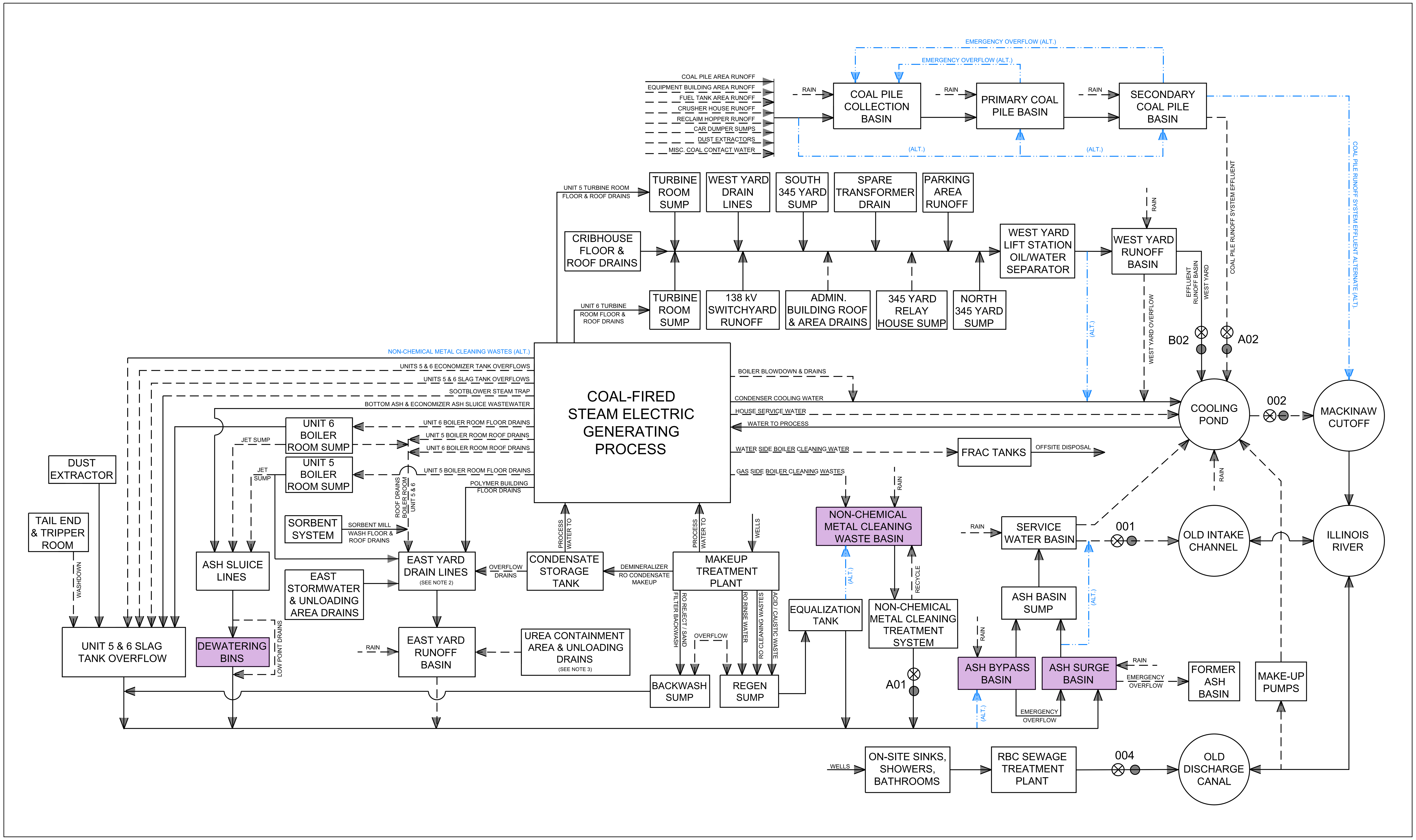
APPENDIX B — PROCESS FLOW DIAGRAMS

Drawing No.	Drawing Title	Rev.	Date
POW-CSK-PFD-001	Existing Water Block Flow Diagram	0	11-25-2020
POW-CSK-PFD-002	Proposed Interim Water Block Flow Diagram for EPA CCR Rule Compliance	0	11-25-2020
POW-CSK-PFD-003	Proposed Final Water Block Flow Diagram for EPA CCR Rule Compliance	0	11-25-2020



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55 EAST MONROE STREET
CHICAGO, ILLINOIS 60603-5780

MWG

LEGEND

(solid line)	TYPICAL
(dashed line)	INTERMITTENT
(dash-dot line)	ALTERNATE
●	OUTFALL NUMBER
⊗	SAMPLING POINT
(shaded box)	CCR TREATMENT/STORAGE FACILITY

NOTES

1. THIS DRAWING WAS DEVELOPED USING MIDWEST GENERATION, LLC DRAWING "GENERAL FLOW DIAGRAM WITH NPDES OUTFALLS, NPDES PERMIT NO. IL0002232," PREPARED BY APTIM ENVIRONMENTAL & INFRASTRUCTURE, LLC (DATED NOVEMBER 2019) AND USED WITH PERMISSION FROM MIDWEST GENERATION, LLC. SARGENT & LUNDY HAS NOT INDEPENDENTLY VERIFIED THE INFORMATION SHOWN ON THIS DRAWING.
2. "EAST YARD DRAIN LINES" INCLUDES FAN BAY DRAINS, DRAINS ON EAST HALF OF PROPERTY.
3. VALVE IS LOCATED ON SUMP FROM UREA CONTAINMENT AREA & UNLOADING DRAINS TO THE EAST YARD RUNOFF BASIN.
4. OUTFALL 006, TREATED ASBESTOS CONTAMINATED STORMWATER, IS NOT INCLUDED IN THIS DIAGRAM AND IS BEING PROPOSED FOR REMOVAL DUE TO THERE NO LONGER BEING DEMOLITION DEBRIS.

PROJECT

MIDWEST GENERATION, LLC
POWERTON
GENERATING STATION
UNITS 5 & 6

DRAWING TITLE

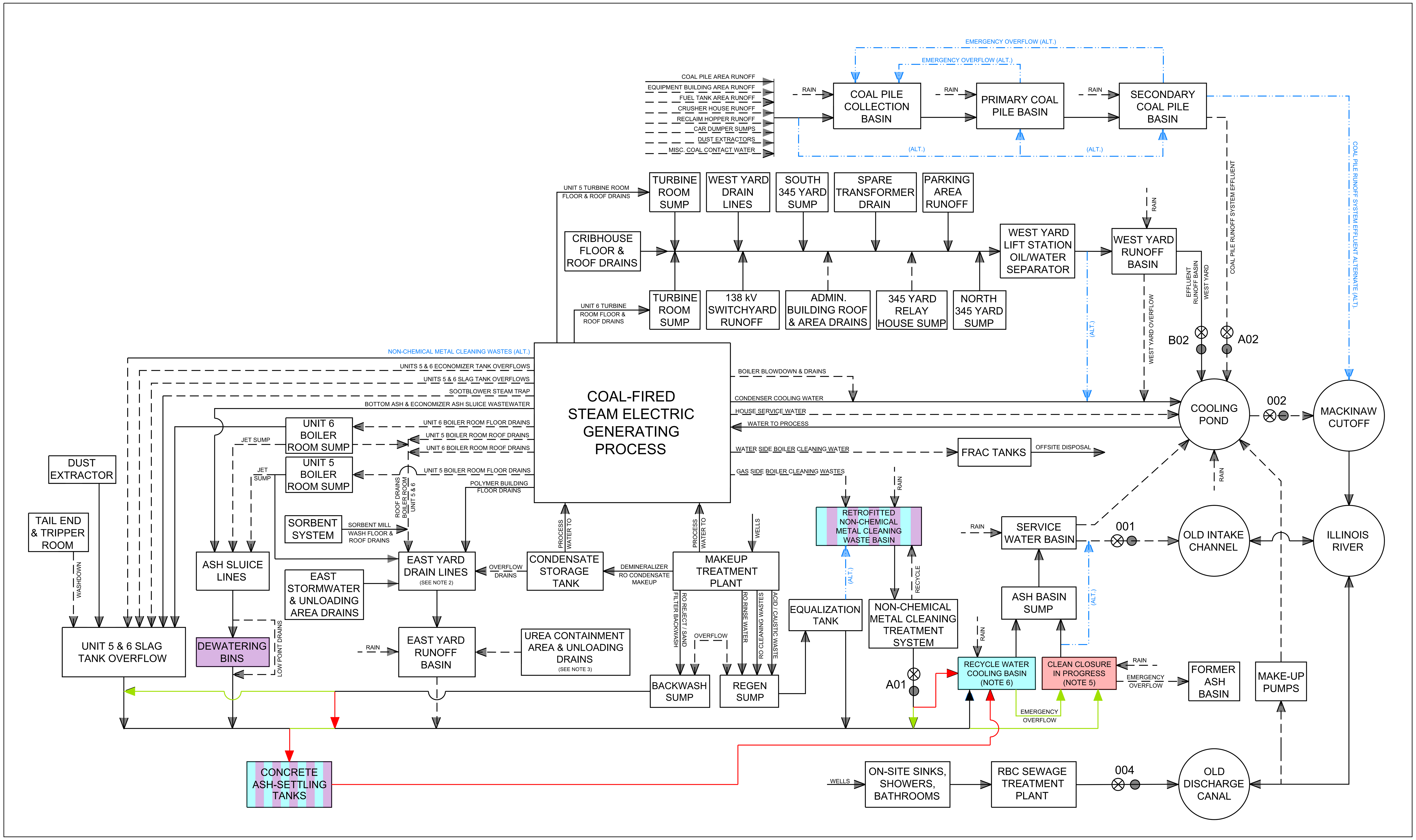
EXISTING WATER BLOCK FLOW DIAGRAM

DRAWING NUMBER	REVISION
POW-CSK-PFD-001	0

SHEET 1 OF 1

PD11153/OM1864/S:*CivilDesign*2-Powerton - CCR*Drawings*POW-CSK-PFD-001.dgn
Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 11A, Revision Date: 04-30-2010

11/24/2020 3:15:33 PM
...*Drawings*POW-CSK-PFD-001.dgn



LEGEND

- TYPICAL
- INTERMITTENT
- ALTERNATE
- NEW LINE
- ABANDONED LINE
- OUTFALL NUMBER
- SAMPLING POINT
- CCR TREATMENT/STORAGE FACILITY
- REPURPOSED / NEW EQUIPMENT

NOTES

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2. "EAST YARD DRAIN LINES" INCLUDES FAN BAY DRAINS, DRAINS ON EAST HALF OF PROPERTY.
3. VALVE IS LOCATED ON SUMP FROM UREA CONTAINMENT AREA & UNLOADING DRAINS TO THE EAST YARD RUNOFF BASIN.
4. OUTFALL 006, TREATED ASBESTOS CONTAMINATED STORMWATER, IS NOT INCLUDED IN THIS DIAGRAM AND IS BEING PROPOSED FOR REMOVAL DUE TO THERE NO LONGER BEING DEMOLITION DEBRIS.
5. ALL FLOWS TO ASH SURGE BASIN WILL BE TEMPORARILY DIVERTED TO RECYCLE WATER COOLING BASIN DURING CLEAN CLOSURE.
6. RECYCLE WATER COOLING BASIN WILL REPLACE THE EXISTING BYPASS BASIN BY CLEAN CLOSING THE EXISTING POND PER THE ILLINOIS EPA CCR RULE AND THEN LINING THE AREA FOR TEMPORARY STORAGE OF ASH TRANSPORT WATER.

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	11-25-2020	FOR USE

ISSUE PURPOSE: FOR USE
SPECIFICATION: ---
PROJECT NO.: 12661-097

CAD FILE NAME: POW-CSK-PFD-002.DGN
PREPARED BY: J. CHAVEZ
REVIEWED BY: T. DEHLIN
APPROVED BY: T. DEHLIN

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Sargent & Lundy LLC
SARGENT & LUNDY LLC
55 EAST MONROE STREET
CHICAGO, ILLINOIS 60603-5780

MWG

PROJECT

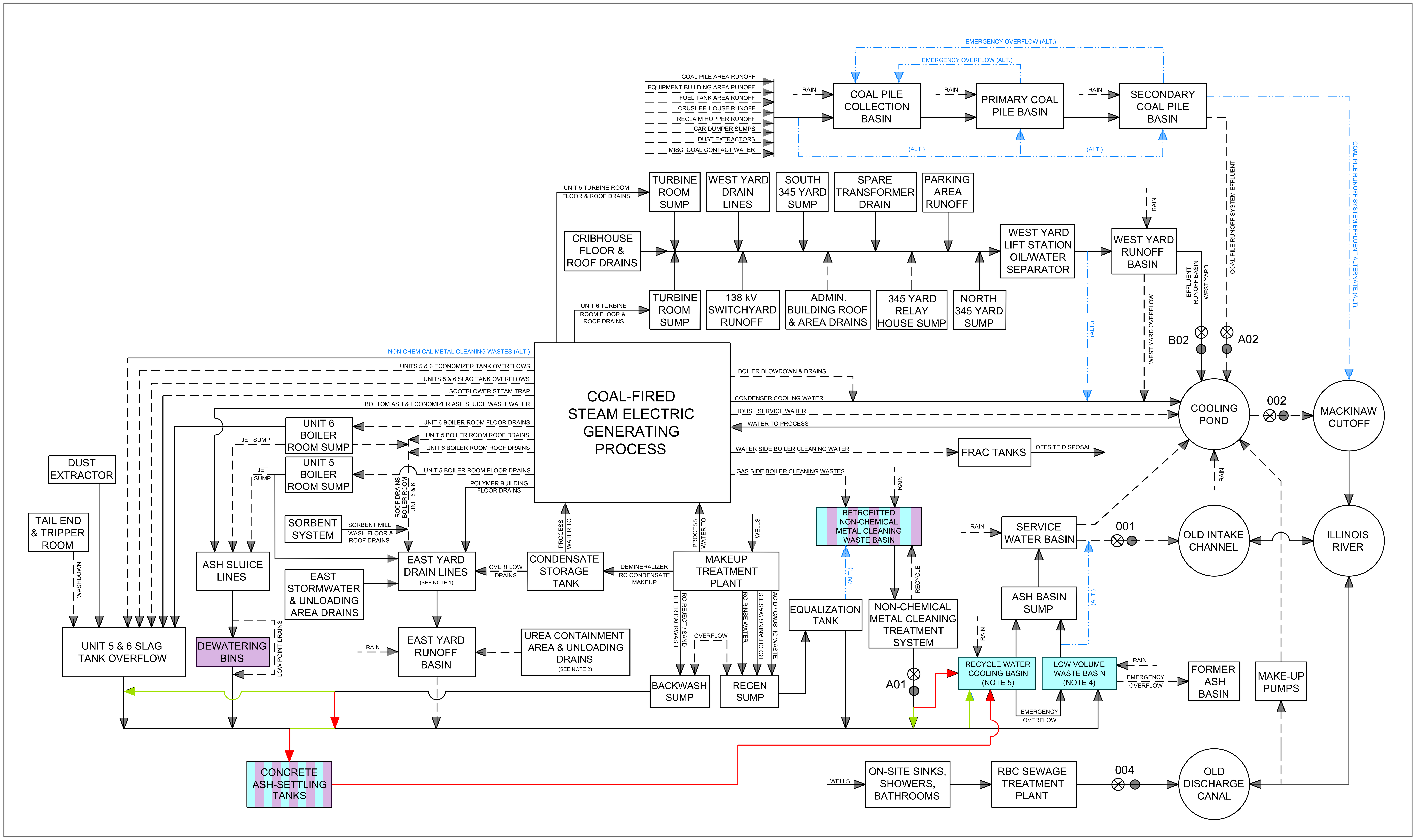
MIDWEST GENERATION, LLC
POWERTON
GENERATING STATION
UNITS 5 & 6

DRAWING TITLE

PROPOSED INTERIM WATER BLOCK FLOW DIAGRAM FOR EPA CCR RULE COMPLIANCE

DRAWING NUMBER	REVISION
POW-CSK-PFD-002	0

SHEET 1 OF 1



LEGEND

———	TYPICAL
– – –	INTERMITTENT
–·–·–	ALTERNATE
——— (red)	NEW LINE
——— (green)	ABANDONED LINE
●	OUTFALL NUMBER
⊗	SAMPLING POINT
(purple)	CCR TREATMENT/STORAGE FACILITY
(cyan)	REPURPOSED / NEW EQUIPMENT

NOTES

1. THIS DRAWING WAS DEVELOPED USING MIDWEST GENERATION, LLC DRAWING "GENERAL FLOW DIAGRAM WITH NPDES OUTFALLS, NPDES PERMIT NO. IL0002232," PREPARED BY APTIM ENVIRONMENTAL & INFRASTRUCTURE, LLC (DATED NOVEMBER 2019) AND USED WITH PERMISSION FROM MIDWEST GENERATION, LLC. SARGENT & LUNDY HAS NOT INDEPENDENTLY VERIFIED THE INFORMATION SHOWN ON THIS DRAWING.
2. EAST YARD DRAIN LINES" INCLUDES FAN BAY DRAINS, DRAINS ON EAST HALF OF PROPERTY.
3. VALVE IS LOCATED ON SUMP FROM UREA CONTAINMENT AREA & UNLOADING DRAINS TO THE EAST YARD RUNOFF BASIN.
4. OUTFALL 006, TREATED ASBESTOS CONTAMINATED STORMWATER, IS NOT INCLUDED IN THIS DIAGRAM AND IS BEING PROPOSED FOR REMOVAL DUE TO THERE NO LONGER BEING DEMOLITION DEBRIS.
5. LOW VOLUME WASTE BASIN WILL REPLACE THE EXISTING ASH SURGE BASIN BY CLEAN CLOSING THE EXISTING POND PER THE ILLINOIS EPA CCR RULE AND THE ILLINOIS EPA AREA FOR FUTURE LOW VOLUME WASTE DISPOSAL. LINER WILL BE GEOMEMBRANE OR SIMILAR MATERIAL.
6. RECYCLE WATER COOLING BASIN WILL REPLACE THE EXISTING BYPASS BASIN BY CLEAN CLOSING THE EXISTING POND PER THE ILLINOIS EPA CCR RULE AND THE ILLINOIS EPA AREA FOR TEMPORARY STORAGE OF ASH TRANSPORT WATER.

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING OF CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	11-25-2020	FOR USE

ISSUE PURPOSE: FOR USE
SPECIFICATION: ---
PROJECT NO.: 12661-097

CAD FILE NAME: POW-CSK-PFD-003.DGN
PREPARED BY: J. CHAVEZ
REVIEWED BY: T. DEHLIN
APPROVED BY: T. DEHLIN

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Sargent & Lundy LLC
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MWG

PROJECT

MIDWEST GENERATION, LLC
POWERTON
GENERATING STATION
UNITS 5 & 6

DRAWING TITLE

PROPOSED FINAL WATER BLOCK FLOW DIAGRAM FOR EPA CCR RULE COMPLIANCE

DRAWING NUMBER	REVISION
POW-CSK-PFD-003	0

SHEET 1 OF 1

APPENDIX C — COMPLIANCE DOCUMENTATION

Appendix No.	Document Title
C.1	Certification of Compliance
C.2	Geology/Hydrogeology
C.3	Analytical Data Tables Thru 2nd Quarter 2020
C.4	Structural Stability & Safety Factor Assessments

EXHIBIT 19

K P R G

ENVIRONMENTAL CONSULTATION & REMEDIATION

KPRG and Associates, Inc.

MEMORANDUM

FROM: Joshua D. Davenport, P.E., KPRG and Associates, Inc.

DATE: November 19, 2020

SUBJECT: Evaluation of Sediment Quantities in Joliet Generating Station's Pond 1 and Pond 3 and Powerton Generating Station's Service Water Basin

Pond 1 and Pond 3 at the Joliet 29 Generating Station and the Service Water Basin at the Powerton Generating Station were evaluated the contents and approximate volume of the contents in the ponds.

SECTION 1-INTRODUCTION

Joliet 29 – Pond 1 and Pond 3

The Joliet 29 Generating Station previously burned coal to generate steam to produce electricity. The Joliet 29 station ceased burning coal on March 18, 2016 and began burning natural gas on May 31, 2016.

All of the coal combustion residual ("CCR") material in Pond 1 was cleaned out in the summer of 2015. The CCR material was removed all the way down to the warning layer of the pond, the liner was power-washed, and any damage to the liner was repaired. After it was cleaned out, Pond 1 did not receive any bottom ash sluice water. Rather, the pond only receives service water/low volume wastewater from the RO sand filter backwash, the west area basin, the former coal pile runoff pump discharge, and the plant drains, including the Station floor drains, and roof drains and area drains. (See Joliet 29 Flow Diagram, Ex. 1). None of these processes produce nor discharge coal ash. Pond 3 is a finishing pond for the process water from Ponds 1 and 2. (Ex. 1). Pond 3 also receives water from the wastewater treatment plant. *Id.* Finally, both ponds receive rainwater from the area surrounding the ponds.

All of the water flow processes and stormwater flow contain sand sized and smaller sized particles. The RO sand filter backwash contains the suspended solids removed by the stations water treatment system, which would be sand, silt, and some clay sized because the treatment system is filtering water removed from the ground by the station's water well so it can be used as process water. The RO sand filter backwash has been described as visually 'dirty' by the Station's personnel, which is expected because the backwash is intended to regenerate the sand filters by removing the solids that accumulate as part of the filtration process. The Station floor drains, roof drains, and area drains, are likely to contain small particles and silt from operations and runoff during storm events. Similarly, the runoff pumped from the coal pile area retention pond contains sand, silt and clay sized particles into Pond 1. These particles would come from the surrounding area through stormwater runoff that drains into the coal pile area retention pond. The areas on the north and east sides of Pond 1 and west, east, and north sides of Pond 3 are slightly elevated and there is a gravel road near the ponds and adjacent soil. Stormwater runoff from the gravel road and soil likely contains sand, silt, and clay sized particles that flow into both ponds. Moreover, the discharge from the wastewater treatment plant drains directly into Pond 3. Based upon sampling directly before discharge into Pond 3, the wastewater treatment plant is also a contributor of solids into Pond 3.

Powerton – Service Water Basin

The Powerton Generating Station burns coal to generate steam to produce electricity. The Service Water Basin (SW Basin) is the end of the wastewater treatment system. The Service Water Basin receives water from the ash surge basin, the ash bypass basin, and rainwater from the property. The CCR material produced by the Powerton coal burning process is the same as what was produced by the Joliet 9 coal burning process because both stations use the same coal and the same coal burning process. Therefore, the CCR material from Joliet 9 was used as the comparison material against the Service Water Basin material.

SECTION 2-EVALUATION PROCESS

The evaluation of each surface impoundment was performed based on the following steps.

The current elevation of the bottom of the surface impoundment was determined with a bathymetric survey. During the bathymetric surveys, samples were collected from the material in each surface impoundment.

The bathymetric surveys were performed by Ruettiger, Tonelli & Associates, Inc (RT&A). RT&A is an Illinois licensed surveying company. The Joliet 29 Pond 1 survey was performed on July 6, 2020, the Pond 3 survey was performed on August 17, 2020, and the SW Basin survey was performed on July 14, 2020. The surveys were performed by navigating each surface impoundment using a boat and electronic depth finder to determine the depth from the water to the bottom of the surface impoundment at the time of the survey. The water elevation in feet above mean sea level at the time of the survey was determined using the appropriate state plane horizontal and vertical data.

The bathymetric surveys were performed using an electronic depth finder instead of a physical survey rod. The physical survey rod was attempted to determine the depth from the water surface to the material in Pond 1, Pond 3, and the SW Basin. However, because the material in the pond lacked sufficient density to create a solid enough surface to place the survey rod and determine an accurate depth, the survey rod was not reliable.

The results of the bathymetric survey was compared to the known existing conditions of the surface impoundment to determine if material had accumulated to a measurable quantity above the known base of the surface impoundment. If a measurable quantity was present, the quantity was calculated.

Samples of the sediment were analyzed for grain size, weight-to-volume relationship of the sediment, and ASTM 2974. The analyses results were used to refine the quantity of the material identified in the surface impoundment.

SECTION 3- SURFACE IMPOUNDMENT EVALUATIONS

JOLIET POND 1

Calculation of the Volume of Material in Pond 1

The bathymetric survey of Pond 1 showed that the water surface elevation was at 532.0 feet above mean sea level (ft amsl) and showed an average depth of material present was 1.5 feet. Based upon the average depth and the contours of Pond 1 from the survey conducted when the pond was relined, the total quantity of material at the base was calculated to be approximately 5,124 cubic yards (CY). The comparison was performed using AutoCAD Civil 3D 2020 to calculate the volume that is occupied between the surface of the survey and the surface of the existing pond conditions.

The material sampled in Pond 1 was black in color, was sticky/pasty in consistency and had a silty/clayey feeling when rubbed between your fingers. Some of the material identified was white in color and was 1/8-inch to ¼-inch in size. It should be noted that the warning layer in Pond 1 consists of limestone screenings. Limestone screenings are typically white in color and consist of material sizes that range from 1/8-inch to ¼-inch in size. The material also had a sewer odor.

The weight-to-volume relationship analysis showed that the material in Pond 1 was fourteen percent (14%) solids and eighty-six percent (86%) water. (See weight-to-volume ratio analysis attached as Exhibit 2). The ASTM 2974 test showed that about thirty-two percent (32%) of the solids in Pond 1 are organic matter and about 68% of the solids are non-organic matter. (See ASTM 2974 results, attached as Exhibit 3). Accordingly, of the volume of the 5,124 CY material in Pond 1, 717 CY is solids (14% of 5,124 CY), and only 489 CY is non-organic matter (68% of 717 CY). The weight-to-volume relationship analysis showed that the density of the material in the pond (not including the water) is 20.6 lbs/cubic feet. (Ex. 2). Based upon that, the tonnage of solid non-organic material in Pond 1 is approximately 136 tons. (*See* Table 1 attached as Ex. 4).

With open topped ponds, about two tons per acre per year (2 tons/acre/year) of matter will accumulate in the bottom of a pond from air dispersion.[1] Pond 1 was last cleaned out during

[1] The 2 t/ac/yr is actually the calculation used to offset potential soil erosion calculated for maintenance of landfill covers. The lost soil is replaced by natural processes at a rate that is the same or greater than the tolerance level (2/t/ac/yr).

the summer of 2015 and the bathymetric survey that determined the volume of material in the pond was performed on July 6, 2020. The amount of time that has passed between these two dates is 1,771.25 days or 4.9 years. The surface area of the pond is approximately 133,372 square feet (3.06 acres) based on the surface area at the top of the pond slope. Based on the above amount of time and above surface area the matter that has accumulated in Pond 1 from air is about 29.7 tons. (Ex. 4).

Grain Size Comparison of the Material In Pond 1

A comparison of the grain size analysis of the material in Pond 1 compared to the grain size of the Joliet 29 CCR shows that the sediments are not the same. (Ex. 4). The analysis shows that the Joliet 29 CCR is described as brown to dark brown silty sand with gravel, whereas the Pond 1 material was black sandy silt. Moreover, the grain size analysis of the material in Pond 1 shows that the material consists primarily of fine sand and silt/clay fines. In comparison, the Joliet 29 CCR is primarily fine gravel and sand. In particular, the Joliet 29 CCR material contains 19% gravel and about 40% course and medium sand, totaling approximately 60% gravel and course to medium sand. In comparison, the material in Pond 1 was approximately 24.9% fine sand and 67.2% fines. In other words, the material in Pond 1 is 92.2% fine sand and fines, and only 7.8% is gravel, and course to medium sand. The difference in the description of the material and in the coarse and medium sand sized particles between the Joliet 29 CCR and the Pond 1 material indicates that the composition of the material in Pond 1 is not CCR material.

JOLIET POND 3

Calculation of the Volume of Material in Pond 3

The bathymetric survey of Pond 3 showed that the water surface elevation was at 526.1 feet above mean sea level (ft amsl), the average depth of material present was 2.4 feet, and the total quantity of material was calculated to be approximately 7,392 cubic yards (CY). The comparison was performed using AutoCAD Civil 3D 2020 to calculate the volume that is occupied between the surface of the survey and the surface of the existing pond conditions.

The material sampled in Pond 3 was black in color, was sticky/pasty in consistency and had a silty/clayey feeling when rubbed between your fingers. The material stuck to the gloves of the sampler during the sampling process. The material also had a sewer odor.

The weight-to-volume relationship analysis showed that the material in Pond 3 was eight percent (8%) solids and ninety-two percent (92%) water. (Ex. 2) Based on the ASTM 2974 test results, about twenty-eight (28%) percent of the solids in Pond 3 are organic matter and about seventy-two percent (72%) of the solids are non-organic matter. (Ex. 3). Accordingly, of the volume of the 7,392 CY material in Pond 3, 591 CY is solids (8% of 7,392 CY), and 423 CY is non-organic matter (72% of 591 CY). The weight-to-volume relationship analysis showed that the density of the material in the pond (not including the water) is 12.1 lbs/cubic feet. (Ex. 2). Based upon that, the tonnage of solid non-organic material in Pond 3 is approximately 69 tons. (Ex. 4).

Using the same calculation to estimate the air dispersion of solids into Pond 3, approximately 29.4 tons of material accumulated in Pond 3 from air dispersion. (Ex. 4).

<u>Grain Size Comparison of the Material in Pond 3</u>

Similar to Pond 1, a comparison of the grain size analysis of the material in Pond 3 compared to the grain size of the Joliet 29 CCR shows that the sediments are not the same. (Ex. 4). The material in Pond 3 was identified as a black organic silty sand, dissimilar from the Joliet 29 CCR, which is brown silty sand with gravel. In addition, the grain size analysis shows that the material in Pond 3 is unlike the Joliet 29 CCR. The material in Pond 3 consists of approximately 73.4% fine sand and fines, and only 26.6% is of coarser material. The Joliet 29 CCR is the opposite.

Prior to the inlet of Pond 3, a coagulant chemical, alum, is added as a flocculant to remove the suspended solids from the Pond 3 influent water. The alum neutralizes the negative charge of the non-settleable solids, such as clay, which allows the neutralized particles to stick together. As the particles stick together, they form larger particles, and this continues until large enough particles form that settle from the water. The addition of alum and the flocculation particles explains the presence and the nature of the material in Pond 3 and why it lacks the density to create a surface against which a survey rod could be placed on. Even with the alum, the density of the particles are not enough to settle completely to the bottom of Pond 3, but are heavy enough to settle and not be passed through the discharge structure. The weight-to-volume relationship of the material also explains this by the fact that the material was identified as only eight percent solids compared to 92% water. It should be noted that the characteristics of the material in Pond 3 are similar to that of suspended solids contained in a wastewater treatment plant.

The nature of the settling of the material in Pond 3 also indicates that the material is not CCR. The material in Pond 3 settles farther away from the inlet when compared to the CCR material in Pond 1 and Pond 2, which settles at the inlet of the pond, which is expected because of the medium sand to gravel particle size. When CCR material was placed in Pond 2 prior to it being cleaned out in 2019, the CCR depth at the inlet extended from the bottom of the pond to about 10 feet in height and lesser heights closer to the pond outlet. The depth of the material in Pond 3 is only 1 feet at the inlet and the depth of the material is about 3 feet on the east side of the pond.

SERVICE WATER BASIN

<u>Calculation of the Volume of Material in the Service Water Basin</u>

The bathymetric survey of the Service Water Basin ("SW Basin") showed that a measurable quantity of material was marginally present or not present. Reviewing the as-built drawings of the basin from when it was re-lined in 2013, the bottom elevation is ±441 ft amsl. The bottom elevations from the bathymetric survey average ±440.80 ft amsl. Based on comparing the bottom elevation from the as-built drawings and the bottom elevations from the bathymetric survey, minimal material is present or not present to a point, which causes minimal change in the bottom elevation determined during the survey. AutoCAD Civil 3D 2020 was also used to compare the as-built drawings with the survey performed by RT&A. The AutoCAD Civil 3D 2020 comparison was performed with the bottom elevations of the survey and the bottom elevations of the as-built drawings considered equal. This comparison determined a volume of about 52 CY.

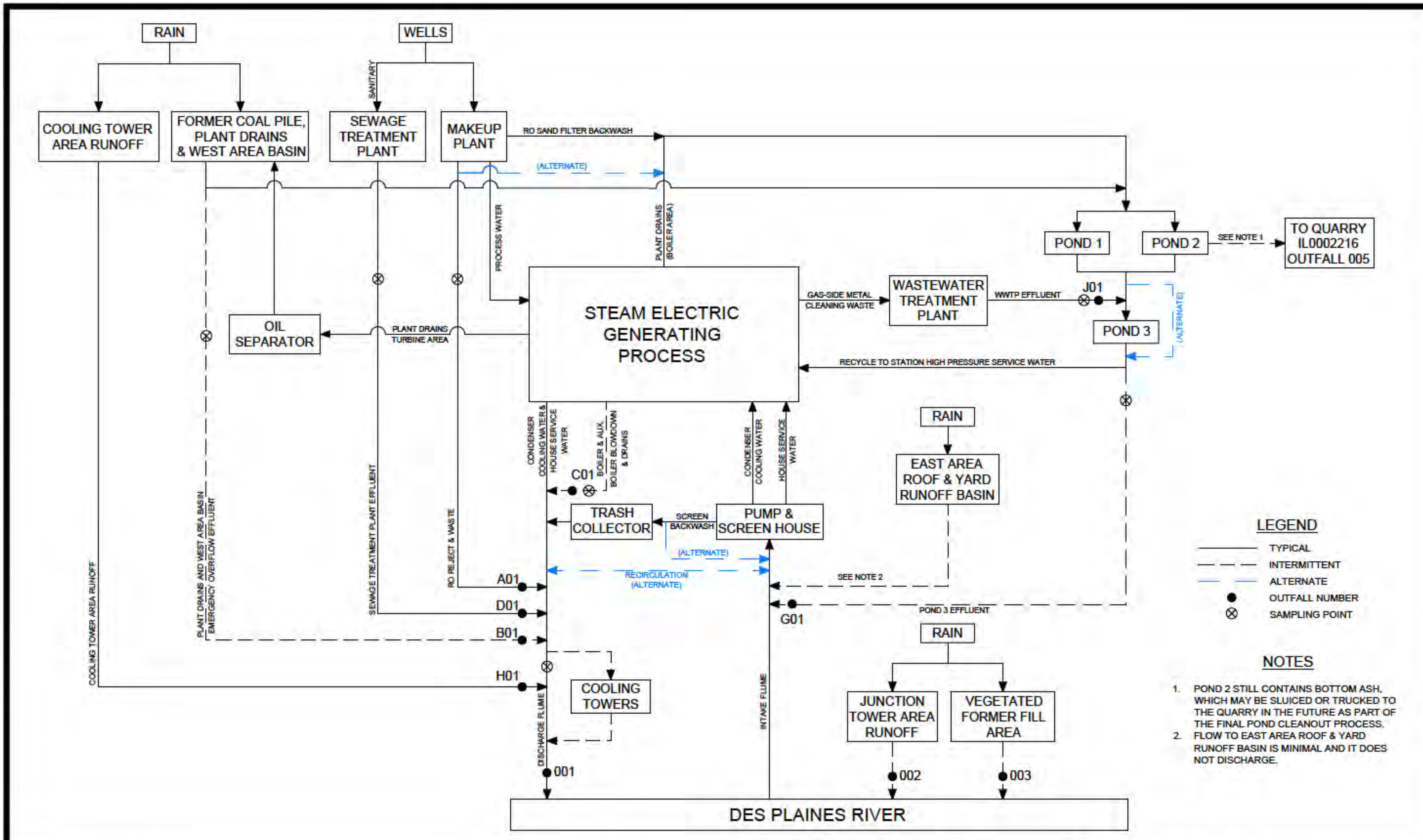
The weight-to-volume relationship analysis showed that the material in the SW Basin was 52% solids. (Ex. 5) Based on the ASTM 2974 test results, about 8.2% of the solids in the SW Basin are organic matter and about 91.8% are non-organic matter. (Ex. 3). Accordingly, of the volume of the 52 CY material, 27 CY is solids and 24.8 CY is non-organic matter. The weigh-to-volume relationship analysis showed that the density of the material in the pond (not including the water) is 85.8 lbs/cubic feet. (Ex. 2). Based upon that, the tonnage of solid non-organic material in SW Basin is approximately 28.7 tons. (*See* Table 3 attached as Ex. 4).

With open topped ponds, about two tons per acre per year (2 tons/acre/year) of matter will accumulate in the bottom of a pond from air dispersion.[2] The SW Basin was last cleaned out during the spring of 2013 and the bathymetric survey that determined the volume of material in the pond was performed on July 14, 2020. The amount of time that has passed between these two dates is 2,257.25 days or 6.2 years. The surface area of the pond is approximately 87,791 square feet (2.02 acres) based on the surface area at the top of the pond slope. Based on the above amount of time and above surface area the matter that has accumulated in SW Basin from air is about 24.9 tons. (Ex. 4, Table 3).

<u>Grain Size Comparison of the Material in SW Basin</u>

Enough material could be collected from the SW Basin to submit a sample for analysis. The sample was analyzed for the grain size, weight–to-volume relationship of the material, and ASTM 2974. The material in the SW Basin was identified as a black/gray silty sand whereas the Joliet 9 CCR was classified as brown sand. The grain size analysis shows that the material in the SW Basin consists of approximately 46.5% fine sand and fines. (Ex. 4, Table 3). By comparison, the grain size of the Joliet 9 CCR consists of approximately 16.9% fine sand and fines and the remainder consists of gravel and coarse to medium sand (approximately 83.1%).

[2] The 2 t/ac/yr is actually the calculation used to offset potential soil erosion calculated for maintenance of landfill covers. The lost soil is replaced by natural processes at a rate that is the same or greater than the tolerance level (2/t/ac/yr).



APTIM Environmental & Infrastructure, Inc.

APTIM

MIDWEST GENERATION, LLC
JOLIET 29 GENERATING STATION

GENERAL FLOW DIAGRAM WITH NPDES OUTFALLS
NPDES PERMIT NO. IL0064254

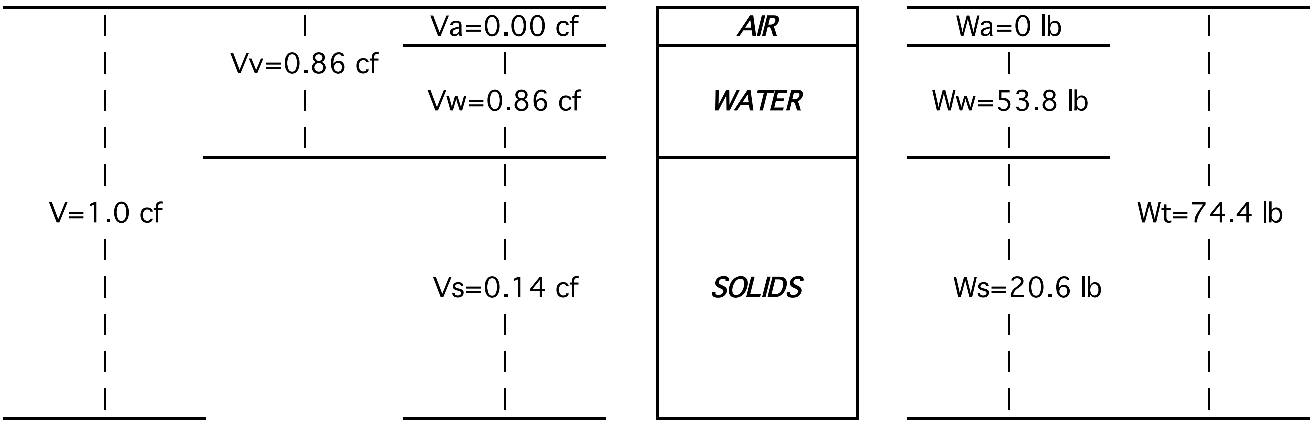
DRAWN BY: ORC	APPROVED BY: SZF	PROJ. NO.: 631237225	DATE: APRIL 2019

T:\AutoCAD\Projects\NRG\Joliet NPDES\Joliet 29 Flow Diagram - Revised.dwg, 4/22/2019 8:30:52 AM, _AutoCAD PDF (General Documentation).pc3

Ex. 1

WEIGHT VOLUME RELATIONSHIPS OF SOIL

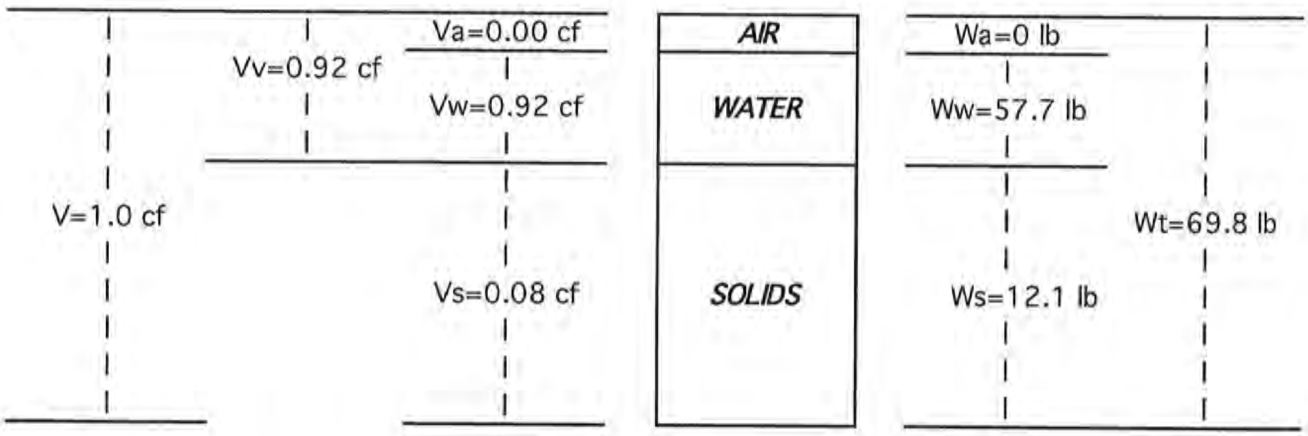
PROJECT NAME:	Pond 3 Sediments	**PROJECT NO:**	20543
SAMPLE LOCATION:	Pond 1 Sample 1	**DATE:**	10/23/20
SOIL CLASSIFICATION:	Black Sandy SILT	**CLIENT:**	KPRG Wisconsin



ENTER LABORATORY MOISTURE CONTENT, %- -	Mc=	261.0	
ENTER SAMPLE WEIGHT, grams- - - - - - - -	W=	118.58	
ENTER SAMPLE DIAMETER, inches- - - - - - -	Ds=		
ENTER SAMPLE LENGTH, inches- - - - - - - -	Ls=		
ENTER ESTIMATED/KNOWN SPECIFIC GRAVITY,Gs	Gs=	2.443	
SAMPLE VOLUME, cubic inches- - - - - - - - -	V=	6.07	((Ds/
WET DENSITY, #/cu ft- - - - - - - - - - - -	Wt=	74.4	
WEIGHT OF SOLIDS, pounds- - - - - - - - - - -	Ws=	20.6	
WEIGHT OF WATER, pounds- - - - - - - - - - -	Ww=	53.8	
VOLUME OF SOLIDS, cubic feet- - - - - - - - -	Vs=	0.14	
VOLUME OF WATER, cubic feet- - - - - - - - -	Vw=	0.86	
VOLUME OF AIR, cubic feet- - - - - - - - - - -	Va=	0.00	
VOLUME OF VOIDS, cubic feet- - - - - - - - -	Vv=	0.86	
POROSITY, n- - - - - - - - - - - - - -	**n=**	**0.86**	
VOID RATIO, e- - - - - - - - - - - - -	**e=**	**6.40**	
DEGREE OF SATURATION, Sr- - - - - - -	**Sr=**	**100%**	
LOSS ON IGNITION - - - - - - - -	**FOC=**	**15.60%**	

WEIGHT VOLUME RELATIONSHIPS OF SOIL

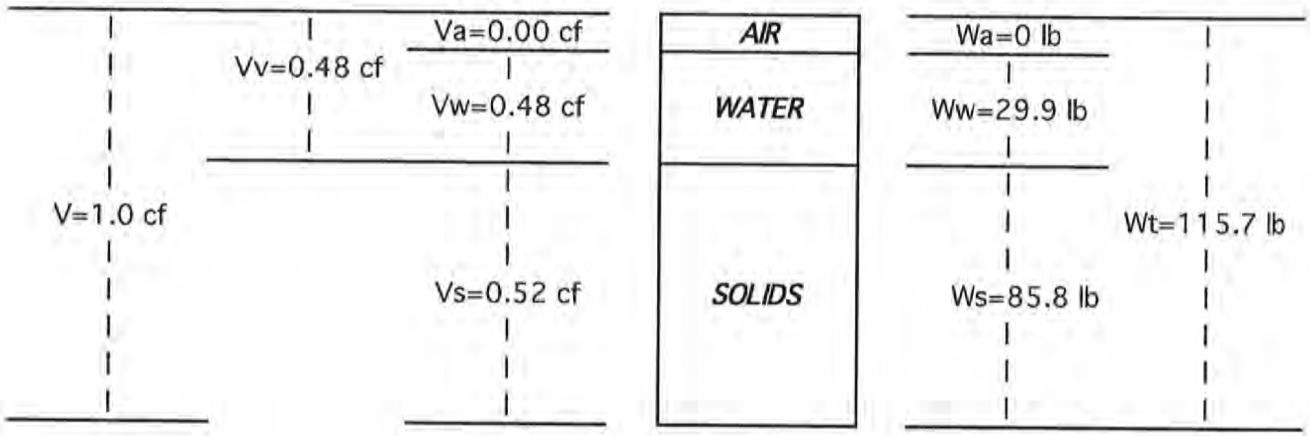
PROJECT NAME:	Pond 3 Sediments	**PROJECT NO:**	20543
SAMPLE LOCATION:	Pond 3 Sample 1	**DATE:**	8/19/20
SOIL CLASSIFICATION:	Black organic Silty SAND	**CLIENT:**	KPRG Wisconsin



ENTER LABORATORY MOISTURE CONTENT, %- -	Mc=	475.0
ENTER SAMPLE WEIGHT, grams- - - - - - - -	W=	111.34
ENTER SAMPLE DIAMETER, inches- - - - - - -	Ds=	
ENTER SAMPLE LENGTH, inches- - - - - - - -	Ls=	
ENTER ESTIMATED/KNOWN SPECIFIC GRAVITY,Gs	Gs=	2.418
SAMPLE VOLUME, cubic inches- - - - - - - - -	V=	6.07 ((Ds/
WET DENSITY, #/cu ft- - - - - - - - - - - -	Wt=	69.8
WEIGHT OF SOLIDS, pounds- - - - - - - - - - -	Ws=	12.1
WEIGHT OF WATER, pounds- - - - - - - - - - -	Ww=	57.7
VOLUME OF SOLIDS, cubic feet- - - - - - - - -	Vs=	0.08
VOLUME OF WATER, cubic feet- - - - - - - - -	Vw=	0.92
VOLUME OF AIR, cubic feet- - - - - - - - - - -	Va=	0.00
VOLUME OF VOIDS, cubic feet- - - - - - - - -	Vv=	0.92
POROSITY, n- - - - - - - - - - - - - -	**n=**	**0.92**
VOID RATIO, e- - - - - - - - - - - - -	**e=**	**11.43**
DEGREE OF SATURATION, Sr- - - - - - -	**Sr=**	**101%**
LOSS ON IGNITION - - - - - - - -	**FOC=**	**28.46%**
pH - - - - - - - - - -	**pH=**	

WEIGHT VOLUME RELATIONSHIPS OF SOIL

PROJECT NAME:	Powerton Station	**PROJECT NO:**	20588
SAMPLE LOCATION:	Service Water Basin Sludge	**DATE:**	9/24/20
SOIL CLASSIFICATION:	Black / grey Silty SAND	**CLIENT:**	KPRG Wisconsin



ENTER LABORATORY MOISTURE CONTENT, %- -	Mc=	34.9	
ENTER SAMPLE WEIGHT, grams- - - - - - - -	W=	184.55	
ENTER SAMPLE DIAMETER, inches- - - - - - -	Ds=		
ENTER SAMPLE LENGTH, inches- - - - - - - -	Ls=		
ENTER ESTIMATED/KNOWN SPECIFIC GRAVITY,Gs	Gs=	2.625	
SAMPLE VOLUME, cubic inches- - - - - - - - -	V=	6.07	((Ds/
WET DENSITY, #/cu ft- - - - - - - - - - - -	Wt=	115.7	
WEIGHT OF SOLIDS, pounds- - - - - - - - - - -	Ws=	85.8	
WEIGHT OF WATER, pounds- - - - - - - - - - -	Ww=	29.9	
VOLUME OF SOLIDS, cubic feet- - - - - - - - -	Vs=	0.52	
VOLUME OF WATER, cubic feet- - - - - - - - -	Vw=	0.48	
VOLUME OF AIR, cubic feet- - - - - - - - - - -	Va=	0.00	
VOLUME OF VOIDS, cubic feet- - - - - - - - -	Vv=	0.48	
POROSITY, n- - - - - - - - - - - - - -	**n=**	**0.48**	
VOID RATIO, e- - - - - - - - - - - - -	**e=**	**0.91**	
DEGREE OF SATURATION, Sr- - - - - - -	**Sr=**	**101%**	
LOSS ON IGNITION - - - - - - - -	FOC=	8.24%	

MIDLAND STANDARD ENGINEERING TESTING, INC.
410 NOLEN DRIVE, SOUTH ELGIN, IL 60177 P(847) 844-1895 F(847) 844-3875

Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils
ASTM 2974

Project # 20543
Project Name: Pond 3- Sediments
Sample Description: Black Sediment

Date Received: 8/19/2020
Date Tested: 8/21/2020
Tested by: JDS

METHOD D, 750°C

METHOD C, 440°C

	SAMPLE ID	Pond 3	Pond 1	
	SPECIMEN #	Sediments	Middle Water	
	TEST DATE:	8/21/2020	8/21/2020	
	TEST TEMP:	440°C	440°C	
1. wt of crucible, no cover	1	53.79	49.42	
2. wt. of crucible & unburnt sample, no	2	68.69	56.20	
3. wt. of crucible & burned sample, no c	3	64.45	54.04	
4. wt. of dry sample at start	B	14.9	6.78	
5. net wt. of ash	C	10.66	4.62	
6. ash content, %	D	71.54	68.22	
7. organic matter, %	OM,%	28.46	31.78	

MIDLAND STANDARD ENGINEERING TESTING, INC.
410 NOLEN DRIVE, SOUTH ELGIN, ILLINOIS 60177 P (847) 844-1895 F(847) 844-3875

Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils
ASTM 2974

Project #: 20588
Project Name: Powerton Station
Sample Description: Black/grey Silty SAND
Location: Pekin, Illinois

Date Received: 9//2020
Date Tested: 9//2020
Tested by: JDS

METHOD D, 750°C
METHOD C, 440°C

	SAMPLE ID	SWB		
	SPECIMEN #			
	TEST DATE:			
	TEST TEMP:	440°C	440°C	440°C
1. wt of crucible, no cover	1	151.92		
2. wt. of crucible & unburnt sample, no cover	2	187.25		
3. wt. of crucible & burned sample, no cover	3	184.34		
4. wt. of dry sample at start	B	35.33		
5. net wt. of ash	C	32.42		
6. ash content, %	D	91.76337		
7. organic matter, %	OM,%	8.24		

SPF013

EXHIBIT 4: Table 1: Comparison of Distribution of Particle Sizes for Joliet 29 CCR and Joliet's Pond 1 Material

Sample	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
Joliet 29 CCR	0.0	0.0	19.0	14.2	25.6	26.8	12.6	1.8
Pond 1 Material	0.0	0.0	1.5	2.7	3.6	24.9	61.3	6.0

Pond 1 surface at top of slope = 133,372 Sq.ft = 3.0618 acres

Material Quantities Based on 2 tons/ac/yr
Pond 1 surface at top of slope = 133,372 Sq.ft

Last clean out occurred between May and September 2015

Time between Clean out and survey is from 9/1/2015 and 7/6/2020 for a total of 1,771.75 days

Pond 1 top slope surface

3.0618 acres	2 tons	1771.75 days	=	29.7 tons
	ac/yr	365 days/yr		

EXHIBIT 4: Table 2: Comparison of Distribution of Particle Sizes for Joliet 29 CCR and Joliet's Pond 3 Material

Sample	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
Joliet 29 CCR	0.0	0.0	19.0	14.2	25.6	26.8	12.6	1.8
Pond 3 Material	0.0	0.0	1.8	10.1	14.7	33.0	23.8	16.6

Pond 3 surface at top of slope = 105578 Sq.ft = 2.42 acres

Material Quantities Based on 2 tons/ac/yr

Pond 3 surface at top of slope = 105578 Sq.ft

Last clean out occurred between May and September 2013

Time between Clean out and survey is from 9/1/2013 and 8/17/2020 for a total of 2,213.25 days

Pond 3 top slope surface

2.4237 acres	2 tons	2213.25 days	=	29.4 tons
	ac/yr	365 days/yr		

EXHIBIT 4: Table 3: Comparison of Distribution of Particle Sizes for Joliet 9 CCR and Powerton's Service Water Bas

Sample	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
Joliet 9 CCR	0.0	0.0	1.6	11.4	70.1	13.6	3.3	
SW Basin Material	0.0	0.0	2.0	8.0	43.5	23.8	18.7	4.0

SW Basin surface at top of slope = 87791.14 Sq.ft = 2.0154 acres

Material Quantities Based on 2 tons/ac/yr

Surface of SW Basin survey = 0 Sq.ft

SW Basin surface at top of slope = 87791.14 Sq.ft

Last clean out occurred between March and June 2013

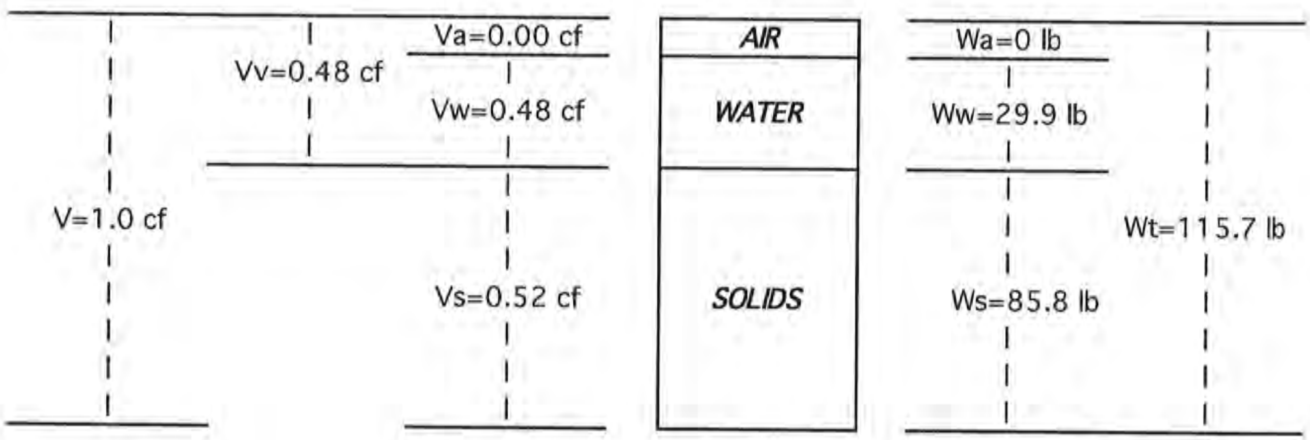
Time between Clean out and survey is from 6/15/2013 and 7/14/2020 for a total of 2,257.25 days

SW Basin top slope surface

2.0154 acres   2 tons / ac/yr   2257.25 days / 365 days/yr   =   24.9 tons

WEIGHT VOLUME RELATIONSHIPS OF SOIL

PROJECT NAME:	Powerton Station	**PROJECT NO:**	20588
SAMPLE LOCATION:	Service Water Basin Sludge	**DATE:**	9/24/20
SOIL CLASSIFICATION:	Black / grey Silty SAND	**CLIENT:**	KPRG Wisconsin



ENTER LABORATORY MOISTURE CONTENT, %- -	Mc=	34.9
ENTER SAMPLE WEIGHT, grams- - - - - - - -	W=	184.55
ENTER SAMPLE DIAMETER, inches- - - - - - -	Ds=	
ENTER SAMPLE LENGTH, inches- - - - - - - -	Ls=	
ENTER ESTIMATED/KNOWN SPECIFIC GRAVITY,Gs	Gs=	2.625
SAMPLE VOLUME, cubic inches- - - - - - - - -	V=	6.07 ((Ds/
WET DENSITY, #/cu ft- - - - - - - - - - - -	Wt=	115.7
WEIGHT OF SOLIDS, pounds- - - - - - - - - - -	Ws=	85.8
WEIGHT OF WATER, pounds- - - - - - - - - - -	Ww=	29.9
VOLUME OF SOLIDS, cubic feet- - - - - - - - -	Vs=	0.52
VOLUME OF WATER, cubic feet- - - - - - - - -	Vw=	0.48
VOLUME OF AIR, cubic feet- - - - - - - - - - -	Va=	0.00
VOLUME OF VOIDS, cubic feet- - - - - - - - -	Vv=	0.48
POROSITY, n- - - - - - - - - - - - - -	**n=**	**0.48**
VOID RATIO, e- - - - - - - - - - - - -	**e=**	**0.91**
DEGREE OF SATURATION, Sr- - - - - - -	**Sr=**	**101%**
LOSS ON IGNITION - - - - - - - -	FOC=	8.24%

EXHIBIT 20

K P R G

ENVIRONMENTAL CONSULTATION & REMEDIATION

KPRG and Associates, Inc.

MEMORANDUM

FROM: Joshua D. Davenport, P.E., KPRG and Associates, Inc.

DATE: February 26, 2021

SUBJECT: Sampling Location Discussion as part of Evaluation of Sediment Quantities in Joliet Generating Station's Pond 1 and Pond 3 and Powerton Generating Station's Service Water Basin

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This memo provides a discussion of the sample locations for Pond 1 and Pond 3 at the Joliet 29 Generating Station and the Service Water Basin at the Powerton Generating Station. This memo is a follow up to the discussion with IEPA that occurred on February 17, 2021.

IEPA had questions regarding the total number of samples collected in each pond and what was the rationale for sample locations. The following provides this discussion with IEPA's initial question provided in italics.

Joliet 29 Generating Station

1) Discussion must be provided about how sample locations were selected and the methodology of collecting the sample

Samples in both Ponds 1 and 3 were collected using a clamshell sampler. Minimal material was able to be collected because mostly water was obtained using the clamshell. Not much material was collected during each drop of the clamshell. The ponds both had water in them during the sampling. Pond 1 had approximately 15-16 feet of water and Pond 3 had approximately 8-9 feet of water.

<u>Sample Collection Method</u>

The samples were collected from a boat using a clamshell sampler. The clamshell was lowered over the side of a boat using a rope with the clamshell held open by a spring. The spring on the clamshell releases once it hits the sediment and the rope is used to pull the sampler to the surface. The collection portion of the clamshell is approximately 2 quarts in volume. When collecting the sample, it requires multiple attempts to collect an adequate amount of sediment for laboratory analysis because the majority of the material collected during each drop is water, with some sediment.

The sample collection from a boat is different from collecting samples at a stationary point when collecting soil and/or groundwater samples. Each attempt to collect sediment using the clamshell will collect sediment from a different part of the pond because the boat naturally drifts on the water. Therefore, the sample locations depicted on the attached figures are more appropriately a sampling area as opposed to a singular point.

Pond 1

Knowing that Pond 1 was cleaned out in 2015, the center of the pond was chosen for Sample 1 to provide a broad representation of the type of material that may be in the pond and sediment would likely be present there if the pond contained any. Many collection attempts were performed in the center area of the pond to collect a sufficient quantity of sediment needed for the laboratory analyses. The sampling attempts were combined and submitted to the laboratory as one sample. The second Pond 1 sample area was collected near the edge of the pond, adjacent to the access road because it was safely accessible without a boat. As performed during the first sampling, several attempts were made to collect the quantity of sediment needed for the material analyses. The sampling attempts were combined and submitted to the laboratory as one sample. The second sampling was performed later to collect additional data. The additional data was warranted to provide further clarification on the type of sediment present in Pond 1 based on the results of the bathymetric survey and the grain size analysis. Because a boat was not available, the second sampling was collected by lowering the clamshell sampler from the side of the pond, releasing the spring, hauling the sampler back up, and collecting the sediment in a jar. Because the samplings were performed at different times, they were submitted to the laboratory at two different times.

The attached Figure 1 shows the sampling areas where the sediment was collected and the bathymetric survey surface in comparison to the existing pond surface/liner. The contours of the pond are based on the as-built drawings and the contours of the bathymetric survey are based on that survey. The attached Figure 2 shows the survey surface in comparison to the existing pond surface/liner. The bathymetric survey contours show approximately 1-2 feet of material is present, which, as noted in our previous submittal, consists of 14% percent sediment and 86% water.

Pond 3

Sediment within Pond 3 was collected from three different sampling areas and combined into one sample that was submitted for laboratory analysis. The three sampling areas were located near the center of the pond, near the pond inlet, and from the side slope of the access road. The inlet sampling area was chosen because if CCR material was likely to be present in the pond, it would be at the inlet because of the CCR's particle size (approximately sand sized) and its tendency to settle from the water first, prior to smaller silt and clay sized particles. The inlet had a minimal quantity of material and most of what was collected was the stone warning layer and not sediment. The center of the pond was chosen because it was more likely to find sediment present at this area and was likely to contain a broad representation of the types and sizes of material in the pond. The third area where sediment was collected was from the side slope of the access road. This area was chosen because the water level in the pond was low enough that this material was exposed and was collected by hand and placed in a plastic bag.

The inlet and center samplings were performed from a boat with the clamshell sampler using the method as was discussed above. The sample next to the access road was collected by hand.

The attached Figure 1 shows the locations where the sediment was collected. Also shown on Figure 1 is the contours of the pond based on the as-built drawings and the contours of the bathymetric survey. The attached Figure 2 shows the bathymetric survey surface in comparison to the existing pond surface/liner. The contours show that approximately 2-3 feet of material is present, which as noted in our previous submittal, consists of 8% percent sediment and 92% water.

Powerton's Service Water Basin

1) *Provide how sample location was selected and obtained*

The sample collected from the Service Water Basin was not collected by KPRG, but was collected by a process engineer that works at the Powerton Generating Station. KPRG spoke with the process engineer and the following is from our conversation.

The water level was low enough that the sample material was collected by hand. The plant personnel walked down the south side of the liner, collected the material with a plastic scoop, and put it in a container. The sample was collected from the south side of the basin. The south side was not chosen for any particular reason, it happened to be the side that was chosen by the plant personnel. The plant engineer noted the following observation, "the sample material was sticky and was stuck to side of basin and did not fall off with a lower water level." It was noted that the basin still contained water and the bottom was not visible. The sediment did not have appear to have a noticeable odor. The plant personnel containerized the sediment sample and shipped it to the same geotechnical testing firm that performed the Pond 1 and Pond 3 samples analyzes. KPRG provided the plant personnel with the name of the testing firm, its address, and the tests that should be performed on the sample.

The attached Figure 3 shows the approximate location where the sediment was collected. Also shown on Figure 3 is the contours of the pond based on the as-built drawings and the contours of the bathymetric survey. The attached Figure 4 shows the bathymetric survey surface in comparison to the existing pond surface/liner. The contours show the bottom of the pond based on the as-built drawings is approximately the same elevation determined by the bathymetric survey.

The comparison of the contours on Figure 4 is based on the as-built survey performed in 2013 prior to the geomembrane liner installation and the 2020 bathymetric survey. The extent of the bathymetric survey on Figure 4 goes beyond the extent of the basin as-built contours. This discrepancy is likely due to changes that occurred following installation of the liner in 2013.

In addition, the profile drawing also has an exaggerated vertical scale to make the vertical differences easier to see because the vertical distances on cross sections are typically much smaller than horizontal distances and they can be hard to see.

Despite the difference, the intent of the drawing still shows that minimal to no sediment is present along the bottom of the basin.

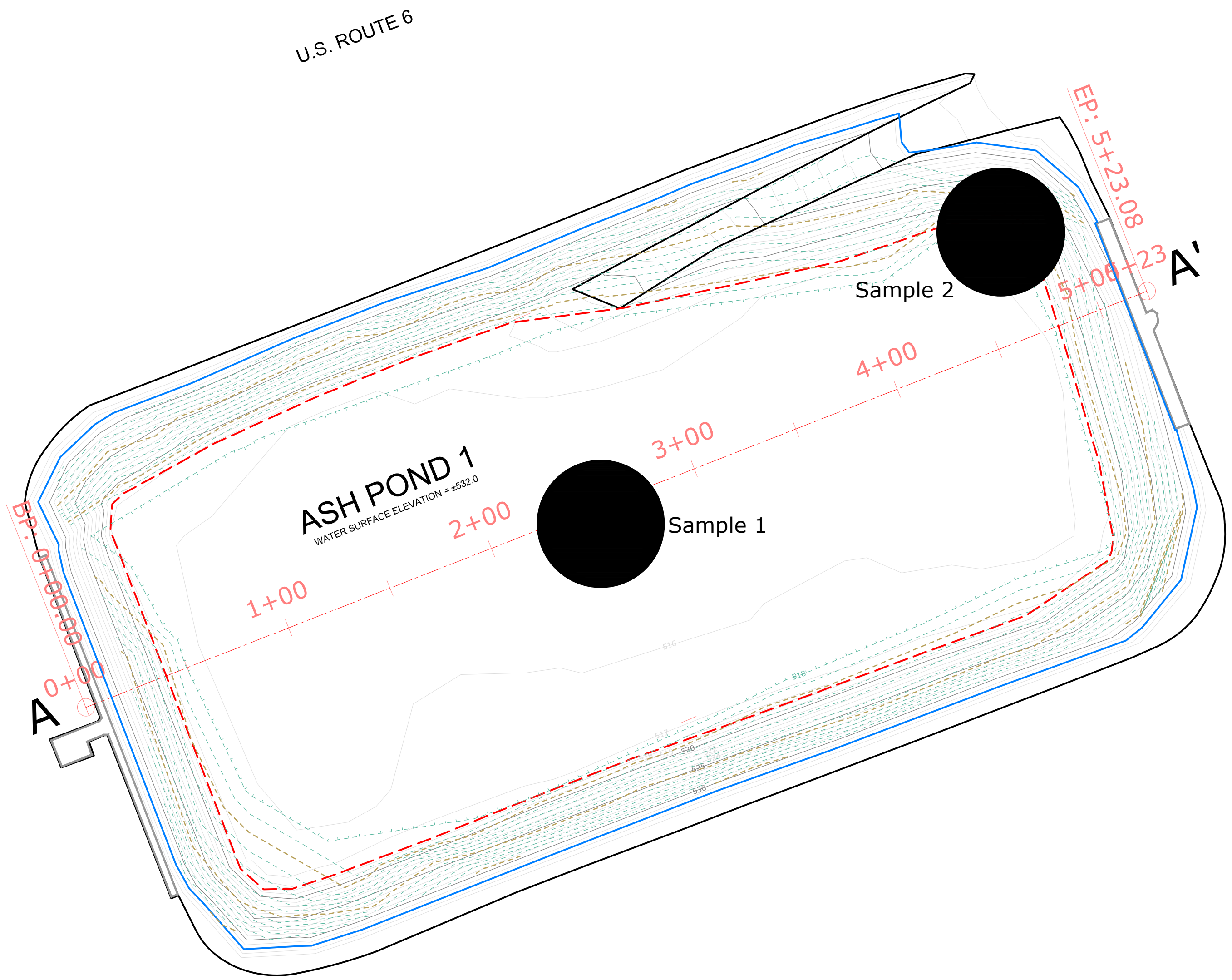
ASTM Method

ASTM D2974 was chosen to determine the organic versus non-organic content of the sediment based on a discussion with the geotechnical company performing the other sediment analyses. The following is a brief summary of the test method described in the ASTM standard.

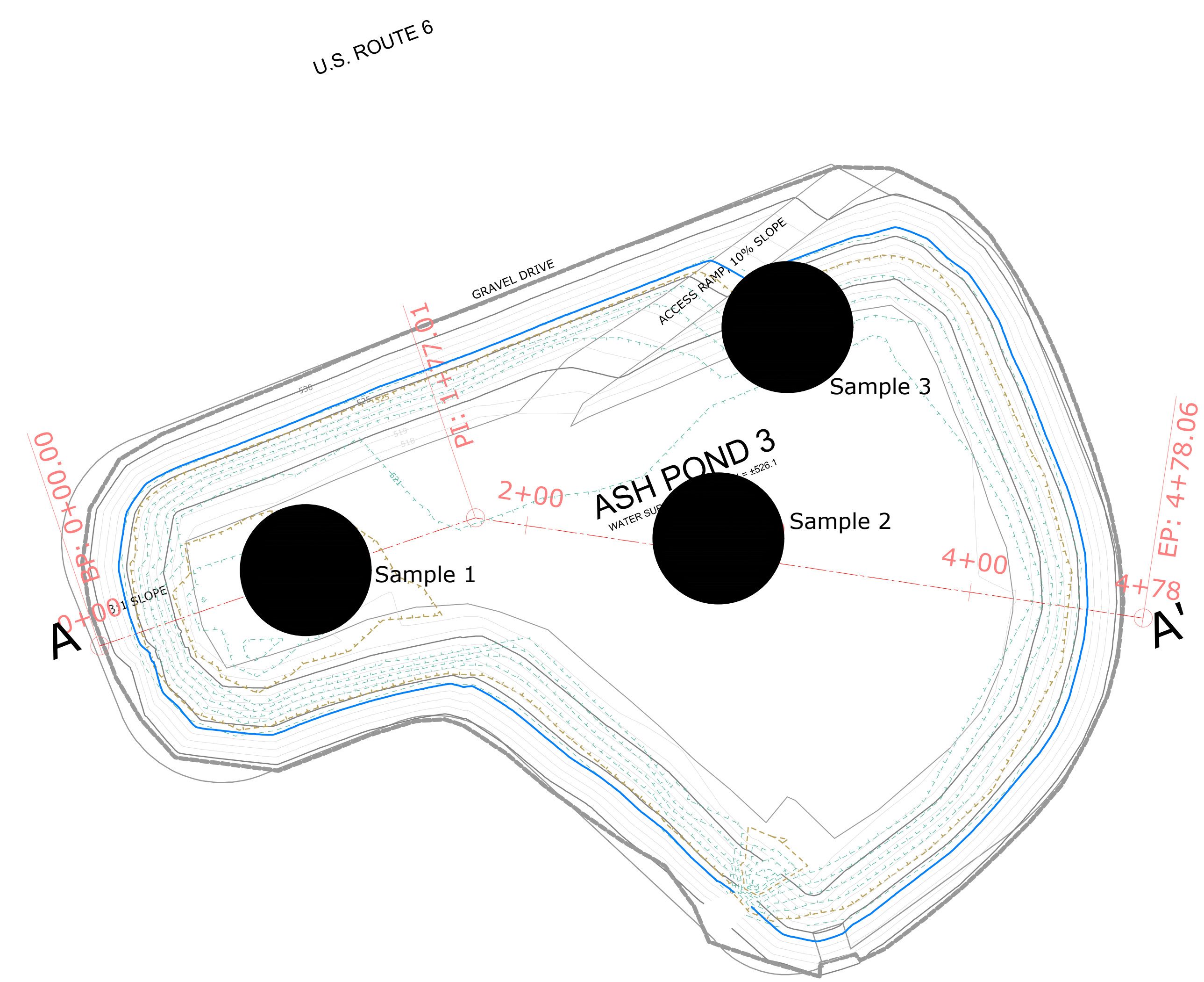
1. The soil sample is dried in an oven at approximately 110°C for a minimum of 16 hours. The sample is allowed to cool and the mass is determined.
2. The sample is then heated in a furnace where the temperature is gradually raised to approximately 440°C. The sample is then heated at this temperature for at least 1 hour. The sample is heated until the entire contents are considered “completely ashed.” The sample is considered completely ashed once there is no change in mass.
3. The sample is allowed to cool and the mass is determined.

The test method does not determine if any particular soil sample contains coal ash. The use of the term ash is in the generic after something has been cooked in a furnace and is completely burned. This test method is used for classification purposes when wanting to determine the organic content of soil.

POND 1



POND 3



N

LEGEND

- 5-FOOT INCREMENT CONTOUR FROM AS-BUILT DRAWINGS
- 1-FOOT INCREMENT CONTOUR FROM AS-BUILT DRAWINGS
- 5-FOOT INCREMENT CONTOUR FROM SURVEY
- 1-FOOT INCREMENT CONTOUR FROM SURVEY

SAMPLE 1 ● POND SAMPLE LOCATION

0 80'
APPROXIMATE SCALE

ENVIRONMENTAL CONSULTATION & REMEDIATION
KPRG
KPRG and Associates, inc.
14665 West Lisbon Road, Suite 1A Brookfield, Wisconsin 53005 Telephone 262-781-0475 Facsimile 262-781-0478
414 Plaza Drive, Suite 106 Westmont, Illinois 60559 Telephone 630-325-1300 Facsimile 630-325-1593

POND 1 AND POND 3 SEDIMENT SAMPLE LOCATIONS	
JOLIET 29 GENERATING STATION JOLIET, ILLINOIS	
Scale: 1" = 80'	Date: February 26, 2021
KPRG Project No. 15020	FIGURE 1

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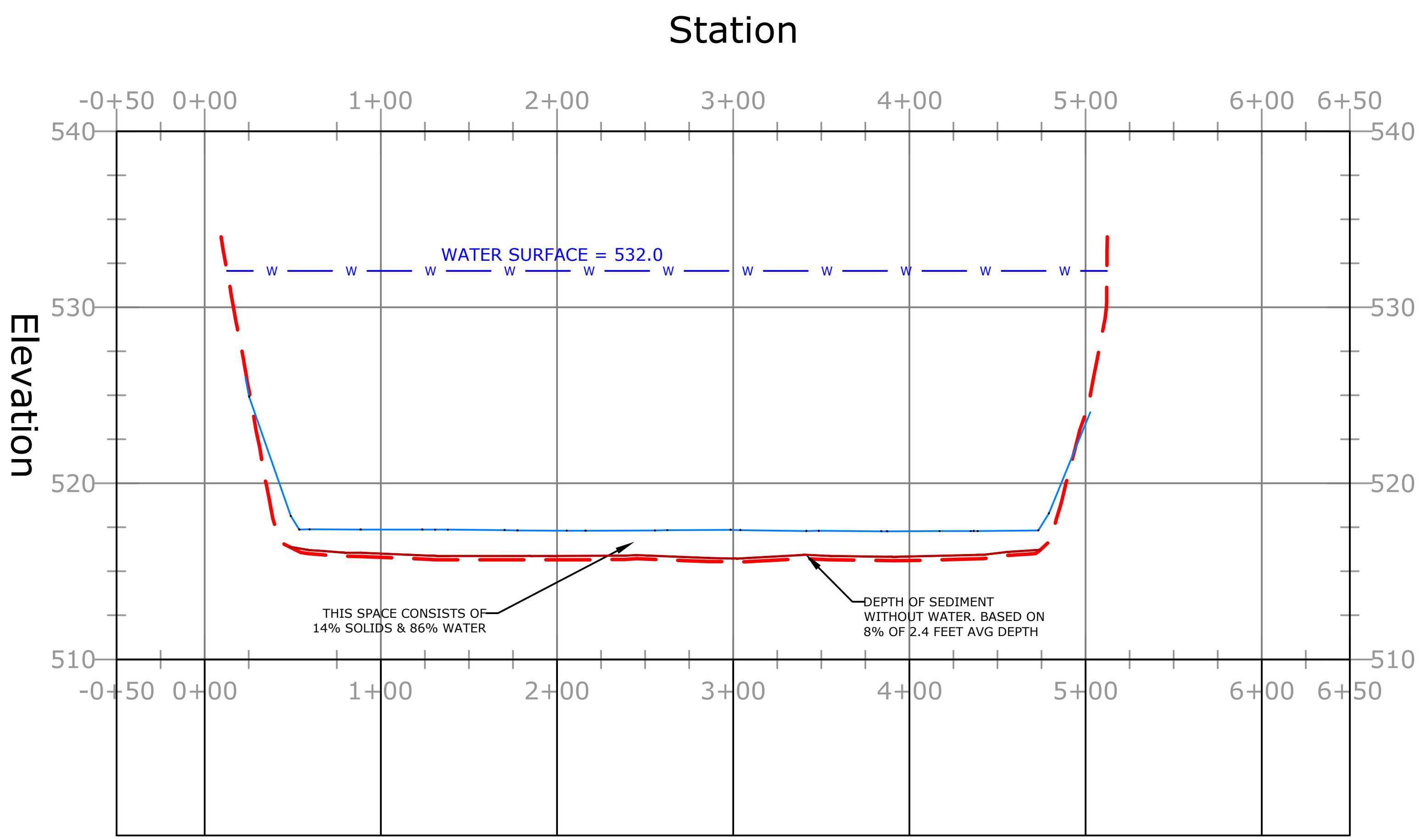
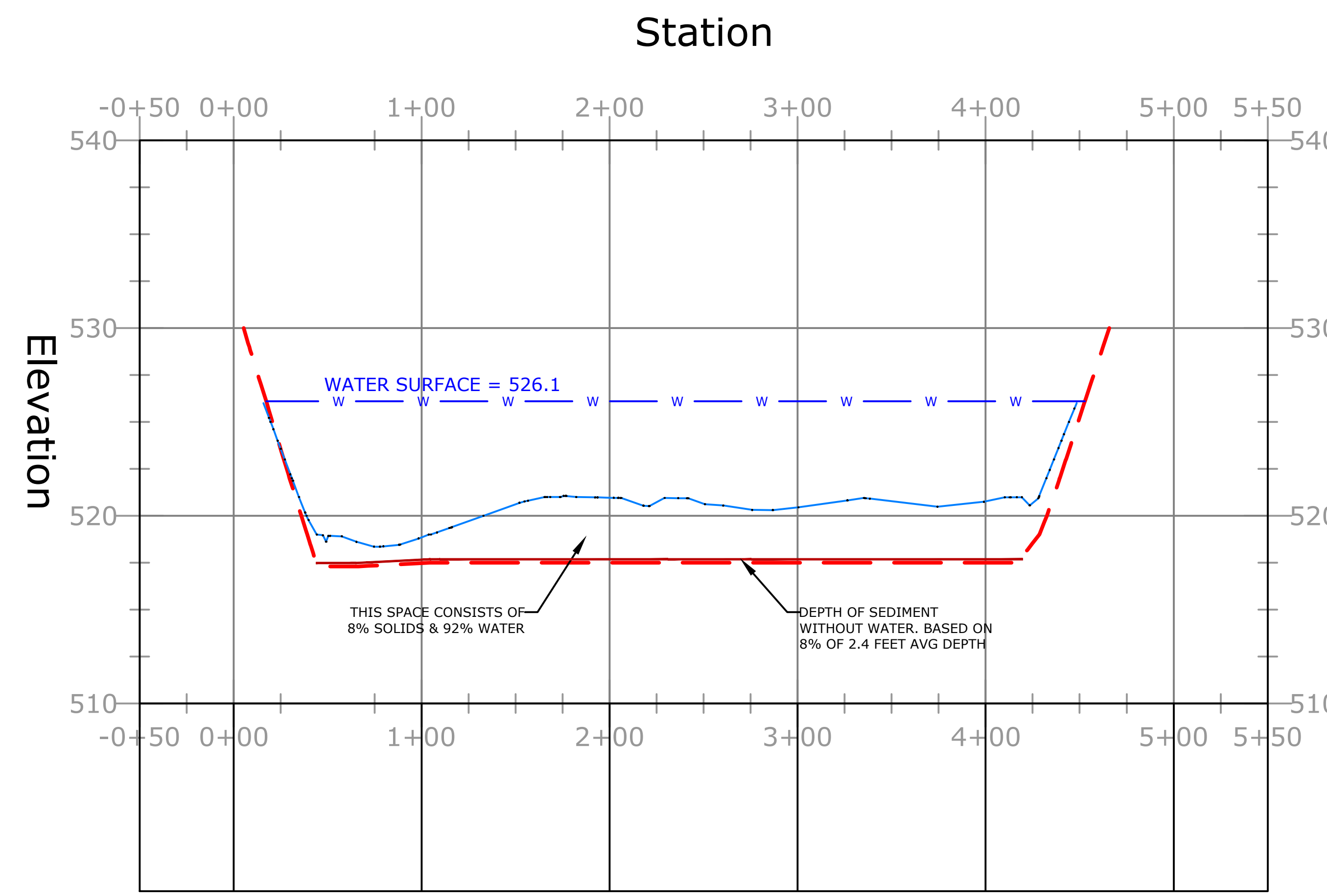
Pond 1 A-A' PROFILE



POND 1

Pond 3 A-A' PROFILE



POND 3

LEGEND

- EXISTING POND LINER SURFACE
- SURVEYED SEDIMENT/WATER SURFACE
- ESTIMATED SEDIMENT SURFACE W/OUT WATER

10' 100' 0'
APPROXIMATE SCALE

ENVIRONMENTAL CONSULTATION & REMEDIATION

KPRG

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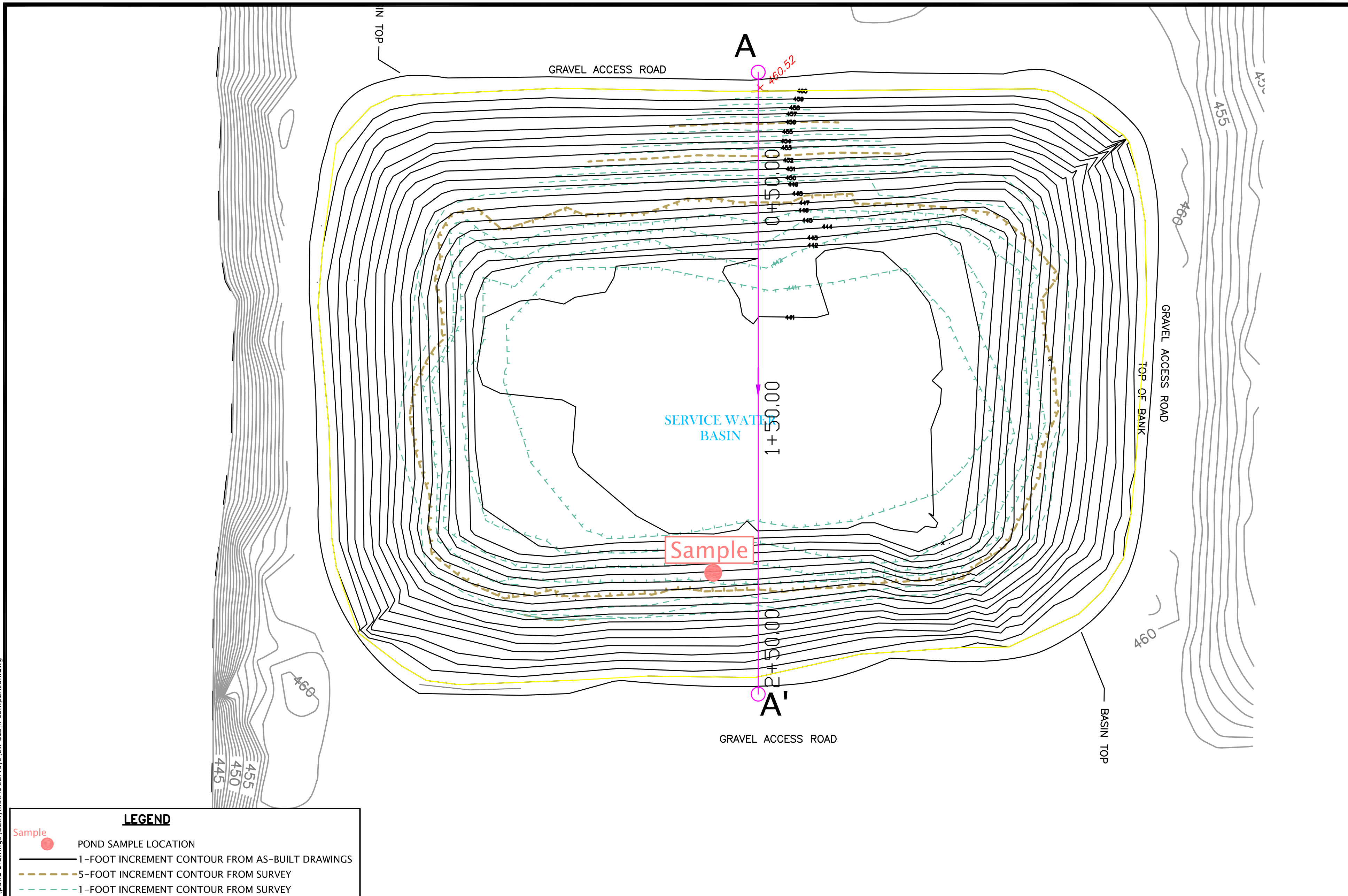
POND 1 AND POND 3 PROFILES	
JOLIET 29 GENERATING STATION JOLIET, ILLINOIS	
Scale: 1" = 100'	Date: February 25, 2021
KPRG Project No. 15020	FIGURE 2



E N V I R O N M E N T A L C O N S U L T A T I O N & R E M E D I A T I O N

KPRG

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414 Plaza Drive, Suite 106 Westmont, Illinois 60559 Telephone 630-325-1300 Facsimile 630-325-1593

SERVICE WATER BASIN SAMPLE LOCATION

POWERTON GENERATING STATION
PEKIN, ILLINOIS

Scale: 1" = 60' | Date: February 26, 2021

KPRG Project No. 15020 | FIGURE 3

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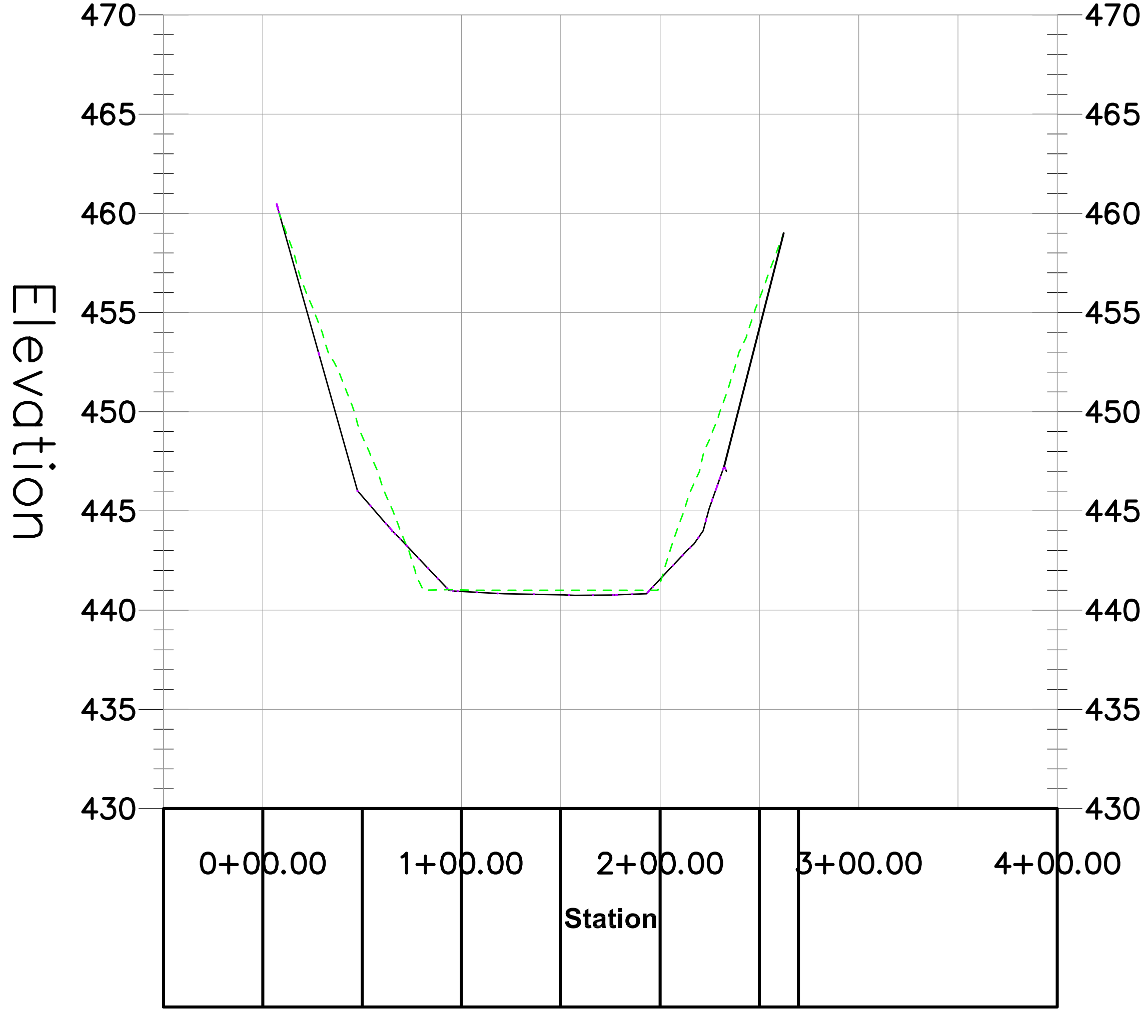
Service Water Basin A-A' Profile



LEGEND

- - - EXISTING POND SURFACE
— SURVEY SURFACE

APPROXIMATE SCALE

E N V I R O N M E N T A L C O N S U L T A T I O N & R E M E D I A T I O N

KPRG and Associates, inc.

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414 Plaza Drive, Suite 106 Westmont, Illinois 60559 Telephone 630-325-1300 Facsimile 630-325-1593

SERVICE WATER BASIN PROFILE A-A'

POWERTON GENERATING STATION
PEKIN, ILLINOIS

Scale: 1" = 60' | Date: February 25, 2021

KPRG Project No. 15020 | FIGURE 4

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EXHIBIT 21

PREDICTING RAINFALL EROSION LOSSES

A GUIDE TO CONSERVATION PLANNING

UNITED STATES DEPARTMENT OF AGRICULTURE

AGRICULTURE HANDBOOK NUMBER 537

PREPARED BY SCIENCE AND EDUCATION ADMINISTRATION

PREDICTING RAINFALL EROSION LOSSES

A GUIDE TO CONSERVATION PLANNING

Supersedes Agriculture Handbook No. 282,
"Predicting Rainfall-Erosion Losses From Cropland East of the Rocky Mountains"

Note: See Supplement Dated January 1981 and the errata at the end of this document.

Science and Education Administration
United States Department of Agriculture
in cooperation with
Purdue Agricultural Experiment Station

December 1978

ABSTRACT

Wischmeier, W. H., and Smith, D.D. 1978. Predicting rainfall erosion losses—a guide to conservation planning. U.S. Department of Agriculture, Agriculture Handbook No. 537.

The Universal Soil Loss Equation (USLE) enables planners to predict the average rate of soil erosion for each feasible alternative combination of crop system and management practices in association with a specified soil type, rainfall pattern, and topography. When these predicted losses are compared with given soil loss tolerances, they provide specific guidelines for effecting erosion control within specified limits. The equation groups the numerous interrelated physical and management parameters that influence erosion rate under six major factors whose site-specific values can be expressed numerically. A half century of erosion research in many States has supplied information from which at least approximate values of the USLE factors can be obtained for specified farm fields or other small erosion prone areas throughout the United States. Tables and charts presented in this handbook make this information readily available for field use. Significant limitations in the available data are identified.

The USLE is an erosion model designed to compute longtime average soil losses from sheet and rill erosion under specified conditions. It is also useful for construction sites and other nonagricultural conditions, but it does not predict deposition and does not compute sediment yields from gully, streambank, and streambed erosion.

Keywords: Conservation practices, conservation tillage, construction sites, crop canopy, crop sequence, delivery ratios, erosion factors, erosion index, erosion prediction, erosion tolerances, erosivity, gross erosion, minimum tillage, no-till, rainfall characteristics, rainfall data, residue mulch, runoff, sediment, sediment delivery, slope effect, water quality, soil erodibility.

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PREDICTING RAINFALL EROSION LOSSES—A GUIDE TO CONSERVATION PLANNING

Walter H. Wischmeier and Dwight D. Smith[1]

PURPOSE OF HANDBOOK

Scientific planning for soil and water conservation requires knowledge of the relations between those factors that cause loss of soil and water and those that help to reduce such losses. Controlled studies on field plots and small watersheds have supplied much valuable information regarding these complex factor interrelations. But the greatest possible benefits from such research can be realized only when the findings are converted to sound practice on the numerous farms and other erosion prone areas throughout the country. Specific guidelines are needed for selecting the control practices best suited to the particular needs of each site.

The soil loss prediction procedure presented in this handbook provides such guidelines. The procedure methodically combines research information from many sources to develop design data for each conservation plan. Widespread field experience for more than two decades has proved it highly valuable as a conservation planning guide.

The procedure is founded on an empirical soil loss equation that is believed to be applicable wherever numerical values of its factors are available. Research has supplied information from which at least approximate values of the equation's factors can be obtained for specific farm fields or other small land areas throughout most of the United States. Tables and charts presented in this handbook make this information readily available for field use.

This revision of the 1965 handbook (*64*) updates the content and incorporates new material that has been available informally or from scattered research reports in professional journals. Some of the original charts and tables are revised to conform with additional research findings, and new ones are developed to extend the usefulness of the soil loss equation. In some instances, expanding a table or chart sufficiently to meet the needs for widespread field application required projection of empirical factor relationships appreciably beyond the physical limits of the data from which the relationships were derived. Estimates obtained in this manner are the best information available for the conditions they represent. However, the instances are identified in the discussions of the specific erosion factors, tables, and charts. Major research needs are suggested by these discussions and were recently summarized in an available publication by Stewart and others (*42*).

HISTORY OF SOIL LOSS EQUATIONS

Developing equations to calculate field soil loss began about 1940 in the Corn Belt. The soil loss estimating procedure developed in that region between 1940 and 1956 has been generally referred to as the slope-practice method. Zingg (*64*)[2] published an equation in 1940 relating soil loss rate to length and percentage of slope. The following year, Smith (*38, 39*) added crop and conservation practice factors and the concept of a specific soil loss limit, to develop a graphical method for

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[2] Numbers in parentheses refer to References p. 48.

determining conservation practices on Shelby and associated soils of the Midwest. Browning and associates (*6*) added soil and management factors and prepared a set of tables to simplify field use of the equation in Iowa. Research scientists and operations personnel of the Soil Conservation Service (SCS) in the North Central States worked together in developing the slope-practice equation for use throughout the Corn Belt.

A national committee met in Ohio in 1946 to adapt the Corn Belt equation to cropland in other regions. This committee reappraised the Corn Belt factor values and added a rainfall factor. The resulting formula, generally known as the Musgrave Equation (*31*), has been widely used for estimating gross erosion from watersheds in flood abatement programs. A graphical solution of the equation was published in 1952 (*19*) and used by the SCS in the Northeastern States.

The soil loss equation presented in this handbook has become known as the Universal Soil Loss Equation (USLE). Regardless of whether the designation is fully accurate, the name does distinguish this equation from the *regionally* based soil loss equations. The USLE was developed at the National Runoff and Soil Loss Data Center established in 1954 by the Science and Education Administration (formerly Agricultural Research Service) in cooperation with Purdue University. Federal-State cooperative research projects at 49 locations[3] contributed more than 10,000 plot-years of basic runoff and soil loss data to this center for summarizing and overall statistical analyses. After 1960, rainfall simulators (*23*) operating from Indiana, Georgia, Minnesota, and Nebraska were used on field plots in 16 states to fill some of the gaps in the data needed for factor evaluation.

Analyses of this large assembly of basic data provided several major improvements for the soil loss equation (*53*): (a) a rainfall erosion index evaluated from local rainfall characteristics; (b) a quantitative soil erodibility factor that is evaluated directly from soil property data and is independent of topography and rainfall differences; (c) a method of evaluating cropping and management effects in relation to local climatic conditions; and (d) a method of accounting for effects of interactions between crop system, productivity level, tillage practices, and residue management.

Developments since 1965 have expanded the use of the soil loss equation by providing techniques for estimating site values of its factors for additional land uses, climatic conditions, and management practices. These have included a soil erodibility nomograph for farmland and construction areas (*58*); topographic factors for irregular slopes (*12, 55*); cover factors for range and woodland (*57*); cover and management effects of conservation tillage practices (*54*); erosion prediction on construction areas (*61, 24, 25*); estimated erosion index values for the Western States and Hawaii (*5, 21, 55*); soil erodibility factors for benchmark Hawaii soils (9); and improved design and evaluation of erosion control support practices (*17, 36*).

Research is continuing with emphasis on obtaining a better understanding of the basic principles and processes of water erosion and sedimentation and development of fundamental models capable of predicting specific-storm soil losses and deposition by overland flow (*10, 11, 22, 26, 32*). The fundamental models have been helpful for understanding the factors in the field soil loss equation and for interpreting the plot data.

SOIL LOSS TOLERANCES

The term "soil loss tolerance" denotes the maximum level of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely.

[3] The data were contributed by Federal-State cooperative research projects at the following locations: Batesville, Ark.; Tifton and Watkinsville, Ga.; Dixon Springs, Joliet, and Urbana, Ill.; Lafayette, Ind.; Clarinda, Castana, Beaconsfield, Independence, and Seymour, Iowa; Hays, Kans.; Baton Rouge, La.; Presque Isle, Maine; Benton Harbor and East Lansing, Mich.; Morris, Minn.; Holly Springs and State College, Miss.; Bethany and McCredie, Mo.; Hastings, Nebr.; Beemerville, Marlboro, and New Brunswick, N.J.; Ithaca, Geneva, and Marcellus, N.Y.; Statesville and Raleigh, N.C.; Coshocton and Zanesville, Ohio; Cherokee and Guthrie, Okla.; State College, Pa.; Clemson and Spartanburg, S.C.; Madison, S.Dak.; Knoxville and Greeneville, Tenn.; Temple and Tyler, Tex.; Blacksburg, Va.; Pullman, Wash.; LaCrosse, Madison, and Owen, Wis.; and Mayaguez, P.R.

The major purpose of the soil loss equation is to guide methodical decisionmaking in conservation planning on a site basis. The equation enables the planner to predict the average rate of soil erosion for each of various alternative combinations of crop system, management techniques, and control practices on any particular site. When these predicted losses can be compared with a soil loss tolerance for that site, they provide specific guidelines for effecting erosion control within the specified limits. Any cropping and management combination for which the predicted erosion rate is less than the tolerance may be expected to provide satisfactory erosion control. From the satisfactory alternatives indicated by this procedure, the one best suited to a particular farm or other enterprise may then be selected.

Soil loss tolerances ranging from 5 to 2 t/A/year for the soils of the United States were derived by soil scientists, agronomists, geologists, soil conservationists, and Federal and State research leaders at six regional workshops in 1961 and 1962. Factors considered in defining these limits included soil depth, physical properties and other characteristics affecting root development, gully prevention, on-field sediment problems, seeding losses, soil organic matter reduction, and plant nutrient losses. A deep, medium-textured, moderately permeable soil that has subsoil characteristics favorable for plant growth has a greater tolerance than soils with shallow root zones or high percentages of shale at the surface. Widespread experience has shown these soil loss tolerances to be feasible and generally adequate for sustaining high productivity levels indefinitely. Some soils with deep favorable root zones may exceed the 5-t tolerance without loss of sustained productivity.

Soil loss limits are sometimes established primarily for water quality control. The criteria for defining field soil loss limits for this purpose are not the same as those for tolerances designed to preserve cropland productivity. Soil depth is not relevant for offsite sediment control, and uniform limits on erosion rates will allow a range in the quantities of sediment per unit area that are delivered to a river. Soil material eroded from a field slope may be deposited in the field boundaries, in terrace channels, in depressional areas, or on flat or vegetated areas traversed by the overland flow before it reaches a river. The erosion damages the cropland on which it occurs, but sediment deposited near its place of origin is not directly relevant for water quality control.

If the soil loss tolerance designed for sustained cropland productivity fails to attain the desired water quality standard, flexible limits that consider other factors should be developed rather than uniformly lowering the soil loss tolerance. These factors include distance of the field from a major waterway, the sediment transport characteristics of the intervening area, sediment composition, needs of the particular body of water being protected, and the probable magnitude of fluctuations in sediment loads (*42*). Limits of sediment yield would provide more uniform water quality control than lowering the limits on soil movement from field slopes. They would also require fewer restrictions on crop system selection for fields from which only small percentages of the eroded soil become off-farm sediment.

SOIL LOSS EQUATION

The erosion rate at a given site is determined by the particular way in which the levels on numerous physical and management variables are combined at that site. Physical measurements of soil loss for each of the large number of possible combinations in which the levels of these variable factors can occur under field conditions would not be feasible. Soil loss equations were developed to enable conservation planners to project limited erosion data to the many localities and conditions that have not been directly represented in the research.

The USLE is an erosion model designed to predict the longtime average soil losses in runoff from specific field areas in specified cropping and management systems. Widespread field use has substantiated its usefulness and validity for this purpose. It is also applicable for such nonagricultural conditions as construction sites.

With appropriate selection of its factor values, the equation will compute the average soil loss for a multicrop system, for a particular crop year in a rotation, or for a particular cropstage period within a crop year. It computes the soil loss for a given site as the product of six major factors whose most likely values at a particular location can be expressed numerically. Erosion variables reflected by these factors vary considerably about their means from storm to storm, but effects of the random fluctuations tend to average out over extended periods. Because of the unpredictable short-time fluctuations in the levels of influential variables, however, present soil loss equations are substantially less accurate for prediction of specific events than for prediction of longtime averages.

The soil loss equation is

$$A = R\,K\,L\,S\,C\,P \qquad (1)$$

where

A is the computed soil loss per unit area, expressed in the units selected for **K** and for the period selected for **R.** In practice, these are usually so selected that they compute **A** in tons per acre per year, but other units can be selected.

R, the rainfall and runoff factor, is the number of rainfall erosion index units, plus a factor for runoff from snowmelt or applied water where such runoff is significant.

K, the soil erodibility factor, is the soil loss rate per erosion index unit for a specified soil as measured on a unit plot, which is defined as a 72.6-ft length of uniform 9-percent slope continuously in clean-tilled fallow.

L, the slope-length factor, is the ratio of soil loss from the field slope length to that from a 72.6-ft length under identical conditions.

S, the slope-steepness factor, is the ratio of soil loss from the field slope gradient to that from a 9-percent slope under otherwise identical conditions.

C, the cover and management factor, is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow.

P, the support practice factor, is the ratio of soil loss with a support practice like contouring, stripcropping, or terracing to that with straight-row farming up and down the slope.

The soil loss equation and factor evaluation charts were initially developed in terms of the English units commonly used in the United States. The factor definitions are interdependent, and direct conversion of acres, tons, inches, and feet to metric units would not produce the kind of integers that would be desirable for an expression of the equation in that system. Therefore, only the English units are used in the initial presentation of the equation and factor evaluation materials, and their counterparts in metric units are given in the Appendix under **Conversion to Metric System.**

Numerical values for each of the six factors were derived from analyses of the assembled research data and from National Weather Service precipitation records. For most conditions in the United States, the approximate values of the factors for any particular site may be obtained from charts and tables in this handbook. Localities or countries where the rainfall characteristics, soil types, topographic features, or farm practices are substantially beyond the range of present U.S. data will find these charts and tables incomplete and perhaps inaccurate for their conditions. However, they will provide guidelines that can reduce the amount of local research needed to develop comparable charts and tables for their conditions.

The subsection on **Predicting Cropland Soil Losses,** page 40 illustrates how to select factor values from the tables and charts. Readers who have had no experience with the soil loss equation may wish to read that section first. After they have referred to the tables and figures and located the values used in the sample, they may move readily to the intervening detailed discussions of the equation's factors.

The soil loss prediction procedure is more valuable as a guide for selection of practices if the user has a general knowledge of the principles and factor interrelations on which the equation is based. Therefore, the significance of each factor is discussed before presenting the reference table or chart from which local values may be obtained. Limitations of the data available for evaluation of some of the factors are also pointed out.

RAINFALL AND RUNOFF FACTOR (R)

Rills and sediment deposits observed after an unusually intense storm have sometimes led to the conclusion that the significant erosion is associated with only a few storms, or that it is solely a function of peak intensities. However, more than 30 years of measurements in many States have shown that this is not the case (*51*). The data show that a rainfall factor used to estimate average annual soil loss must include the cumulative effects of the many moderate-sized storms, as well as the effects of the occasional severe ones.

The numerical value used for **R** in the soil loss equation must quantify the raindrop impact effect and must also provide relative information on the amount and rate of runoff likely to be associated with the rain. The rainfall erosion index derived by Wischmeier (*49*) appears to meet these requirements better than any other of the many rainfall parameters and groups of parameters tested against the assembled plot data. The local value of this index generally equals **R** for the soil loss equation and may be obtained directly from the map in figure 1. However, the index does not include the erosive forces of runoff from thaw, snowmelt, or irrigation. A procedure for evaluating **R** for locations where this type of runoff is significant will be given under the topic **R Values for Thaw and Snowmelt.**

Rainfall Erosion Index

The research data indicate that when factors other than rainfall are held constant, storm soil losses from cultivated fields are directly proportional to a rainstorm parameter identified as the **EI** (defined below) (*49*). The relation of soil loss to this parameter is linear, and its individual storm values are directly additive. The sum of the storm **EI** values for a given period is a numerical measure of the erosive potential of the rainfall within that period. The average annual total of the storm **EI** values in a particular locality is the rainfall erosion index for that locality. Because of apparent cyclical patterns in rainfall data (*33*), the published rainfall erosion index values were based on 22-year station rainfall records.

Rain showers of less than one-half inch and separated from other rain periods by more than 6 hours were omitted from the erosion index computations, unless as much as 0.25 in of rain fell in 15 min. Exploratory analyses showed that the **EI** values for such rains are usually too small for practical significance and that, collectively, they have little effect on monthly percentages of the annual **EI.** The cost of abstracting and analyzing 4,000 location-years of rainfall-intensity data was greatly reduced by adopting the 0.5-in threshold value.

EI Parameter

By definition, the value of **EI** for a given rainstorm equals the product, total storm energy (**E**) times the maximum 30-min intensity (I_{30}), where **E** is in hundreds of foot-tons per acre and I_{30} is in inches per hour (in/h). **EI** is an abbreviation for energy-times-intensity, and the term should not be considered simply an energy parameter. The data show that rainfall energy, itself, is not a good indicator of erosive potential. The storm energy indicates the volume of rainfall and runoff, but a long, slow rain may have the same **E** value as a shorter rain at much higher intensity. Raindrop erosion increases with intensity. The I_{30} component indicates the prolonged-peak rates of detachment and runoff. The product term, **EI,** is a statistical interaction term that reflects how total energy and peak inensity are combined in each particular storm. Technically, it indicates how particle detachment is combined with transport capacity.

The energy of a rainstorm is a function of the amount of rain and of all the storm's component intensities. Median raindrop size increases with rain intensity (*62*), and terminal velocities of free-falling waterdrops increase with increased dropsize (*13*). Since the energy of a given mass in motion is proportional to velocity-squared, rainfall energy is directly related to rain intensity. The relationship is expressed by the equation,

$$E = 916 + 331 \log_{10} I, \qquad (2)$$

where **E** is kinetic energy in foot-tons per acre-inch and **I** is intensity in inches per hour (*62*). A limit of 3 in/h is imposed on **I** by the finding that median dropsize does not continue to increase when intensities exceed 3 in/h (*7, 15*). The energy

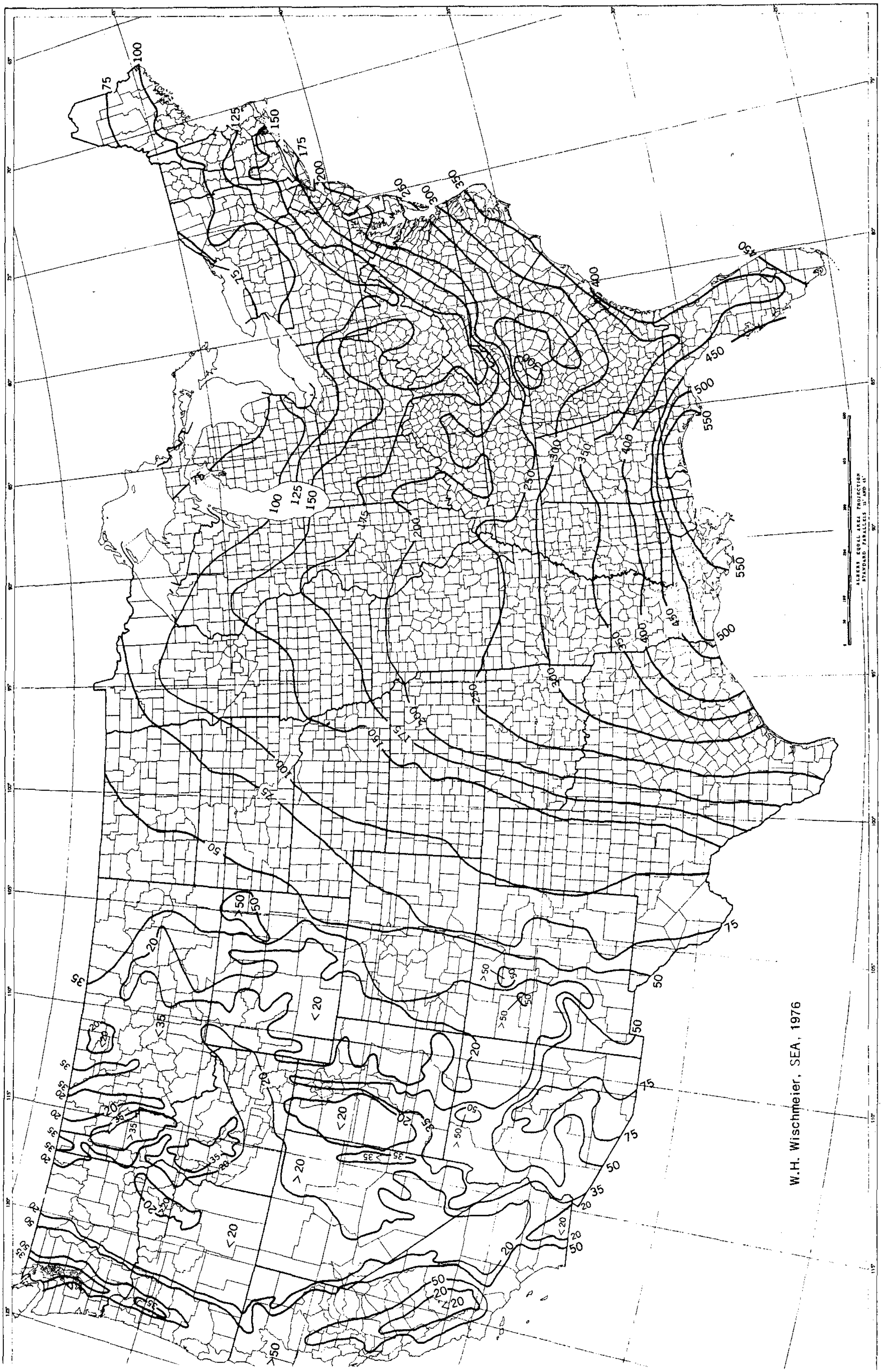

FIGURE 1.—Average annual values of the rainfall erosion index.

of a rainstorm is computed from recording-rain gage data. The storm is divided into successive increments of essentially uniform intensity, and a rainfall energy-intensity table derived from the above formula (app., table 19) is used to compute the energy for each increment. (Because the energy equation and energy-intensity table have been frequently published with energy expressed in foot-tons per acre-inch, this unit was retained in table 19. However, for computation of **EI** values, storm energy is expressed in hundreds of foot-tons per acre. Therefore, energies computed by the published formula or table 19 must be divided by 100 before multiplying by $\mathbf{I}_{30}$ to compute **EI**.)

Isoerodent Maps

Local values of the rainfall erosion index may be taken directly from the isoerodent maps, figures 1 and 2. The plotted lines on the maps are called isoerodents because they connect points of equal rainfall erosivity. Erosion index values for locations between the lines are obtained by linear interpolation.

The isoerodent map in the original version of this handbook (*64*) was developed from 22-year station rainfall records by computing the **EI** value for each storm that met the previously defined threshold criteria. Isoerodents were then located between these point values with the help of published rainfall intensity-frequency data (*47*) and topographic maps. The 11 Western States were omitted from the initial map because the rainfall patterns in this mountainous region are sporadic and not enough long-term, recording-rain gage records were available to establish paths of equal erosion index values.

The isoerodent map was extended to the Pacific Coast in 1976 by use of an estimating procedure. Results of investigations at the Runoff and Soil Loss Data Center at Purdue University showed that the known erosion index values in the Western Plains and North Central States could be approximated with reasonable accuracy by the quantity 27.38 $\mathbf{P}^{2.17}$, where **P** is the 2-year, 6-h rainfall amount (*55*). This relationship was used with National Weather Service isopluvial maps to approximate erosion index values for the Western States. The resulting isoerodents are compatible with the few point values that had been established within the 11 Western States and can provide helpful guides for conservation planning on a site basis. However, they are less precise than those computed for the 37-State area, where more data were available and rainfall patterns are less erratic. Also, linear interpolations between the lines will not always be accurate in mountain regions because values of the erosion index may change rather abruptly with elevation changes. The point values that were computed directly from long-term station rainfall records in the Western States are included in table 7, as reference points.

Figure 2 was developed by computing the erosion index for first-order weather stations in Hawaii and deriving the relation of these values to National Weather Service intensity-frequency data for the five major islands. When the present short-term, rainfall-intensity records have been sufficiently lengthened, more point values of the index should be computed by the standard procedure.

Figure 1 shows that local, average-annual values of the erosion index in the 48 conterminous States range from less than 50 to more than 500. The erosion index measures the combined effect of rainfall and its associated runoff. If the soil and topography were exactly the same everywhere, average annual soil losses from plots maintained in continuous fallow would differ in direct proportion to the erosion index values. However, this potential difference is partially offset by differences in soil, topography, vegetative cover, and residues. On fertile soils in the high rainfall areas of the Southern States, good vegetal cover protects the soil surface throughout most of the year and heavy plant residues may provide excellent cover also during the dormant season. In the regions where the erosion index is extremely low, rainfall is seldom adequate for establishing annual meadows and the cover provided by other crops is often for relatively short periods. Hence, serious soil erosion hazards exist in semiarid regions as well as in humid.

Frequency Distribution

The isoerodent maps present 22-year-average annual values of **EI** for the delineated areas. However, both the annual and the maximum-storm values at a particular location vary from year to year. Analysis of 181 station rainfall records showed that they tend to follow log-normal frequency distributions that are usually well defined by continuous records of from 20 to 25 years (*49*). Tables of specific probabilities of annual and maximum-storm **EI** values at the 181 locations are presented in the appendix (tables 17 and 18).

R Values for Thaw and Snowmelt

The standard rainfall erosion index estimates the erosive forces of the rainfall and its directly associated runoff. In the Pacific Northwest, as much as 90 percent of the erosion on the steeply rolling wheatland has been estimated to derive from runoff associated with surface thaws and snowmelt. This type of erosion is not accounted for by the rainfall erosion index but is considered either predominant or appreciable in much of the Northwest and in portions of the central Western States. A linear precipitation relationship would not account for peak losses in early spring because as the winter progresses, the soil becomes increasingly more erodible as the soil moisture profile is being filled, the surface structure is being broken down by repeated freezing and thawing, and puddling and surface sealing are taking place. Additional research of the erosion processes and means of control under these conditions is urgently needed.

In the meantime, the early spring erosion by runoff from snowmelt, thaw, or light rain on frozen soil may be included in the soil loss computations by adding a subfactor, $\mathbf{R_s}$, to the location's erosion index to obtain **R**. Investigations of limited data indicated that an estimate of $\mathbf{R_s}$ may be obtained by taking 1.5 times the local December-through-March precipitation, measured as inches of water. For example, a location in the North-

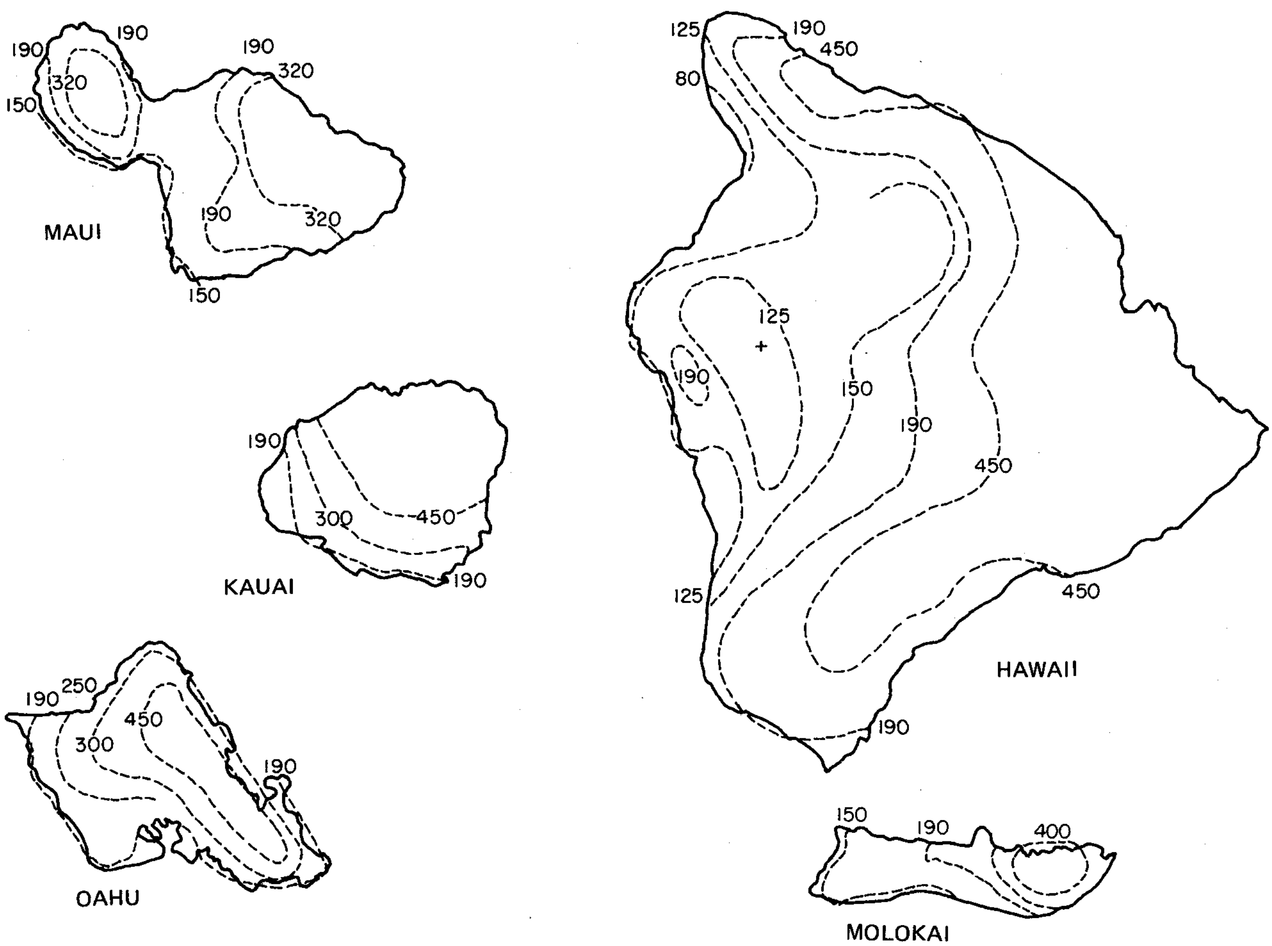

FIGURE 2.—Estimated average annual values of the rainfall erosion index in Hawaii.

west that has an erosion index of 20 (fig. 1) and averages 12 in of precipitation between December 1 and March 31 would have an estimated average annual **R** of 1.5(12) + 20, or 38.

This type of runoff may also be a significant factor in the northern tier of Central and Eastern States. Where experience indicates this to be the case, it should be included in **R** and also in the erosion index distribution curves as illustrated on page 27.

SOIL ERODIBILITY FACTOR (K)

The meaning of the term "soil erodibility" is distinctly different from that of the term "soil erosion." The rate of soil erosion, **A,** in the soil loss equation, may be influenced more by land slope, rainstorm characteristics, cover, and management than by inherent properties of the soil. However, some soils erode more readily than others even when all other factors are the same. This difference, caused by properties of the soil itself, is referred to as the soil erodibility. Several early attempts were made to determine criteria for scientific classifications of soils according to erodibility (*6, 18, 28, 35*), but classifications used for erosion prediction were only relative rankings.

Differences in the natural susceptibilities of soils to erosion are difficult to quantify from field observations. Even a soil with a relatively low erodibility factor may show signs of serious erosion when it occurs on long or steep slopes or in localities with numerous high-intensity rainstorms. A soil with a high natural erodibility factor, on the other hand, may show little evidence of actual erosion under gentle rainfall when it occurs on short and gentle slopes, or when the best possible management is practiced. The effects of rainfall differences, slope, cover, and management are accounted for in the prediction equation by the symbols **R, L, S, C,** and **P.** Therefore, the soil erodibility factor, **K,** must be evaluated independently of the effects of the other factors.

Definition of Factor K

The soil erodibility factor, **K,** in the USLE is a quantitative value experimentally determined. For a particular soil, it is the rate of soil loss per erosion index unit as measured on a "unit" plot, which has been arbitrarily defined as follows:

A unit plot is 72.6 ft long, with a uniform lengthwise slope of 9 percent, in continuous fallow, tilled up and down the slope. Continuous fallow, for this purpose, is land that has been tilled and kept free of vegetation for more than 2 years. During the period of soil loss measurements, the plot is plowed and placed in conventional corn seedbed condition each spring and is tilled as needed to prevent vegetative growth and severe surface crusting. When all of these conditions are met, **L, S, C,** and **P** each equal 1.0, and **K** equals **A/EI.**

The 72.6 ft length and 9 percent steepness were selected as base values for **L, S,** and **K** because they are the predominant slope length and about the average gradient on which past erosion measurements in the United States had been made. The designated management provides a condition that nearly eliminates effects of cover, management, and land use residual and that can be duplicated on any cropland.

Direct measurements of **K** on well-replicated, unit plots as described reflect the combined effects of all the soil properties that significantly influence the ease with which a particular soil is eroded by rainfall and runoff if not protected. However, **K** is an average value for a given soil, and direct measurement of the factor requires soil loss measurements for a representative range of storm sizes and antecedent soil conditions. (See **Individual Storm Soil Losses** under **APPLYING THE SOIL LOSS EQUATION.**) To evaluate **K** for soils that do not usually occur on a 9-percent slope, soil loss data from plots that meet all the other specified conditions are adjusted to this base by **S.**

Values of K for Specific Soils

Representative values of **K** for most of the soil types and texture classes can be obtained from tables prepared by soil scientists using the latest available research information. These tables are available from the Regional Technical Service Centers or State offices of SCS. Values for the exact

TABLE 1.—*Computed* **K** *values for soils on erosion research stations*

Soil	Source of data	Computed K
Dunkirk silt loam	Geneva, N.Y.	[1]0.69
Keene silt loam	Zanesville, Ohio	.48
Shelby loam	Bethany, Mo.	.41
Lodi loam	Blacksburg, Va.	.39
Fayette silt loam	LaCrosse, Wis.	[1].38
Cecil sandy clay loam	Watkinsville, Ga.	.36
Marshall silt loam	Clarinda, Iowa	.33
Ida silt loam	Castana, Iowa	.33
Mansic clay loam	Hays, Kans.	.32
Hagerstown silty clay loam	State College, Pa.	[1].31
Austin clay	Temple, Tex.	.29
Mexico silt loam	McCredie, Mo.	.28
Honeoye silt loam	Marcellus, N.Y.	[1].28
Cecil sandy loam	Clemson, S.C.	[1].28
Ontario loam	Geneva, N.Y.	[1].27
Cecil clay loam	Watkinsville, Ga.	.26
Boswell find sandy loam	Tyler, Tex.	.25
Cecil sandy loam	Watkinsville, Ga.	.23
Zaneis fine sandy loam	Guthrie, Okla.	.22
Tifton loamy sand	Tifton, Ga.	.10
Freehold loamy sand	Marlboro, N.J.	.08
Bath flaggy silt loam with surface stones > 2 inches removed	Arnot, N.Y.	[1].05
Albia gravelly loam	Beemerville, N.J.	.03

[1] Evaluated from continuous fallow. All others were computed from rowcrop data.

soil conditions at a specific site can be computed by use of the soil erodibility nomograph presented in the next subsection.

Usually a soil type becomes less erodible with decrease in silt fraction, regardless of whether the corresponding increase is in the sand fraction or the clay fraction. Overall, organic matter content ranked next to particle-size distribution as an indicator of erodibility. However, a soil's erodibility is a function of complex interactions of a substantial number of its physical and chemical properties and often varies within a standard texture class.

Values of **K** determined for 23 major soils on which erosion plot studies under natural rain were conducted since 1930 are listed in table 1. Seven of these values are from continuous fallow. The others are from row crops averaging 20 plot-years of record and grown in systems for which the cropping effect had been measured in other studies. Other soils on which valuable erosion studies have been conducted[4] were not included in the table because of uncertainties involved in adjustments of the data for effects of cropping and management.

Direct measurement of the erodibility factor is both costly and time consuming and has been feasible only for a few major soil types. To achieve a better understanding of how and to what extent each of various properties of a soil affects its erodibility, an interregional study was initiated in 1961. The study included the use of field-plot rainfall simulators in at least a dozen States to obtain comparative data on numerous soils, laboratory determinations of physical and chemical properties, and operation of additional fallow plots under natural rain. Several empirical erodibility equations were reported (*3, 60*). A soil erodibility nomograph for farmland and construction sites (*58*) provided a more generally applicable working tool. Approximate **K** values for 10 benchmark soils in Hawaii are listed in table 2.

[4] See footnote 3, p. 2.

TABLE 2.—*Approximate values of the soil erodibility factor,* **K**, *for 10 benchmark soils in Hawaii*

Order	Suborder	Great group	Subgroup	Family	Series	K
Ultisols	Humults	Tropohumults	Humoxic Tropohumults	Clayey, kaolinitic, isohyperthermic	Waikane	0.10
Oxisols	Torrox	Torrox	Typic Torrox	Clayey, kaolinitic, isohyperthermic	Molokai	.24
Oxisols	Ustox	Eutrustox	Tropeptic Eutrustox	Clayey, kaolinitic, isohyperthermic	Wahiawa	.17
Vertisols	Usterts	Chromusterts	Typic Chromusterts	Very fine, montmorillonitic, isohyperthermic	Lualualei	.28
Aridisols	Orthids	Camborthids	Ustollic Camborthids	Medial, isohyperthermic	Kawaihae (Extremely stony phase)	.32
Inceptisols	Andepts	Dystrandepts	Hydric Dystrandepts	Thixotropic, isothermic	Kukaiau	.17
Inceptisols	Andepts	Eutrandepts	Typic Eutrandepts	Medial, isohyperthermic	Naolehu (Variant)	.20
Inceptisols	Andepts	Eutrandepts	Entic Eutrandepts	Medial, isohyperthermic	Pakini	.49
Inceptisols	Andepts	Hydrandepts	Typic Hydrandepts	Thixotropic, isohyperthermic	Hilo	.10
Inceptisols	Tropepts	Ustropepts	Vertic Ustropepts	Very fine, kaolinitic, isohyperthermic	Waipahu	.20

SOURCE: El-Swaify and Dangler (9).

Soil Erodibility Nomograph

The soil loss data show that very fine sand (0.05-0.10 mm) is comparable in erodibility to silt-sized particles and that mechanical-analysis data are much more valuable when expressed by an interaction term that describes the proportions in which the sand, silt, and clay fractions are combined in the soil. When mechanical analysis data based on the standard USDA classification are used for the nomograph in figure 3, the percentage of very fine sand (0.1-0.05 mm) must first be transferred from the sand fraction to the silt fraction. The mechanical analysis data are then effectively described by a particle-size parameter **M**, which equals percent silt (0.1-0.002 mm) times the quantity 100-minus-percent-clay. Where the silt fraction does not exceed 70 percent, erodibility varies approximately as the 1.14 power of this parameter, but prediction accuracy is improved by adding information on organic matter content, soil structure, and profile permeability class.

For soils containing less than 70 percent silt and very fine sand, the nomograph (fig. 3) solves the equation:

$$100\,K = 2.1\,M^{1.14}\,(10^{-4})\,(12 - a) + 3.25\,(b - 2) + 2.5\,(c - 3) \quad (3)$$

where

M = the particle-size parameter defined above,
a = percent organic matter,
b = the soil-structure code used in soil classification, and
c = the profile-permeability class.

The intersection of the selected percent-silt and percent-sand lines computes the value of **M** on the unidentified horizontal scale of the nomograph. (Percent clay enters into the computation as 100 minus the percentages of sand and silt.)

The data indicate a change in the relation of **M** to erodibility when the silt and very fine sand fraction exceeds about 70 percent. This change was empirically reflected by inflections in the percent-sand curves at that point but has not been described by a numerical equation.

Readers who would like more detail regarding the data and relationships underlying the nomograph equation may obtain this from journal articles (*58, 60*).

Nomograph Solution

With appropriate data, enter the scale at the left and proceed to points representing the soil's percent sand (0.10-2.0 mm), percent organic matter, structure code, and permeability class as illustrated by the dotted line on the nomograph. The horizontal and vertical moves must be made in the listed sequence. Use linear interpolations between plotted lines. The structure code and permeability classes are defined on the nomograph for reference.

Many agricultural soils have both fine granular topsoil and moderate permeability. For these soils, **K** may be read from the scale labeled "first approximation of **K**," and the second block of the graph is not needed. For all other soils, however, the procedure must be completed to the soil erodibility scale in the second half of the graph.

The mechanical analysis, organic matter, and structure data are those for the topsoil. For evaluation of **K** for desurfaced subsoil horizons, they pertain to the upper 6 in of the new soil profile. The permeability class is the profile permeability. Coarse fragments are excluded when determining percentages of sand, silt, and clay. If substantial, they may have a permanent mulch effect which can be evaluated from the upper curve of the chart on mulch and canopy effects (p. 19, fig. 6) and applied to the number obtained from the nomograph solution.

Confidence Limits

In tests against measured **K** values ranging from 0.03 to 0.69, 65 percent of the nomograph solutions differed from the measured **K** values by less than 0.02, and 95 percent of them by less than 0.04. Limited data available in 1971 for mechanically exposed **B** and **C** subsoil horizons indicated about comparable accuracy for these conditions. However, more recent data taken on desurfaced high-clay subsoils showed the nomograph solution to lack the desired sensitivity to differences in erodibilities of these soil horizons. For such soils the content of free iron and aluminum oxides ranks next to particle-size distribution as an indicator of erodibility (*37*). Some high-clay soils form what has been called irreversible aggregates on the surface when tilled. These behave like larger primary particles.

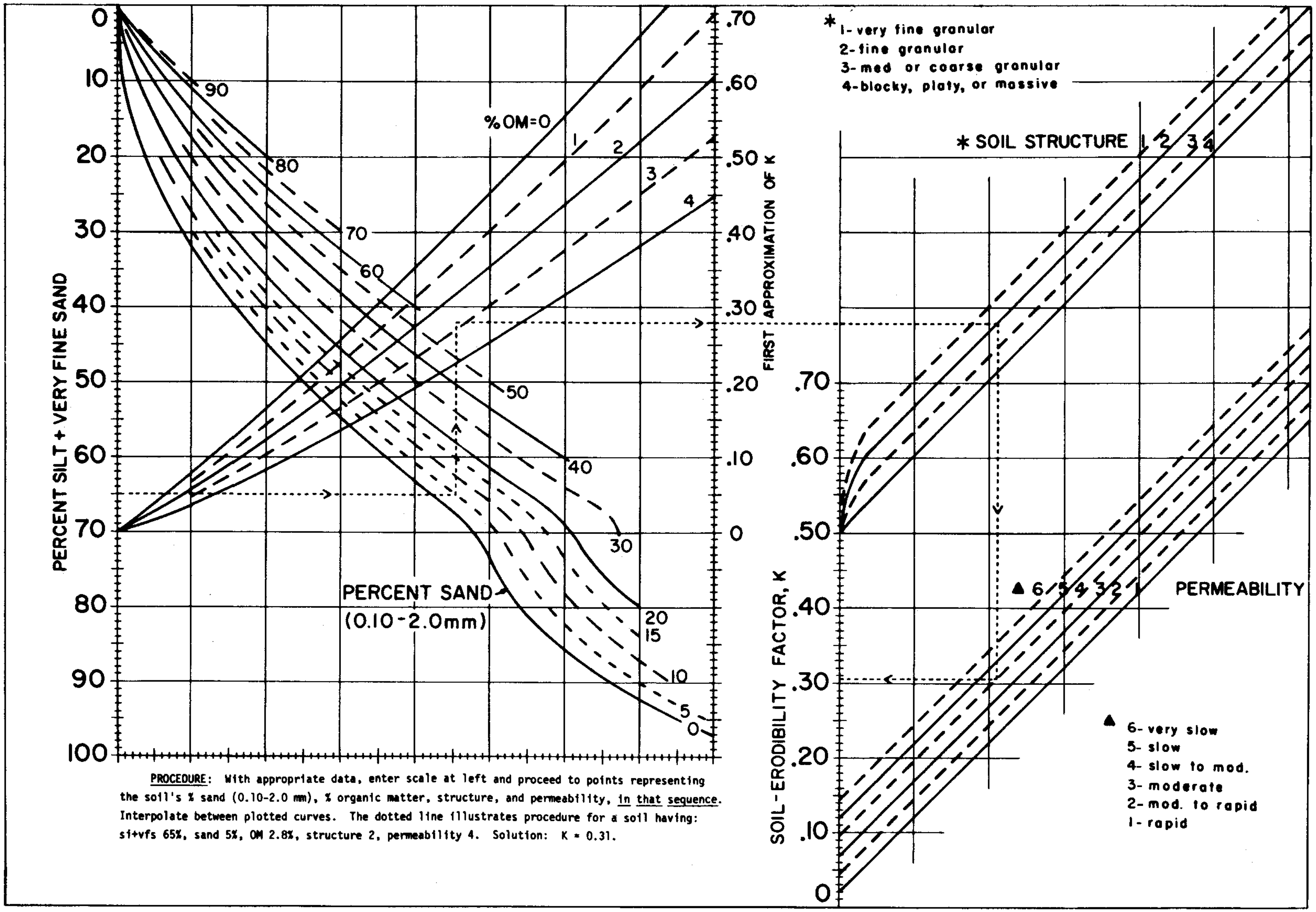

FIGURE 3.—The soil-erodibility nomograph. Where the silt fraction does not exceed 70 percent, the equation is $100\ K = 2.1\ M^{1.14}\ (10^{-4})\ (12 - a) + 3.25\ (b - 2) + 2.5\ (c - 3)$ where $M =$ (percent si + vfs) (100 — percent c), $a =$ percent organic matter, $b =$ structure code, and $c =$ profile permeability class.

TOPOGRAPHIC FACTOR (LS)

Both the length and the steepness of the land slope substantially affect the rate of soil erosion by water. The two effects have been evaluated separately in research and are represented in the soil loss equation by **L** and **S**, respectively. In field applications, however, considering the two as a single topographic factor, **LS**, is more convenient.

Slope-Effect Chart

LS is the expected ratio of soil loss per unit area from a field slope to that from a 72.6-ft length of uniform 9-percent slope under otherwise identical conditions. This ratio for specified combinations of field slope length and uniform gradient may be obtained directly from the slope-effect chart (fig. 4). Enter on the horizontal axis with the field slope length, move vertically to the appropriate percent-slope curve, and read **LS** on the scale at the left. For example, the **LS** factor for a 300-ft length of 10-percent slope is 2.4. Those who prefer a table may use table 3 and interpolate between listed values.

To compute soil loss from slopes that are appreciably convex, concave, or complex, the chart **LS** values need to be adjusted as indicated in the section **LS Values for Irregular Slopes.** Figure 4 and table 3 assume slopes that have essentially uniform gradient. The chart and table were derived by the equation

$$LS = (\lambda/72.6)^m \; (65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065) \quad (4)$$

where λ = slope length in feet;
θ = angle of slope; and
m = 0.5 if the percent slope is 5 or more, 0.4 on slopes of 3.5 to 4.5 percent, 0.3 on slopes of 1 to 3 percent, and 0.2 on uniform gradients of less than 1 percent.

The basis for this equation is given in the subsection discussing the individual effects of slope length and steepness. However, the relationships expressed by the equation were derived from data obtained on cropland, under natural rainfall, on slopes ranging from 3 to 18 percent in steepness and about 30 to 300 ft in length. How far beyond these ranges in slope characteristics the relationships derived from the data continue to be accurate has not been determined by direct soil loss measurements.

The Palouse Region of the Northwest represents

TABLE 3.—*Values of the topographic factor,* **LS**, *for specific combinations of slope length and steepness*[1]

Percent slope	Slope length (feet)											
	25	50	75	100	150	200	300	400	500	600	800	1,000
0.2	0.060	0.069	0.075	0.080	0.086	0.092	0.099	0.105	0.110	0.114	0.121	0.126
0.5	.073	.083	.090	.096	.104	.110	.119	.126	.132	.137	.145	.152
0.8	.086	.098	.107	.113	.123	.130	.141	.149	.156	.162	.171	.179
2	.133	.163	.185	.201	.227	.248	.280	.305	.326	.344	.376	.402
3	.190	.233	.264	.287	.325	.354	.400	.437	.466	.492	.536	.573
4	.230	.303	.357	.400	.471	.528	.621	.697	.762	.820	.920	1.01
5	.268	.379	.464	.536	.656	.758	.928	1.07	1.20	1.31	1.52	1.69
6	.336	.476	.583	.673	.824	.952	1.17	1.35	1.50	1.65	1.90	2.13
8	.496	.701	.859	.992	1.21	1.41	1.72	1.98	2.22	2.43	2.81	3.14
10	.685	.968	1.19	1.37	1.68	1.94	2.37	2.74	3.06	3.36	3.87	4.33
12	.903	1.28	1.56	1.80	2.21	2.55	3.13	3.61	4.04	4.42	5.11	5.71
14	1.15	1.62	1.99	2.30	2.81	3.25	3.98	4.59	5.13	5.62	6.49	7.26
16	1.42	2.01	2.46	2.84	3.48	4.01	4.92	5.68	6.35	6.95	8.03	8.98
18	1.72	2.43	2.97	3.43	4.21	3.86	5.95	6.87	7.68	8.41	9.71	10.9
20	2.04	2.88	3.53	4.08	5.00	5.77	7.07	8.16	9.12	10.0	11.5	12.9

[1] $LS = (\lambda/72.6)^m \; (65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065)$ where λ = slope length in feet; m = 0.2 for gradients $<$ 1 percent, 0.3 for 1 to 3 percent slopes, 0.4 for 3.5 to 4.5 percent slopes, 0.5 for 5 percent slopes and steeper; and θ = angle of slope. (For other combinations of length and gradient, interpolate between adjacent values or see fig. 4.)

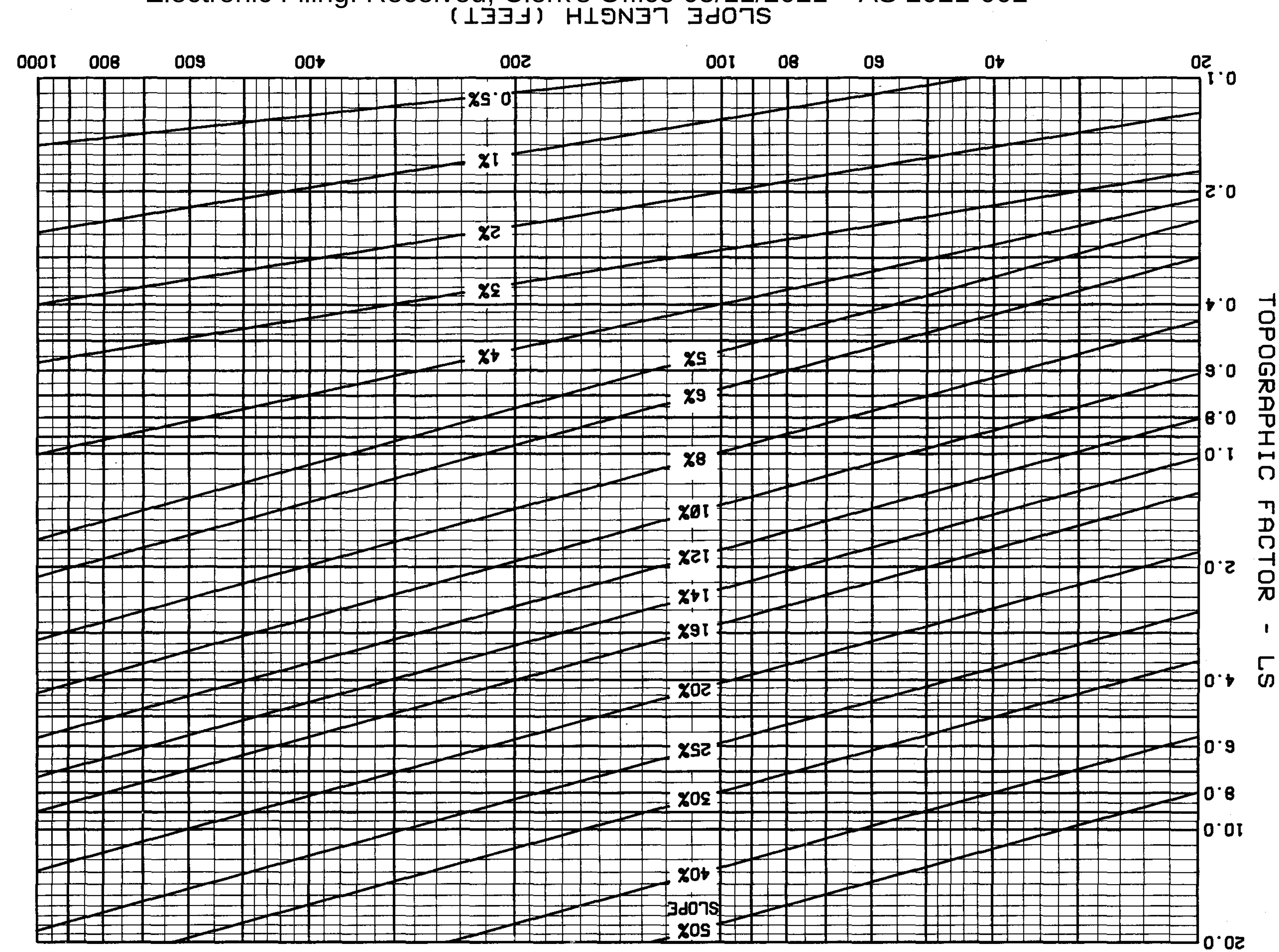

FIGURE 4.—Slope-effect chart (topographic factor, LS). LS = $(\lambda/72.6)^m$ $(65.41 \sin^2\theta + 4.56 \sin\theta + 0.065)$ where λ = slope length in feet; θ = angle of slope; and m = 0.2 for gradients < 1 percent, 0.3 for 1 to 3 percent slopes, 0.4 for 3.5 to 4.5 percent slopes, and 0.5 for slopes of 5 percent or steeper.

a different situation. The rainfall erosion index is quite low because most of the rain comes as small drops and at low intensities. But many of the cropland slopes are long or steep, and substantial erosion occurs because of runoff from snowmelt or light rains over saturated soil surfaces. Limited erosion data from this region, mostly observational, strongly indicate that for this type of runoff (not accompanied by raindrop impact) the effects of percent and length of slope are of lower magnitude than indicated by the humid region data. Investigations designed to develop a more accurate **LS** equation for this region are underway at Pullman, Wash. (*21*). In the meantime, the researchers are temporarily recommending using a modified equation which computes **LS** values that are close to those that would be calculated by the equation given above if $\sin^{1.5}\theta$ were substituted for $\sin^2\theta$ and the length-exponent, **m**, were assumed to equal 0.3. Intuitively, these changes seem reasonable for the conditions under which about 90 percent of the erosion in this region occurs.

Slope-Length Effect

Slope length is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins, or the runoff water enters a well-defined channel that may be part of a drainage network or a constructed channel (*40*). A change in land cover or a substantial change in gradient along a slope does not begin a new slope length for purposes of soil loss estimation.

The effect of slope length on annual *runoff* per unit area of cropland may generally be assumed negligible. In some of the studies runoff per unit area was slightly lower on the longer slopes during the growing season and slightly higher during the dormant season, but the differences were relatively small and neither of the relationships was consistent (*52*).

However, the *soil loss* per unit area generally increases substantially as slope length increases. The greater accumulation of runoff on the longer slopes increases its detachment and transport capacities.

The plot data showed average soil loss per unit area to be proportional to a power of slope length. Because **L** is the ratio of field soil loss to the corresponding loss from 72.6-ft slope length, its value may be expressed as $L = (\lambda/72.6)^m$, where λ is the field slope length in feet, and **m** assumes approximately the values given in the **LS** equation in the preceding section. These are average values of **m** and are subject to some variability caused by interaction effects which are not now quantitatively predictable.

The existing field plot data do not establish a general value greater than 0.5 for **m** on slopes steeper than 10 percent, as was suggested in 1965 (*64*). Although apparent values up to 0.9 were observed in some of the data (*63*), the higher values appear to have been related to soil, crop, and management variables rather than to greater slope steepness. However, basic modeling work has suggested that **m** may appreciably exceed 0.5 on steep slopes that are highly susceptible to rilling, like some construction slopes (*10*). Additional research data are greatly needed to quantify the significant interaction effects so that specific site values of **m** can be more precisely computed. Subdividing erosion between interrill (or sheet) erosion and rill erosion, being done in recent modeling work (*10, 11, 22*), promises to be quite helpful for solving this problem.

Some observations have indicated that the values of the length exponent that were derived from the plot data may overestimate soil loss when applied to lengths in the range of a quarter of a mile or more. This is logical because slopes of such lengths would rarely have a constant gradient along their entire length, and the slope irregularities would affect the amount of soil movement to the foot of the slope. By the definition of slope length quoted earlier, such slopes would usually consist of several lengths, between points where deposition occurs.

Slope length is difficult to determine for long slopes with an average gradient of less than 1 percent, unless they are precisely formed with a land leveler. On flat slopes, reflecting both the erosion and the deposition accurately by a length factor may not be possible. However, on a nearly zero-percent slope, increased length would have minor effect on runoff velocity, and the greater depths of accumulated runoff water would cushion the raindrop impact. An exponent of 0.2 for gradients of less than 1 percent is compatible with the scarce data available for such slopes and was used to derive figure 4 and table 3.

Distribution of Length Effect

LS values from figure 4 or table 3 predict the *average* erosion over the entire slope. But this erosion is not evenly distributed over the entire length. The rate of soil loss per unit of area increases as the $\mathbf{m}^{th}$ power of the distance from the top of the slope, where **m** is the length exponent in the preceding equation.

An equation by Foster and Wischmeier (*12*) estimates the relative amounts of soil loss from successive segments of a slope under conditions where there is no deposition by overland flow. When the gradient is essentially uniform and the segments are of equal length, the procedure can be shortened (*55*). Table 4, derived by this procedure, shows the proportionate amounts of soil detachment from successive equal-length segments of a uniform slope.

Table 4 is entered with the total number of equal-length segments, and the fraction of the soil loss for each segment is read beneath the applicable value of **m**. For example, three equal-length segments of a uniform 6-percent slope would be expected to produce 19, 35, and 46 percent, respectively, of the loss from the entire slope.

TABLE 4.—*Estimated relative soil losses from successive equal-length segments of a uniform slope*[1]

Number of segments	Sequence number of segment	Fraction of soil loss		
		m = 0.5	m = 0.4	m = 0.3
2	1	0.35	0.38	0.41
	2	.65	.62	.59
3	1	.19	.22	.24
	2	.35	.35	.35
	3	.46	.43	.41
4	1	.12	.14	.17
	2	.23	.24	.24
	3	.30	.29	.28
	4	.35	.33	.31
5	1	.09	.11	.12
	2	.16	.17	.18
	3	.21	.21	.21
	4	.25	.24	.23
	5	.28	.27	.25

[1] Derived by the formula:

$$\text{Soil loss fraction} = \frac{j^{m+1} - (j-1)^{m+1}}{N^{m+1}}$$

where **j** = segment sequence number; **m** = slope-length exponent (0.5 for slopes ≥ 5 percent, 0.4 for 4 percent slopes, and 0.3 for 3 percent or less); and **N** = number of equal-length segments into which the slope was divided.

Four segments would produce 12, 23, 30, and 35 percent, respectively. Segment No. 1 is always at the top of the slope.

Percent Slope

Runoff from cropland generally increases with increased slope gradient, but the relationship is influenced by such factors as type of crop, surface roughness, and profile saturation. In the natural rain slope-effect studies, the logarithm of runoff from row crops was linearly and directly proportional to percent slope. With good meadow sod and with smooth bare surfaces, the relationship was insignificant. The effect of slope on runoff decreased in extremely wet periods.

Soil loss increases much more rapidly than runoff as slopes steepen. The slope-steepness factor, **S**, in the soil loss equation is evaluated by the equation

$$S = 65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065 \qquad (5)$$

where θ is the angle of slope.

This equation was used to develop the slope-effect chart. The values reflect the average effect of slope steepness on soil loss in the plot studies. The relation of percent slope to soil loss is believed to be influenced by interactions with soil properties and surface conditions, but the interaction effects have not been quantified by research data. Neither are data available to define the limits on the equation's applicability.

This equation can be derived from the formerly published equation for **S**. Expressing the factor as a function of the sine of the angle of slope rather than the tangent is more accurate because raindrop-impact forces along the surface and runoff shear stress are functions of the sine. Substituting 100 sin θ for percent slope, which is 100 tan θ, does not significantly affect the initial statistical derivation or the equation's solutions for slopes of less than 20 percent. But as slopes become steeper, the difference between the sine and the tangent becomes appreciable and projections far beyond the range of the plot data become more realistic. The numerator was divided by the constant denominator for simplification.

Irregular Slopes

Soil loss is also affected by the shape of a slope. Many field slopes either steepen toward the lower end (convex slope) or flatten toward the lower end (concave slope). Use of the average gradient to enter figure 4 or table 3 would underestimate soil movement to the foot of a convex slope and would overestimate it for concave slopes. Irregular slopes can usually be divided into segments that have nearly uniform gradient, but the segments cannot be evaluated as independent slopes when runoff flows from one segment to the next.

However, where two simplifying assumptions can be accepted, **LS** for irregular slopes can be routinely derived by combining selected values from the slope-effect chart and table 4 (*55*). The assumptions are that (1) the changes in gradient are not sufficient to cause upslope deposition, and (2) the irregular slope can be divided into a small number of equal-length segments in such a manner that the gradient within each segment for practical purposes can be considered uniform.

After dividing the convex, concave, or complex slope into equal-length segments as defined earlier, the procedure is as follows: List the segment gradients in the order in which they occur on the slope, beginning at the upper end. Enter the slope-effect chart with the total slope length and read **LS** for each of the listed gradients. Multiply these by the corrresponding factors from table 4 and add the products to obtain **LS** for the entire slope. The following tabulation illustrates the procedure for a 400-ft convex slope on which the upper third has a gradient of 5 percent; the middle third, 10 percent; and the lower third, 15 percent:

Segment	*Percent slope*	*Table 3*	*Table 4*	*Product*
1	5	1.07	0.19	0.203
2	10	2.74	.35	.959
3	15	5.12	.46	2.355
				LS = 3.517

For the concave slope of the same length, with the segment gradients in reverse order, the values in the third column would be listed in reverse order. The products would then be 0.973, 0.959, and 0.492, giving a sum of 2.42 for **LS**.

Research has not defined just how much gradient change is needed under various conditions for deposition of soil particles of various sizes to begin, but depositional areas can be determined by observation. When the slope breaks are sharp enough to cause deposition, the procedure can be used to estimate **LS** for slope segments above and below the depositional area. However, it will not predict the total sediment moved from such an interrupted slope because it does not predict the amount of deposition.

Changes in Soil Type or Cover Along the Slope

The procedure for irregular slopes can include evaluation of changes in soil type within a slope length (*55*). The products of values selected from table 3 or figure 4 and table 4 to evaluate **LS** for irregular slopes are multiplied by the respective values of **K** before summing. To illustrate, assume the **K** values for the soils in the three segments of the convex slope in the preceding example were 0.27, 0.32, and 0.37, respectively. The average **KLS** for the slope would be obtained as follows:

Segment No.	*Table 3*	*Table 4*	**K**	*Product*
1	1.07	0.19	0.27	0.055
2	2.74	.35	.32	.307
3	5.12	.46	.37	.871
				KLS = 1.233

Within limits, the procedure can be further extended to account for changes in cover along the slope length by adding a column of segment **C** values. However, it is not applicable for situations where a practice change along the slope causes deposition. For example, a grass buffer strip across the foot of a slope on which substantial erosion is occurring induces deposition. The amount of this deposition is a function of transport relationships (*10*) and cannot be predicted by the USLE.

Equation for Soil Detachment on Successive Segments of a Slope

This procedure is founded on an equation (12) that can be applied also when the slope segments are not of equal length. Concepts underlying this equation include the following:

Sediment load at a location on a slope is controlled either by the transport capacity of the runoff and rainfall or by the amount of detached soil material available for transport. When the amount of detached material exceeds the transport capacity, deposition occurs and the sediment load is determined primarily by the transport capacity of the runoff at that location. Where upslope detachment has not equaled the transport capacity, sediment load at a given location is a function of erosion characteristics of the upslope area and can be computed by the USLE. Soil loss from a given segment of the slope can then be computed as the difference between the sediment loads at the lower and upper ends of the segment.

Foster and Wischmeier (12) present a procedure for using this equation to evaluate **LS** for irregular slopes and to account for the effects of the soil or coverage changes along a slope, so long as the changes do not cause deposition to occur.

COVER AND MANAGEMENT FACTOR (C)

Cover and management effects cannot be independently evaluated because their combined effect is influenced by many significant interrelations. Almost any crop can be grown continuously, or it can be grown in rotations. Crop sequence influences the length of time between successive crop canopies, and it also influences the benefits obtained from residual effects of crops and management. The erosion control effectiveness of meadow sod turned under before a row crop depends on the type and quality of the meadow and on the length of time elapsed since the sod was turned under. Seedbeds can be clean tilled, or they can be protected by prior crop residues. They can be left rough, with much available capacity for surface storage and reduction of runoff velocity, or they can be smoothed by secondary tillage.

Crop residues can be removed, left on the surface, incorporated near the surface, or plowed under. When left on the surface, they can be chopped or dragged down, or they can be allowed to remain as left by the harvesting operation. The effectiveness of crop residue management will depend on the amount of residue available. This, in turn, depends on the amount and distribution of rainfall, on the fertility level, and on the management decisions made by the farmer.

The canopy protection of crops not only depends on the type of vegetation, the stand, and the quality of growth, but it also varies greatly in different months or seasons. Therefore, the overall erosion-reducing effectiveness of a crop depends largely on how much of the erosive rain occurs during those periods when the crop and management practices provide the least protection.

Definition of Factor C

Factor **C** in the soil loss equation is the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled, continuous fallow. This factor measures the combined effect of all the interrelated cover and management variables.

The loss that would occur on a particular field if it were continuously in fallow condition is computed by the product of **RKLS** in the soil loss equation. Actual loss from the cropped field is usually much less than this amount. Just how much less depends on the particular combination of cover, crop sequence, and management practices. It also depends on the particular stage of growth and development of the vegetal cover at the time of the rain. **C** adjusts the soil loss estimate to suit these conditions.

The correspondence of periods of expected highly erosive rainfall with periods of poor or good plant cover differs between regions or locations. Therefore, the value of **C** for a particular cropping system will not be the same in all parts of the country. Deriving the appropriate **C** values for a given locality requires knowledge of how the erosive rainfall in that locality is likely to be distributed through the 12 months of the year and how much erosion control protection the growing plants, crop residues, and selected management practices will provide at the time when erosive rains are most likely to occur. A procedure is presented for deriving local values of **C** on the basis of available weather records and research data that reflect effects of crops and management in successive segments of a rotation cycle. The cropping and weather data needed for this purpose appear in reference form in the subsections entitled, **Soil Loss Ratios** and **Erosion Index Distribution Data.**

Cropstage Periods

The change in effectiveness of plant cover within the crop year is gradual. For practical purposes, the year is divided into a series of cropstage periods defined so that cover and management effects may be considered approximately uniform within each period.

Initially, five periods were used, with the seedling and establishment periods defined as the first and second months after crop seeding (*50*). Because of the existing ranges in soil fertility, row spacing, plant population, and general growing conditions, however, soil loss prediction accuracy is improved when the cropstage periods are defined according to percentage of canopy cover rather than for uniform time periods. The lengths of the respective periods will then vary with crop, climate, and management and will be determined by conditions in a particular geographic area.

The soil loss ratios presented in the next subsection for computation of **C** were evaluated for six cropstage periods defined as follows:

Period F (rough fallow)—Inversion plowing to secondary tillage.

Period SB (seedbed)—Secondary tillage for seedbed preparation until the crop has developed 10 percent canopy cover.

Period 1 (establishment)—End of *SB* until crop has developed a 50 percent canopy cover. (Exception: period 1 for cotton ends at 35 percent canopy cover.)

Period 2 (development)—End of period 1 until canopy cover reaches 75 percent. (60 percent for cotton.)

Period 3 (maturing crop)—End of period 2 until crop harvest. This period was evaluated for three levels of final crop canopy.

Period 4 (residue or stubble)—Harvest to plowing or new seeding.

Quantitative Evaluations of Crop and Management Effects

More than 10,000 plot-years of runoff and soil loss data from natural rain,[5] and additional data from a large number of erosion studies under simulated rainfall, were analyzed to obtain empirical measurements of the effects of cropping system and management on soil loss at successive stages of crop establishment and development. Soil losses measured on the cropped plots were compared with corresponding losses from clean-tilled, continuous fallow to determine the soil loss reductions ascribable to effects of the crop system and management. The reductions were then analyzed to identify and evaluate influential subfactors, interactions, and correlations. Mathematical relationships observed for one crop or geographic region were tested against data from other research sites for consistency. Those found compatible with all the relevant data were used to compute soil loss reductions to be expected from conditions not directly represented in the overall plot studies.

The value of **C** on a particular field is determined by many variables, one of which is weather. Major variables that can be influenced by management decisions include crop canopy, residue mulch, incorporated residues, tillage, land use residual, and their interactions. Each of these effects may be treated as a subfactor whose numerical value is the ratio of soil loss with the effect to corresponding loss without it (*57*). **C** is the product of all the pertinent subfactors.

Crop Canopy

Leaves and branches that do not directly contact the soil have little effect on amount and velocity of *runoff* from prolonged rains, but they reduce the effective rainfall energy by intercepting falling raindrops. Waterdrops falling from the canopy may regain appreciable velocity but usually less than the terminal velocities of free-falling

[5] See footnote 3, p. 2.

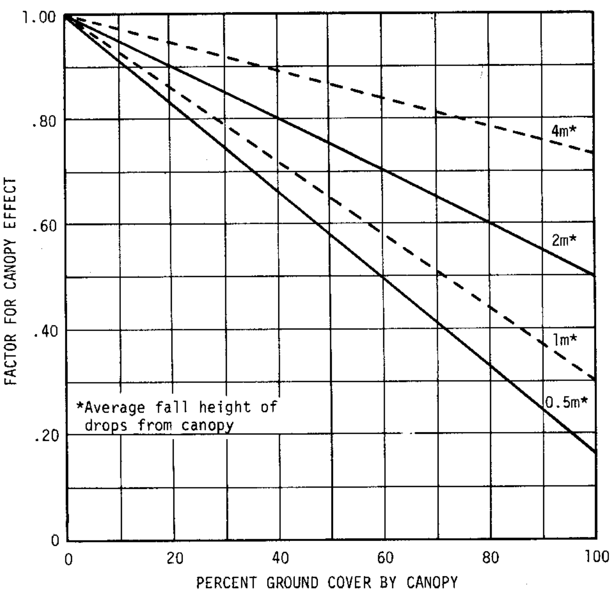

FIGURE 5.—Influence of vegetative canopy on effective EI values. Canopy factor is a subfactor of **C**.

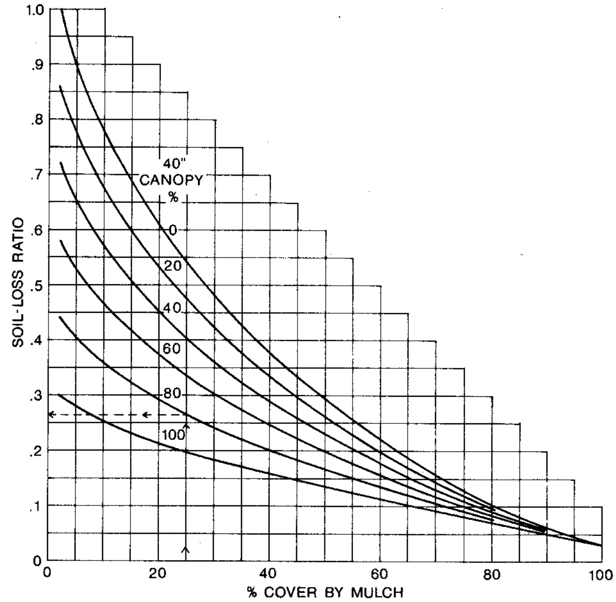

FIGURE 6.—Combined mulch and canopy effects when average fall distance of drops from canopy to the ground is about 40 inches (1 m).

raindrops. The amount by which energy expended at the soil surface is reduced depends on the height and density of the canopy. The subfactor for canopy effect can be estimated for specified conditions by reference to figure 5.

Residue Mulch

Residue mulches and stems from close-growing vegetation are more effective than equivalent percentages of canopy cover. Mulches intercept falling raindrops so near the surface that the drops regain no fall velocity, and they also obstruct runoff flow and thereby reduce its velocity and transport capacity. Measurements of the effectiveness of several types and rates of mulch have been published (*1, 2, 20, 27, 43*). Average subfactors for specific percentages of surface cover by plant materials at the soil surface are given by the upper curve of figure 6. Guides for estimating percent cover are given in the appendix.

If the cover includes both canopy and mulch, the two are not fully additive; the impact energy of drops striking the mulch is dissipated at that point regardless of whether canopy interception has reduced its velocity. The expected effects of mulch and canopy combinations have been computed and are given in figures 6 and 7. Figure 6 applies to corn, sorghum, and cotton in the maturing stage. Figure 7 applies to small grain, soybeans, potatoes, and the establishment period for taller row crops. Enter either figure 6 or 7 along the horizontal scale, move vertically to the appro-

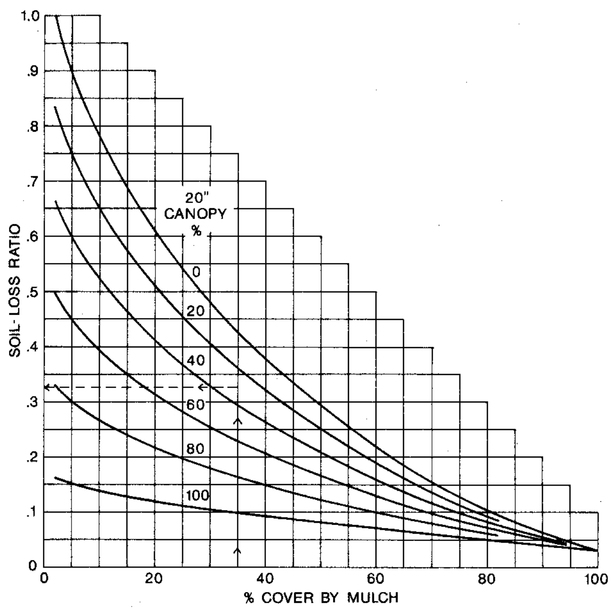

FIGURE 7.—Combined mulch and canopy effects when average fall distance of drops from canopy to the ground is about 20 inches (0.5 m).

priate percent-canopy curve, and read at the left the soil loss ratio from cover effect. This ratio is a subfactor that may be combined with other pertinent subfactors to account for the cropstage soil loss of table 5 or to estimate others.

Incorporated Residues

The plot data indicate that, at least during the seedbed and establishment periods, the erosion-reducing effectivensss of residues mixed into the upper few inches of soil by shallow tillage is appreciably greater than the residual effect of long-term annual incorporation with a moldboard plow. However, the incorporated residues are less effective than if left on the surface.

Tillage

The type, frequency, and timing of tillage operations influence porosity, roughness, cloddiness, compaction, and microtopography. These, in turn, affect water intake, surface storage, runoff velocity, and soil detachability, all of which are factors in potential erosion. These effects are highly correlated with cropland residual effects.

Land Use Residuals

These include effects of plant roots; long-term residue incorporation by plowing; changes in soil structure, detachability, density, organic matter content, and biological activity; and probably other factors. The residual effects are most apparent during seedbed and establishment periods.

Some residual effect will be apparent on nearly any cropland, but the magnitude of its erosion-reducing effectiveness will differ substantially with crops and practices. Tillage and land use residuals are influenced by so many factor interrelations that development of charts like those for canopy and mulch has not been feasible. However, apparent values of these subfactors for some situations were derived from the data and used for expansion of the soil loss ratio table to include conditions somewhat different from those directly represented in the plot studies.

Plowing residues down is far less effective than leaving them on the surface but better than burning them or removing them from the land. After several years of turning the crop residues under with a moldboard plow before row crop seeding in plot studies under natural rainfall, both runoff and soil loss from the row crops were much less than from similar plots from which cornstalks and grain straw were removed at harvesttimes (*52*, *54*, *59*).

Short periods of rough fallow in a rotation will usually lose much less soil than the basic, clean-tilled, continuous fallow conditions for which **C** = 1. This is largely because of residual effects and is also partly because of the roughness and cloddiness.

The most pronounced residual effect is that from long-term sod or forest. The effect of a grass-and-legume rotation meadow turned under diminishes gradually over about 2 years. In general, the erosion-reducing effectiveness of sod residual (from grass or grass-and-legume meadows) in the plot studies was directly proportional to hay yields. Site values of the subfactor for sod residuals in rotations can be obtained from soil loss ratio table 5-D. The effectiveness of virgin sod and of long periods of alfalfa in which grass became well established was longer lasting. Mixtures of grasses and legumes were more effective than legumes alone.

Residual effectiveness of winter cover crops plowed under in spring depends largely on the type and quality of the crop and its development stage at the time it is plowed under. The effectiveness of grass-and-legume catch crops turned under in spring was less and of shorter duration than that of full-year rotation meadows. Covers such as vetch and ryegrass seeded between corn or cotton rows before harvest and turned under in April were effective in reducing erosion during the winter and showed some residual effect in the following seedbed and establishment periods. Small grain seeded alone in corn or cotton residues showed no residual effect under the next crop. Small grain or vetch on fall-plowed seedbed and turned at spring planting time lost more soil than adjacent plots with undisturbed cotton residues on the surface.

Soil Loss Ratios

Factor **C** is usually given in terms of its average annual value for a particular combination of crop system, management, and rainfall pattern. To derive site values of **C**, soil loss ratios for the individual cropstage periods must be combined with erosion-index distribution data, as demonstrated later. Ratios of soil losses in each cropstage period of specified cropping and management systems to corresponding losses from the basic long-term fallow condition were derived from analysis of about a quarter million plot soil loss observations. The ratios are given in table 5 as percentages.

The observed soil loss ratios for given conditions often varied substantially from year to year because of influences of unpredictable random variables and experimental error. The percentages listed in table 5 are the best available averages for the specified conditions. To make the table inclusive enough for general field use, expected ratios had to be computed for cover, residue, and management combinations that were not directly represented in the plot data. This was done by using empirical relationships of soil losses to the subfactors and interactions discussed in the preceding subsection. The user should recognize that the tabulated percentages are subject to appreciable experimental error and could be improved through additional research. However, because of the large volume of data considered in developing the table, the listed values should be near enough to the true averages to provide highly valuable planning and monitoring guidelines. A ratio derived locally from 1-year rainfall simulator tests on a few plots would not necessarily represent the true average for that locality more accurately. Small samples are more subject to bias by random variables and experimental error than larger samples.

Table for Cropland

Table 5, with its supplements 5A, B, C, and D, replaces tables 2, 3, and 4 in the 1965 edition. The supplements had to be separated from the main table to accommodate changes in format requirements. The ratios are expressed as percentages in the tables to eliminate decimal points.

More than half the lines in table 5 are for conditions associated with conservation tillage practices (*65*), which were not included in the 1965 edition. Also, it provides a direct means of crediting effects of faster and more complete canopy development by improved fertility, closer row spacing, and greater plant population. Because the table includes several times as many specific conditions as the table in the 1965 edition and defines applicable field conditions more accurately, some simplicity has been sacrificed. However, it is not intended for direct use by each field technician or farmer.

Table 5 as presented here is designed to provide the details needed by a trained agronomist to develop simple handbook tables of **C** values for conditions in specific climatic areas. It is designed for use of the revised definitions of cropstage periods given in the preceding section. The agronomist will first determine, for the particular climatic area, the number of weeks normally required for the crop canopies to attain 10, 50, and 75 percent surface cover, respectively. The table will then be used as illustrated in the next major section. Linear interpolation between ratios listed in the table is recommended where appropriate.

Semiarid Regions

Water erosion is a serious problem also in subhumid and semiarid regions. Inadequate moisture and periodic droughts reduce the periods when growing plants provide good soil cover and limit the quantities of plant residue produced. Erosive rainstorms are not uncommon, and they are usually concentrated within the season when cropland is least protected. Because of the difficulty of establishing rotation meadows and the competition for available soil moisture, sod-based rotations are often impractical. One of the most important opportunities for a higher level of soil and moisture conservation is through proper management of available residues. The effects of mulch-tillage practices in these areas can be evaluated from lines 129 to 158 of table 5 and item 12 of 5-B.

Erosion Index Distribution Data

The rainfall factor, **R**, in the soil loss equation does not completely describe the effects of local differences in rainfall pattern on soil erosion. The erosion control effectiveness of a cropping system on a particular field depends, in part, on how the year's erosive rainfall is distributed among the six cropstage periods of each crop included in the system. Therefore, expected monthly distribution

TABLE 5.—*Ratio of soil loss from cropland to corresponding loss from continuous fallow*

Line No.	Cover, crop sequence, and management[1]	Spring residue[2]	Cover after plant[3]	Soil loss ratio[4] for cropstage period and canopy cover[5]							
				F	SB	1	2	3:80	90	96	4L[6]
		Lb	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*
	CORN AFTER C, GS, G OR COT IN MEADOWLESS SYSTEMS										
	Moldboard plow, conv till:										
1	RdL, sprg TP	4,500	—	31	55	48	38	—	—	20	23
2		3,400	—	36	60	52	41	—	24	20	30
3		2,600	—	43	64	56	43	32	25	21	37
4		2,000	—	51	68	60	45	33	26	22	47
5	RdL, fall TP	HP[2]	—	44	65	53	38	—	—	20	—
6		GP	—	49	70	57	41	—	24	20	—
7		FP	—	57	74	61	43	32	25	21	—
8		LP	—	65	78	65	45	32	26	22	—
9	RdR, sprg TP	HP	—	66	74	65	47	—	—	22	56
10		GP	—	67	75	66	47	—	27	23	62
11		FP	—	68	76	67	48	35	27	—	69
12		LP	—	69	77	68	49	35	—	—	74
13	RdR, fall TP	HP	—	76	82	70	49	—	—	22	—
14		GP	—	77	83	71	50	—	27	23	—
15		FP	—	78	85	72	51	35	27	—	—
16		LP	—	79	86	73	52	35	—	—	—
17	*Wheeltrack pl, RdL, TP*[8]	4,500	—	—	31	27	25	—	—	18	23
18		3,400	—	—	36	32	30	—	22	18	30
19		2,600	—	—	43	36	32	29	23	19	37
20		2,000	—	—	51	43	36	31	24	20	47
21	*Deep off-set disk or*	4,500	10	—	45	38	34	—	—	20	23
22	*disk plow*	3,400	10	—	52	43	37	—	24	20	30
23		2,600	5	—	57	48	40	32	25	21	37
24		2,000	—	—	61	51	42	33	26	22	47
25	*No-till plant in crop residue*[9]	6,000	95	—	2	2	2	—	—	2	14
26		6,000	90	—	3	3	3	—	—	3	14
27		4,500	80	—	5	5	5	—	—	5	15
28		3,400	70	—	8	8	8	—	8	6	19
29		3,400	60	—	12	12	12	12	9	8	23
30		3,400	50	—	15	15	14	14	11	9	27
31		2,600	40	—	21	20	18	17	13	11	30
32		2,600	30	—	26	24	22	21	17	14	36
	Chisel, shallow disk, or fld cult, as only tillage:										
33	On moderate slopes	6,000	70	—	8	8	7	—	—	7	17
34			60	—	10	9	8	—	—	8	17
35			50	—	13	11	10	—	—	9	18
36			40	—	15	13	11	—	—	10	19
37			30	—	18	15	13	—	—	12	20
38			20	—	23	20	18	—	—	16	21
39	Do.	4,500	70	—	9	8	7	—	—	7	18
40			60	—	12	10	9	—	—	8	18
41			50	—	14	13	11	—	—	9	19
42			40	—	17	15	13	—	—	10	20
43			30	—	21	18	15	—	—	13	21
44			20	—	25	22	19	—	—	16	22

Line No.	Cover, crop sequence, and management[1]	Spring residue[2]	Cover after plant[3]	Soil loss ratio[4] for cropstage period and canopy cover[5]							
				F	SB	1	2	3:80	90	96	4L[6]
		Lb	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*
	CORN AFTER WC OF RYEGRASS OR WHEAT SEEDED IN C STUBBLE										
	WC reaches stemming stage:										
79	No-till pl in killed WC	4,000	—	—	7	7	7	—	7	6	([13])
80		3,000	—	—	11	11	11	11	9	7	
81		2,000	—	—	15	15	14	14	11	9	
82		1,500	—	—	20	19	18	18	14	11	
	Strip till one-fourth row space										
83	Rows U/D slope	4,000	—	—	13	12	11	—	11	9	([13])
84		3,000	—	—	18	17	16	16	13	10	
85		2,000	—	—	23	22	20	19	15	12	
86		1,500	—	—	28	26	24	22	17	14	
87	Rows on contour[11]	4,000	—	—	10	10	10	—	10	8	([13])
88		3,000	—	—	15	15	15	15	12	9	
89		2,000	—	—	20	20	19	19	15	12	
90		1,500	—	—	25	24	23	22	17	14	
91	TP, conv seedbed	4,000	—	36	60	52	41	—	24	20	([13])
92		3,000	—	43	64	56	43	31	25	21	
93		2,000	—	51	68	60	45	33	26	22	
94		1,500	—	61	73	64	47	35	27	23	
	WC succulent blades only:										
95	No-till pl in killed WC	3,000	—	—	11	11	17	23	18	16	([13])
96		2,000	—	—	15	15	20	25	20	17	
97		1,500	—	—	20	20	23	26	21	18	
98		1,000	—	—	26	26	27	27	22	19	
99	Strip till one-fourth row space	3,000	—	—	18	18	21	25	20	17	([13])
100		2,000	—	—	23	23	25	27	21	18	
101		1,500	—	—	28	28	28	28	22	19	
102		1,000	—	—	33	33	31	29	23	20	
	CORN IN SOD-BASED SYSTEMS										
	No-till pl in killed sod:										
103	3 to 5 tons hay yld	—	—	—	1	1	1	—	1	1	1
104	1 to 2 tons hay yld	—	—	—	2	2	2	2	2	2	2
	Strip till, 3-5 ton M:										
105	50 percent cover, tilled strips	—	—	—	2	2	2	—	2	2	4
106	20 percent cover, tilled strips	—	—	—	3	3	3	—	3	3	5
	Strip till, 1-2 ton M:										
107	40 percent cover, tilled strips	—	—	—	4	4	4	4	4	4	6
108	20 percent cover, tilled strips	—	—	—	5	5	5	5	5	5	7
	Other tillage after sod:			([14])	([14])	([14])	([14])	([14])	([14])	([14])	([14])
	CORN AFTER SOYBEANS										
109	*Sprg TP, conv till*	HP	—	40	72	60	48	—	—	25	29
110		GP	—	47	78	65	51	—	30	25	37
111		FP	—	56	83	70	54	40	31	26	44
112	*Fall TP, conv till*	HP	—	47	75	60	48	—	—	25	—
113		GP	—	53	81	65	51	—	30	25	—
114		FP	—	62	86	70	54	40	31	26	—

45	Do.	3,400	60	—	13	11	10	—	10	8	20
46			50	—	16	13	12	—	12	9	24
47			40	—	19	17	16	—	14	11	25
48			30	—	23	21	19	—	17	14	26
49			20	—	29	25	23	—	21	16	27
50			10	—	36	32	29	—	24	20	30
51	Do.	2,600	50	—	17	16	15	15	13	10	29
52			40	—	21	20	19	19	15	12	30
53			30	—	25	23	22	22	18	14	32
54			20	—	32	29	28	27	22	17	34
55			10	—	41	36	34	32	25	21	37
56	Do.	2,000	40	—	23	21	20	20	15	12	37
57			30	—	27	25	24	23	19	15	39
58			20	—	35	32	30	28	22	18	42
59			10	—	46	42	38	33	26	22	47
	On slopes > 12 percent.										
60	Lines 33-59 times factor of:	—	—	—	1.3	1.3	1.1	1.0	1.0	1.0	1.0
	Disk or harrow after spring chisel or fld cult:										
	Lines 33-59 times factor of:										
61	On moderate slopes	—	—	—	1.1	1.1	1.1	1.0	1.0	1.0	1.0
62	On slopes > 12 percent	—	—	—	1.4	1.4	1.2	1.0	1.0	1.0	1.0
	Ridge plant:[10]										
	Lines 33-59 times factor of:										
63	Rows on contour[11]	—	—	—	.7	.7	.7	.7	.7	.7	.7
64	Rows U/D slope < 12 percent	—	—	—	.7	.7	1.0	1.0	1.0	1.0	1.0
65	Rows U/D slope > 12 percent	—	—	—	.9	.9	1.0	1.0	1.0	1.0	1.0
	Till plant:										
	Lines 33-59 times factor of:										
66	Rows on contour[11]	—	—	—	.7	.85	1.0	1.0	1.0	1.0	1.0
67	Rows U/D slope < 7 percent	—	—	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Strip till one-fourth of row spacing:										
68	Rows on contour[11]	4,500	[12]60	—	12	10	9	—	—	8	23
69		3,400	50	—	16	14	12	—	11	10	27
70		2,600	40	—	22	19	17	17	14	12	30
71		2,000	30	—	27	23	21	20	16	13	36
72	Rows U/D slope	4,500	[12]60	—	16	13	11	—	—	9	23
73		3,400	50	—	20	17	14	—	12	11	27
74		2,600	40	—	26	22	19	17	14	12	30
75		2,000	30	—	31	26	23	20	16	13	36
	Vari-till:										
76	Rows on contour[11]	3,400	40	—	13	12	11	—	—	11	22
77		3,400	30	—	16	15	14	14	13	12	26
78		2,600	20	—	21	19	19	19	16	14	34

115	*Fall & sprg chisel or cult*	HP	[15]30	—	40	35	29	—	—	23	29
116		GP	25	—	45	39	33	—	27	23	37
117		GP	20	—	51	44	39	34	27	23	37
118		FP	15	—	58	51	44	36	28	23	44
119		LP	10	—	67	59	48	36	28	23	54
120	*No-till pl in crop res'd*	HP	[15]40	—	25	20	19	—	14	11	26
121		GP	30	—	33	29	25	22	18	14	33
122		FP	20	—	44	38	32	27	23	18	40
	BEANS AFTER CORN										
123	*Sprg TP, RdL, conv till*	HP	—	33	60	52	38	—	20	17	(16)
124		GP	—	39	64	56	41	—	21	18	
125		FP	—	45	68	60	43	29	22	—	
126	*Fall TP, RdL, conv till*	HP	—	45	69	57	38	—	20	17	(16)
127		GP	—	52	73	61	41	—	21	18	
128		FP	—	59	77	65	43	29	22	—	
	Chisel or fld cult:			(17)	(17)	(17)	(17)	(17)	(17)	(17)	(18)
	BEANS AFTER BEANS			(18)	(18)	(18)	(18)	(18)	(18)	(18)	(16)
	GRAIN AFTER C, G, GS, COT[19]										
129	*In disked residues:*	4,500	70	—	12	12	11	7	4	2	(20)
130		3,400	60	—	16	14	12	7	4	2	
131			50	—	22	18	14	8	5	3	
132			40	—	27	21	16	9	5	3	
133			30	—	32	25	18	9	6	3	
134			20	—	38	30	21	10	6	3	
135	Do.	2,600	40	—	29	24	19	9	6	3	(20)
136			20	—	43	34	24	11	7	4	
137			10	—	52	39	27	12	7	4	
138	Do.	2,000	30	—	38	30	23	11	7	4	(20)
139			20	—	46	36	26	12	7	4	
140			10	—	56	43	30	13	8	5	
141	*In disked stubble, RdR*	—	—	—	79	62	42	17	11	6	(20)
142	*Winter G after fall TP, RdL*	HP	—	31	55	48	31	12	7	5	(20)
143		GP	—	36	60	52	33	13	8	5	
144		FP	—	43	64	56	36	14	9	5	
145		LP	—	53	68	60	38	15	10	6	
	GRAIN AFTER SUMMER FALLOW										
146	*With grain residues*	200	10	—	70	55	43	18	13	11	(21)
147		500	30	—	43	34	23	13	10	8	
148		750	40	—	34	27	18	10	7	7	
149		1,000	50	—	26	21	15	8	7	6	
150		1,500	60	—	20	16	12	7	5	5	
151		2,000	70	—	14	11	9	7	5	5	
152	*With row crop residues*	300	5	—	82	65	44	19	14	12	(21)
153		500	15	—	62	49	35	17	13	11	
154		750	23	—	50	40	29	14	11	9	
155		1,000	30	—	40	31	24	13	10	8	
156		1,500	45	—	31	24	18	10	8	7	
157		2,000	55	—	23	19	14	8	7	5	
158		2,500	65	—	17	14	12	7	5	4	
	POTATOES										
159	*Rows with slope*	—	—	43	64	56	36	26	19	16	
160	*Contoured rows, ridged when canopy cover is about 50 percent*[11]	—	—	43	64	56	18	13	10	8	

See footnotes, p. 24.

Footnotes for table 5.

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[1] Symbols: B, soybeans; C, corn; conv till, plow, disk and harrow for seedbed; cot, cotton; F, rough fallow; fld cult, field cultivator; G, small grain; GS, grain sorghum; M, grass and legume meadow, at least 1 full year; pl, plant; RdL, crop residues left on field; RdR, crop residues removed; SB, seedbed period; sprg, spring; TP, plowed with moldboard; WC, winter cover crop; —, insignificant or an unlikely combination of variables.

[2] Dry weight per acre after winter loss and reductions by grazing or partial removal: 4,500 lbs represents 100 to 125 bu corn; 3,400 lbs, 75 to 99 bu; 2,600 lbs, 60 to 74 bu; and 2,000 lbs, 40 to 59 bu; with normal 30-percent winter loss. For RdR or fall-plow practices, these four productivity levels are indicated by HP, GP, FP and LP, respectively (high, good, fair, and low productivity). In lines 79 to 102, this column indicates dry weight of the winter-cover crop.

[3] Percentage of soil surface covered by plant residue mulch *after* crop seeding. The difference between spring residue and that on the surface after crop seeding is reflected in the soil loss ratios as residues mixed with the topsoil.

[4] The soil loss ratios, given as percentages, assume that the indicated crop sequence and practices are followed consistently. One-year deviations from normal practices do not have the effect of a permanent change. Linear interpolation between lines is recommended when justified by field conditions.

[5] Cropstage periods are as defined on p. 18. The three columns for cropstage 3 are for 80, 90, and 96 to 100 percent canopy cover at maturity.

[6] Column 4L is for all residues left on field. Corn stalks partially standing as left by some mechanical pickers. If stalks are shredded and spread by picker, select ratio from table 5-C. When residues are reduced by grazing, take ratio from lower spring-residue line.

[7] Period 4 values in lines 9 to 12 are for corn stubble (stover removed).

[8] Inversion plowed, no secondary tillage. For this practice, residues must be left and incorporated.

[9] Soil surface and chopped residues of *matured* preceding crop undisturbed except in narrow slots in which seeds are planted.

[10] Top of old row ridge sliced off, throwing residues and some soil into furrow areas. Reridging assumed to occur near end of cropstage 1.

[11] Where lower soil loss ratios are listed for rows on the contour, this reduction is in addition to the standard field contouring credit. The *P* value for contouring is used with these reduced loss ratios.

[12] Field-average percent cover; probably about three-fourths of percent cover on undisturbed strips.

[13] If again seeded to WC crop in corn stubble, evaluate winter period as a winter grain seeding (lines 132 to 148). Otherwise, see table 5-C.

[14] Select the appropriate line for the crop, tillage, and productivity level and multiply the listed soil loss ratios by sod residual factors from table 5-D.

[15] Spring residue may include carryover from prior corn crop.

[16] See table 5-C.

[17] Use values from lines 33 to 62 with appropriate dates and lengths of cropstage periods for beans in the locality.

[18] Values in lines 109 to 122 are best available estimates, but planting dates and lengths of cropstages may differ.

[19] When meadow is seeded with the grain, its effect will be reflected through higher percentages of cover in cropstages 3 and 4.

[20] Ratio depends on percent cover. See table 5-C.

[21] See item 12, table 5-B.

TABLE 5-A.—*Approximate soil loss ratios for cotton*

Expected final canopy percent cover:	65	80	95
Estimated initial percent cover from defoliation + stalks down:	30	45	60
Practice Number — Tillage operation(s)	Soil loss ratio[1]		
COTTON ANNUALLY:	*Percent*		
1. . . .*None:*			
Defoliation to Dec. 31	36	24	15
Jan. 1 to Feb. or Mar. tillage:			
Cot Rd only	52	41	32
Rd & 20 percent cover vol veg[2]	32	26	20
Rd & 30 percent cover vol veg	26	20	14
2. . . .*Chisel plow soon after cot harvest:*			
Chiseling to Dec. 31	40	31	24
Jan. 1 to sprg tillage	56	47	40
3. . . .*Fall disk after chisel:*			
Disking to Dec. 31	53	45	37
Jan. 1 to sprg tillage	62	54	47
4. . . .*Chisel plow Feb-Mar, no prior tillage:*			
Cot Rd only	50	42	35
Rd & 20 percent vol veg	39	33	28
Rd & 30 percent vol veg	34	29	25
5. . . .*Bed ("hip") Feb-Mar, no prior tillage:*			
Cot Rd only	100	84	70
Rd & 20 percent vol veg	78	66	56
Rd & 30 percent vol veg	68	58	50
Split ridges & plant after hip, or Disk & plant after chisel (SB):			
Cot Rd only	61	54	47
Rd & 20 percent vol veg	53	47	41
Rd & 30 percent vol veg	50	44	38
Cropstage 1:			
Cot Rd only	57	50	43
Rd & 20 percent vol veg	49	43	38
Rd & 30 percent vol veg	46	41	36
Cropstage 2	45	39	34
Cropstage 3	40	27	17
6. . . .*Bed (hip) after 1 prior tillage:*			
Cot Rd only	110	96	84
Rd & 20 percent veg	94	82	72
Rd & 30 percent veg	90	78	68
Split ridges after hip (SB):			
Cot Rd only	66	61	52
Rd & 20 to 30 percent veg	61	55	49
Cropstage 1:			
Cot Rd only	60	56	49
Rd & 20 to 30 percent veg	56	51	46
Cropstage 2	47	44	38
Cropstage 3	42	30	19
7. . . .*Hip after 2 prior tillages:*			
Cot Rd only	116	108	98
Rd & 20-30 percent veg	108	98	88
Split ridges after hip (SB)	67	62	57
8. . . .*Hip after 3 or more tillages:*	120	110	102
Split ridges after hip (SB)	68	64	59
9. . . .*Conventional moldboard plow and disk:*			
Fallow period	42	39	36
Seedbed period	68	64	59
Cropstage 1	63	59	55
Cropstage 2	49	46	43
Cropstage 3	44	32	22
Cropstage 4 (See practtices 1, 2, and 3)			

COTTON AFTER SOD CROP:

For the first or second crop after a grass or grass-and-legume meadow has been turnplowed, multiply values given in the last five lines above by sod residual factors from table 5-D.

COTTON AFTER SOYBEANS:

Select values from above and multiply by 1.25.

See footnotes at right.

of erosive rainfall at a particular location is an element in deriving the applicable value of cover and management, **C.**

Central and Eastern States

A location's erosion index is computed by summing **EI** values of individual rainstorms over periods from 20 to 25 years. Thus, the expected monthly distribution of the erosion index can be computed from the same data. For each rainfall record abstracted for development of the isoerodent map, the monthly **EI** values were computed and expressed as percentages of the location's average annual erosion index. When the monthly percentages are plotted cumulatively against time, they define **EI** distribution curves such as illustrated in figure 8 for three locations. The three contrasting curves are presented to demonstrate how drastically the normal **EI** distribution can differ among climatic regions.

On the basis of observed seasonal distributions of **EI**, the 37 States east of the Rocky Mountains were divided into the 33 geographic areas delineated in figure 9. The changes in distribution are usually gradual transitions from one area to the next, but the average distribution within any one of the areas may, for practical purposes, be considered applicable for the entire area. The **EI** distributions in the 33 areas, expressed as cumulative percentages of annual totals, are given in table 6. The area numbers in the table correspond to those in figure 9. The data in the table were

[1] *Alternate procedure for estimating the soil loss ratios:*

The ratios given above for cotton are based on estimates for reductions in percent cover through normal winter loss and by the successive tillage operations. Research is underway in Mississippi to obtain more accurate residue data in relation to tillage practices. This research should provide more accurate soil loss ratios for cotton within a few years.

Where the reductions in percent cover by winter loss and tillage operations are small, the following procedure may be used to compute soil loss ratios for the preplant and seedbed periods: Enter figure 6 with the percentage of the field surface covered by residue mulch, move vertically to the upper curve, and read the mulch factor on the scale at the left. Multiply this factor by a factor selected from the following tabulation to credit for effects of land-use residual, surface roughness and porosity.

Productivitty level	No tillage	Rough surface	Smoothed surface
High	0.66	0.50	0.56
Medium	.71	.54	.61
Poor	.75	.58	.65

Values for the bedded period on slopes of less than 1 percent should be estimated at twice the value computed above for rough surfaces.

[2] Rd, crop residue; vol veg, volunteer vegetation.

TABLE 5-B.—*Soil loss ratios for conditions not evaluated in table 5*

COTTON:
See table 5-A.
CROPSTAGE 4 FOR ROWCROPS:
Stalks broken and partially standing: Use col. 4L.
Stalks standing after hand picking: Col. 4L times 1.15.
Stalks shredded without soil tillage: See table 5-C.
Fall chisel: Select values from lines 33-62, seedbed column.
CROPSTAGE 4 FOR SMALL GRAIN:
See table 5-C.
DOUBLE CROPPING:
Derive annual C value by selecting from table 5 the soil loss percentages for the successive cropstage periods of each crop.
ESTABLISHED MEADOW, FULL-YEAR PERCENTAGES:

Grass and legume mix, 3 to 5 t hay	0.4
Do. 2 to 3 t hay	.6
Do. 1 t hay	1.0
Sericea, after second year	1.0
Red clover	1.5
Alfalfa, lespedeza, and second-year sericea	2.0
Sweetclover	2.5

MEADOW SEEDING WITHOUT NURSE CROP:
Determine appropriate lengths of cropstage periods SB, 1, and 2 and apply values given for small grain seeding.
PEANUTS:
Comparison with soybeans is suggested.
PINEAPPLES:
Direct data not available. Tentative values derived analytically are available from the SCS in Hawaii or the Western Technical Service Center at Portland, Oreg. (Reference 5).
SORGHUM:
Select values given for corn, on the basis of expected crop residues and canopy cover.
SUGARBEETS:
Direct data not available. Probably most nearly comparable to potatoes, without the ridging credit.
SUGARCANE:
Tentative values available from sources given for pineapples.
SUMMER FALLOW IN LOW-RAINFALL AREAS, USE GRAIN OR ROW CROP RESIDUES:
The approximate soil loss percentage after each successive tillage operation may be obtained from the following tabulation by estimating the percent surface cover after that tillage and selecting the column for the appropriate amount of initial residue. The given values credit benefits of the residue mulch, residues mixed with soil by tillage, and the crop system residual.

Percent cover by mulch	Initial residue (lbs/A) >4,000	3,000	2,000	1,500
90	4	—	—	—
80	8	[1]8	—	—
70	12	13	[1]14	—
60	16	17	[1]18	[1]19
50	20	22	24	[1]25
40	25	27	30	32
30	29	33	37	39
20	35	39	44	48
10	47	55	63	68

[1] For grain residue only.

WINTER COVER SEEDING IN ROW CROP STUBBLE OR RESIDUES:
Define cropstage periods based on the cover seeding date and apply values from lines 129 to 145.

TABLE 5-C.—*Soil loss ratios (percent) for cropstage 4 when stalks are chopped and distributed without soil tillage*

Mulch cover[1]	Corn or Sorghum: Tilled seedbed[2]	Corn or Sorghum: No-till	Soybeans: Tilled seedbed[2]	Soybeans: No-till in corn rd[3]	Grain Stubble[4]
20	48	34	60	42	48
30	37	26	46	32	37
40	30	21	38	26	30
50	22	15	28	19	22
60	17	12	21	16	17
70	12	8	15	10	12
80	7	5	9	6	7
90	4	3	—	—	4
95	3	2	—	—	3

[1] Part of a field surface directly covered by pieces of residue mulch.
[2] This column applies for all systems other than no-till.
[3] Cover after bean harvest may include an appreciable number of stalks carried over from the prior corn crop.
[4] For grain with meadow seeding, include meadow growth in percent cover and limit grain period 4 to 2 mo. Thereafter, classify as established meadow.

abstracted from the published EI distribution curves.

The percentage of the annual erosion index that is to be expected within each cropstage period may be obtained by reading from the appropriate line of table 6, the values for the last and first date of the period, and subtracting. Interpolate

TABLE 5-D.—*Factors to credit residual effects of turned sod*[1]

Crop	Hay yield	Factor for cropstage period: F	SB and 1	2	3	4
	Tons					
First year after mead:						
Row crop or grain ...	3-5	0.25	0.40	0.45	0.50	0.60
	2-3	.30	.45	.50	.55	.65
	1-2	.35	.50	.55	.60	.70
Second year after mead:						
Row crop	3.5	.70	.80	.85	.90	.95
	2-3	.75	.85	.90	.95	1.0
	1-2	.80	.90	.95	1.0	1.0
Spring grain	3-5	—	.75	.80	.85	.95
	2-3	—	.80	.85	.90	1.0
	1-2	—	.85	.90	.95	1.0
Winter grain	3-5	—	.60	.70	.85	.95
	2-3	—	.65	.75	.90	1.0
	1-2	—	.70	.85	.95	1.0

[1] These factors are to be multiplied by the appropriate soil loss percentages selected from table 5. They are directly applicable for sod-forming meadows of at least 1 full year duration, plowed not more than 1 month before final seedbed preparation.

When sod is fall plowed for spring planting, the listed values for all cropstage periods are increased by adding 0.02 for each additional month by which the plowing precedes spring seedbed preparation. For example, September plowing would precede May disking by 8 months and 0.02(8—1), or 0.14, would be added to each value in the table. For nonsod-forming meadows, like sweetclover or lespedeza, multiply the factors by 1.2. When the computed value is greater than 1.0, use as 1.0.

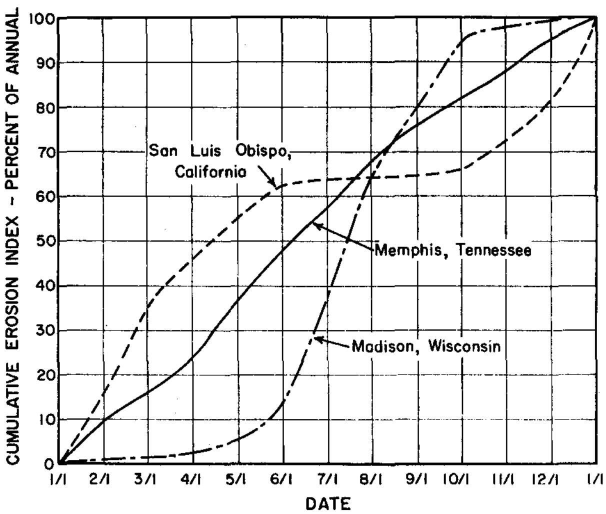

FIGURE 8.—Typical **EI**-distribution curves for three rainfall patterns.

between values in the selected line when the desired dates are not listed.

Western States, Hawaii, and Puerto Rico

Normal rainfall patterns in these mountainous States often change abruptly within a short distance. Figure 9 was not extended to include these States because long-term intensity data were not available for enough locations to delineate boundaries of homogeneous areas. However, **EI** distributions indicated by station records that were abstracted are given in table 7 for reference.

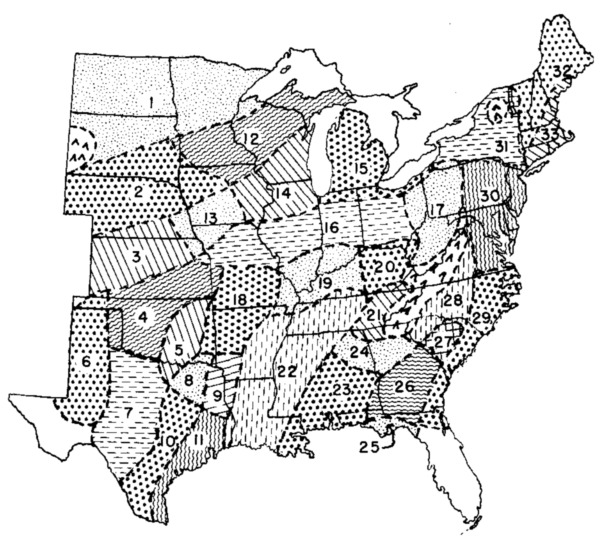

FIGURE 9.—Key map for selection of applicable **EI**-distribution data from table 6.

Winter Periods

Site **EI** values reflect only rain falling at erosive intensities. Where the winter precipitation comes as snow or light rain, **EI** distribution curves may show insignificant percentages for several winter months. Yet, snowmelt and low intensity rains on frozen soil may cause appreciable runoff that is erosive even though the associated maximum 30-minute rainfall intensity is extremely low or zero. The section on **Isoerodent Maps** pointed out that where this type of runoff is significant its erosive force must be reflected in an $\mathbf{R}_s$ value that is added to the **EI** value to obtain **R**. This additional erosive force must also be reflected in the *monthly distribution* of **R**. Otherwise, poor management during the winter period will not be reflected in the USLE estimate of annual soil loss because a zero cropstage **R** value would predict zero soil loss regardless of the relevant soil loss ratio.

Soil erosion by thaw runoff is most pronounced in the Northwest, where $\mathbf{R}_s$ values often exceed the average annual **EI**. However, it may also be significant in other Northern States. Probable amounts of thaw runoff were not available for inclusion in the calculations of the **EI** distributions given in tables 6 and 7, but the significance and probable time of occurrence of such runoff can be estimated by local people. The procedure for adjusting table 6 cumulative percentages to include this erosive potential will be illustrated.

Based on the previously described estimating procedure, $\mathbf{R}_s$ values in area No. 1, figure 9, appear to equal about 8 percent of the annual **EI**. Assuming that the thaw runoff in that area normally occurs between March 15 and April 15, the percentage in table 6 for April 1 is increased by 4, the April 15 and all subsequent readings are increased by 8, and all the adjusted readings are then divided by 1.08. This procedure corrects the data given in line 1, table 6, for dates April 1 to September 1 to the following cumulative percentages listed in chronological sequence: 5, 9, 10, 13, 18, 29, 41, 53, 66, 79, 91. The other values are unchanged. Such adjustments in monthly distribution of **R** where thaw runoff is significant will be particularly helpful when the USLE is used to estimate seasonal distribution of sediment from agricultural watersheds.

TABLE 6.—*Percentage of the average annual* **EI** *which normally occurs between January 1 and the indicated dates.*[1] *Computed for the geographic areas shown in figure 9*

Area No.	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15
1	0	0	0	0	0	0	1	2	3	6	11	23	36	49	63	77	90	95	98	99	100	100	100	100
2	0	0	0	0	1	1	2	3	6	10	17	29	43	55	67	77	85	91	96	98	99	100	100	100
3	0	0	0	0	1	1	2	3	6	13	23	37	51	61	69	78	85	91	94	96	98	99	99	100
4	0	0	1	1	2	3	4	7	12	18	27	38	48	55	62	69	76	83	90	94	97	98	99	100
5	0	1	2	3	4	6	8	13	21	29	37	46	54	60	65	69	74	81	87	92	95	97	98	99
6	0	0	0	0	1	1	1	2	6	16	29	39	46	53	60	67	74	81	88	95	99	99	100	100
7	0	1	1	2	3	4	6	8	13	25	40	49	56	62	67	72	76	80	85	91	97	98	99	99
8	0	1	3	5	7	10	14	20	28	37	48	56	61	64	68	72	77	81	86	89	92	95	98	99
9	0	2	4	6	9	12	17	23	30	37	43	49	54	58	62	66	70	74	78	82	86	90	94	97
10	0	1	2	4	6	8	10	15	21	29	38	47	53	57	61	65	70	76	83	88	91	94	96	98
11	0	1	3	5	7	9	11	14	18	27	35	41	46	51	57	62	68	73	79	84	89	93	96	98
12	0	0	0	0	1	1	2	3	5	9	15	27	38	50	62	74	84	91	95	97	98	99	99	100
13	0	0	0	1	1	2	3	5	7	12	19	33	48	57	65	74	82	88	93	96	98	99	100	100
14	0	0	0	1	2	3	4	6	9	14	20	28	39	52	63	72	80	87	91	94	97	98	99	100
15	0	0	1	2	3	4	6	8	11	15	22	31	40	49	59	69	78	85	91	94	96	98	99	100
16	0	1	2	3	4	6	8	10	14	18	25	34	45	56	64	72	79	84	89	92	95	97	98	99
17	0	1	2	3	4	5	6	8	11	15	20	28	41	54	65	74	82	87	92	94	96	97	98	99
18	0	1	2	4	6	8	10	13	19	26	34	42	50	58	63	68	74	79	84	89	93	95	97	99
19	0	1	3	6	9	12	16	21	26	31	37	43	50	57	64	71	77	81	85	88	91	93	95	97
20	0	2	3	5	7	10	13	16	19	23	27	34	44	54	63	72	80	85	89	91	93	95	96	98
21	0	3	6	10	13	16	19	23	26	29	33	39	47	58	68	75	80	83	86	88	90	92	95	97
22	0	3	6	9	13	17	21	27	33	38	44	49	55	61	67	71	75	78	81	84	86	90	94	97
23	0	3	5	7	10	14	18	23	27	31	35	39	45	53	60	67	74	80	84	86	88	90	93	95
24	0	3	6	9	12	16	20	24	28	33	38	43	50	59	69	75	80	84	87	90	92	94	96	98
25	0	1	3	5	7	10	13	17	21	24	27	33	40	46	53	61	69	78	89	92	94	95	97	98
26	0	2	4	6	8	12	16	20	25	30	35	41	47	56	67	75	81	85	87	89	91	93	95	97
27	0	1	2	3	5	7	10	14	18	22	27	32	37	46	58	69	80	89	93	94	95	96	97	99
28	0	1	3	5	7	9	12	15	18	21	25	29	36	45	56	68	77	83	88	91	93	95	97	99
29	0	1	2	3	4	5	7	9	11	14	17	22	31	42	54	65	74	83	89	92	95	97	98	99
30	0	1	2	3	4	5	6	8	10	14	19	26	34	45	56	66	76	82	86	90	93	95	97	99
31	0	0	0	1	2	3	4	5	7	12	17	24	33	42	55	67	76	83	89	92	94	96	98	99
32	0	1	2	3	4	5	6	8	10	13	17	22	31	42	52	60	68	75	80	85	89	92	96	98
33	0	1	2	4	6	8	11	13	15	18	21	26	32	38	46	55	64	71	77	81	85	89	93	97

[1] For dates not listed in the table, interpolate between adjacent values.

Procedure for Deriving Local C Values

Factor **C** in the USLE measures the combined effect of all the interrelated cover and management variables and is defined as the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled continuous fallow. It is usually expressed as an annual value for a particular cropping and management system. Soil loss ratios, as used in table 5, express a similar ratio for a short time interval within which cover and management effects are relatively uniform. The cropstage soil loss ratios must be combined in proportion to the applicable percentages of **EI** to derive annual **C** values.

To compute the value of **C** for any particular crop and management system on a given field, one needs first to determine the most likely seeding and harvest dates, rate of canopy development, and final canopy cover. Also, the system to be evaluated must be carefully defined with regard to crop and residue management details. Within the broad limits of tables 5 and 6, these tables then supply the research data needed to complete

TABLE 7.—*Monthly distribution of* **EI** *at selected raingage locations*

Location[1]	Average percentage of annual EI occurring from 1/1 to:											
	2/1	3/1	4/1	5/1	6/1	7/1	8/1	9/1	10/1	11/1	12/1	12/31
California												
Red Bluff (69)	18	36	47	55	62	64	65	65	67	72	82	100
San Luis Obispo (51)	19	39	54	63	65	65	65	65	65	67	83	100
Colorado												
Akron (91)	0	0	0	1	18	33	72	87	98	99	100	100
Pueblo (68)	0	0	0	5	14	23	40	82	84	100	100	100
Springfield (98)	0	0	1	4	26	36	60	94	96	99	100	100
Hawaii												
Hilo (770)	9	23	34	44	49	51	55	60	65	72	87	100
Honolulu (189)	19	33	43	51	54	55	56	57	58	62	81	100
Kahului (107)	14	32	49	62	67	68	69	70	71	76	86	100
Lihue (385)	19	29	36	41	44	45	48	51	56	64	80	100
Montana												
Billings (18)	0	0	1	6	22	49	86	88	96	100	100	100
Great Falls (17)	1	1	2	6	20	56	74	93	98	99	100	100
Miles City (28)	0	0	0	1	10	32	65	93	98	100	100	100
New Mexico												
Albuquerque (15) ..	1	1	2	4	10	21	52	67	89	98	99	100
Roswell (52)	0	0	2	7	20	34	55	71	92	99	99	100
Oregon												
Pendleton (6)	8	12	15	22	56	64	67	67	74	87	96	100
Portland (43)	15	27	35	37	40	45	46	47	54	65	81	100
Puerto Rico												
Mayaguez (600)	1	2	3	6	15	31	47	63	80	91	99	100
San Juan (345)	5	8	11	17	33	43	53	66	75	84	93	100
Washington												
Spokane (8)	5	9	11	15	25	56	61	76	84	90	94	100
Wyoming												
Casper (11)	0	0	1	6	32	44	70	90	96	100	100	100
Cheyenne (32)	0	1	2	5	17	42	73	90	97	99	100	100

[1] Numbers in parentheses are the observed average annual EI.

the computation of **C**. The procedure will be explained by an example that, for illustration purposes, was selected to include many changes in field conditions.

Problem. Evaluate **C** for a 4-year rotation of wheat-meadow-corn-corn on moderately sloping land in Central Illinois or Indiana, assuming the following management details and dates: Wheat is seeded October 15 in a 40-percent cover of disked corn residue, and a grass and legume meadow mix is seeded with the wheat. The wheat would normally develop a 10-percent cover by November 1, 50 percent by December 1, 75 percent by April 15, and nearly 100 percent in the maturing stage. It is harvested July 15, leaving an 80-percent surface cover of straw and small grass. The sod developed under 1 full year of meadow, yielding more than 3 t of hay, is turned under in April. The field is disked May 5 and is harrowed and planted to corn May 10. The first-year corn, harvested October 15, is followed by fall chiseling about November 15 and spring disking for second-year corn. Residue cover is 50 percent after fall chiseling and 30 percent after corn planting on May 10. Fertility, row spacing, and plant population for both corn years are such that 10, 50, and 75 percent canopy covers will be developed in 20, 40, and 60 days, respectively, from planting, and final canopy cover is more than 95 percent.

Procedure. Set up a working table similar to the one illustrated in table 8, obtaining the needed information as follows:

Column 1. List in chronological sequence all the land-cover changes that begin new cropstage periods, as previously defined.

Column 2. List the date on which each cropstage period begins.

Column 3. Select the applicable area number

TABLE 8.—*Sample working table for derivation of a rotation* **C** *value*

(1) Event	(2) Date	(3) Table 6, area 16	(4) Cropstage period	(5) EI in period	(6) Soil loss ratio[1]	(7) Sod Factor	(8) Cropstage C value	(9) Crop year
Pl W[2]	10/15	92	SB	0.03	0.27(132)	0.95	0.0077	
10 percent c	11/1	95	1	.03	.21	.95	.0060	
50 percent c	12/1	98	2	.12	.16	1.0	.0192	
75 percent c	4/15	10	3	.46	.03		.0138	
Hv W	7/15	56	4	.28	.07(5C)		.0196	0.066
Meadow	9/15	84		1.26	.004(5B)	1.0	.0050	.005
TP	4/15	10	F	.05	.36(2)	.25	.0045	
Disk	5/5	15	SB	.10	.60	.40	.0240	
Pl C	5/10	—						
10 percent c	6/1	25	1	.13	.52	.40	.0270	
50 percent c	6/20	38	2	.14	.41	.45	.0258	
75 percent c	7/10	52	3	.40	.20	.50	.0400	
Hv C	10/15	92	4L	.05	.30	.60	.0090	.130
Chisel	11/15	97	4c	.17	.16(46)	.60	.0163	
Disk	5/1	14	SB	.11	.25(48 & 61)	.80	.0220	
Pl C	5/10	—						
10 percent c	6/1	25	1	.13	.23	.80	.0239	
50 percent c	6/20	38	2	.14	.21	.85	.0250	
75 percent c	7/10	52	3	.40	.14(48)	.90	.0504	.138
Hv C & pl W	10/15	92		——			——	
Rotation totals				4.0			0.3392	
Average annual C value for rotation							.085	

[1] Numbers in parentheses are line numbers in table 5.

[2] Abbreviations: c, canopy cover; C, corn; hv, harvest; pl, plant; TP, moldboard plow; W, wheat.

from figure 9, and from the line in table 6 having the corresponding area number (in this case, 16), read the cumulative percentage of **EI** for each date in column 2. Values for the corn planting dates were omitted in table 8 because the seedbed periods had begun with the spring diskings. The **EI** percentage for May 5 was obtained by interpolating between readings from May 1 and 15.

Column 4. Identify the cropstage periods.

Column 5. Subtract the number in column 3 from the number in the next lower line. If the cropstage period includes a year end, subtract from 100 and add the number in the next lower line. The differences are percentages and may be pointed off as hundredths.

Column 6. Obtain from table 5. Enter the table with crop and management, pounds of spring residue or production level, and percent mulch cover after planting, in that sequence. The data in the selected line are percentages and are used as hundredths in the computation of **C**. For cropstage 3, use the column whose heading corresponds with expected final canopy. For conditions not listed in the primary table, consult supplements 5-A to D. Lines used for the examples are given in parentheses in column 6.

Column 7. From table 5-D.

Column 8. The product of values in columns 5, 6 and 7. The sum of these products is the value of **C** for the entire rotation. Because **C** is usually desired as an average annual value, this sum is divided by the number of years in the rotation.

Column 9. The subtotals in this column are **C** values for the individual crop-years. They also show the relative contributions of the four crops to the rotation **C** value.

Changes in geographic area or in planting dates would affect the **C** value by changing columns 3 and 5. Changes in amount or disposition of residues, tillage practices, or canopy development would change column 6. Thus **C** can vary substantially for a given crop system.

Values of **C** for one-crop systems are derived by the same procedure but would require only a few lines. Also, column 7 is omitted for meadowless systems.

C-Value Tables for Cropland

It will rarely, if ever, be necessary for a field technician or farmer to compute values of **C**. Persons experienced in the procedures outlined above have prepared **C** value tables for specific geographic areas. Such a table will list all the one-crop and multicrop systems likely to be found within the designated area and will list the **C** values for each system for each of the combinations of management practices that may be associated with it. They are usually listed in ascending or descending order of magnitude of the **C** values. The user can then quickly determine all the potential combinations of cropping and management that have **C** values smaller than any given threshold value. Persons in need of **C** values for a particular locality can usually obtain a copy of the applicable table from the nearest SCS state office.

C Values for Construction Areas

Site preparations that remove all vegetation and also the root zone of the soil not only leave the surface completely without protection but also remove the residual effects of prior vegetation. This condition is comparable to the previously defined continuous fallow condition, and **C** = 1. Roots and residual effects of prior vegetation, and partial covers of mulch or vegetation, substantially reduce soil erosion. These reductions are reflected in the soil loss prediction by **C** values of less than 1.0.

Applied mulches immediately restore protective cover on denuded areas and drastically reduce **C** (*1, 2, 20, 27, 43*). Soil loss ratios for various percentages of mulch cover on field slopes are given by the upper curve of figure 6. Where residual effects are insignificant, these ratios equal **C**. The percentage of surface cover provided by a given rate of uniformly spread straw mulch may be estimated from figure 10 (appendix).

Straw or hay mulches applied on steep construction slopes and not tied to the soil by anchoring and tacking equipment may be less effective than equivalent mulch rates on cropland. In Indiana tests on a 20 percent slope of scalped subsoil, a 2.3-t rate of unanchored straw mulch allowed soil loss of 12 t/A when 5 in of simulated rain was applied at 2.5 in/h on a 35-ft plot (*61*). There was evidence of erosion from flow beneath the straw. Mulches of crushed stone at 135 or more t/A, or wood chips at 7 or more t/A, were more effective. (Broadcast seedings of grass after the tests gave good stands on the plots mulched with 135 or 240 t crushed stone, 70 t road gravel, 12 t wood chips, or 2.3 t straw. Stands were poor on the no-mulch and the 15-t rate of crushed stone mulch.)

Table 9 presents approximate **C** values for straw, crushed stone, and woodchip mulches on construction slopes where no canopy cover exists, and also shows the maximum slope lengths on which these values may be assumed applicable.

Soil loss ratios for many conditions on construc-

TABLE 9.—*Mulch factors and length limits for construction slopes*[1]

Type of mulch	Mulch Rate	Land Slope	Factor C	Length limit[2]
	Tons per acre	*Percent*		*Feet*
None	0	all	1.0	—
Straw or hay,	1.0	1-5	0.20	200
tied down by anchoring and tacking	1.0	6-10	.20	100
	1.5	1-5	.12	300
equipment[3]	1.5	6-10	.12	150
Do.	2.0	1-5	.06	400
	2.0	6-10	.06	200
	2.0	11-15	.07	150
	2.0	16-20	.11	100
	2.0	21-25	.14	75
	2.0	26-33	.17	50
	2.0	34-50	.20	35
Crushed stone,	135	<16	.05	200
¼ to 1½ in	135	16-20	.05	150
	135	21-33	.05	100
	135	34-50	.05	75
Do.	240	<21	.02	300
	240	21-33	.02	200
	240	34-50	.02	150
Wood chips	7	<16	.08	75
	7	16-20	.08	50
Do.	12	<16	.05	150
	12	16-20	.05	100
	12	21-33	.05	75
Do.	25	<16	.02	200
	25	16-20	.02	150
	25	21-33	.02	100
	25	34-50	.02	75

[1] From Meyer and Ports (*24*). Developed by an interagency workshop group on the basis of field experience and limited research data.

[2] Maximum slope length for which the specified mulch rate is considered effective. When this limit is exceeded, either a higher application rate or mechanical shortening of the effective slope length is required.

[3] When the straw or hay mulch is not anchored to the soil, **C** values on moderate or steep slopes of soils having **K** values greater than 0.30 should be taken at double the values given in this table.

tion and developmental areas can be obtained from table 5 if good judgment is exercised in comparing the surface conditions with those of agricultural conditions specified in lines of the table. Time intervals analogous to cropstage periods will be defined to begin and end with successive construction or management activities that appreciably change the surface conditions. The procedure is then similar to that described for cropland.

Establishing vegetation on the denuded areas as quickly as possible is highly important. A good sod has a **C** value of 0.01 or less (table 5-B), but such a low **C** value can be obtained quickly only by laying sod on the area, at a substantial cost. When grass or small grain is started from seed, the probable soil loss for the period while cover is developing can be computed by the procedure outlined for estimating cropstage-period soil losses. If the seeding is on topsoil, without a mulch, the soil loss ratios given in line 141 of table 5 are appropriate for cropstage **C** values. If the seeding is on a desurfaced area, where residual effects of prior vegetation are no longer significant, the ratios for periods SB, 1 and 2 are 1.0, 0.75 and 0.50, respectively, and line 141 applies for cropstage 3. When the seedbed is protected by a mulch, the pertinent mulch factor from the upper curve of figure 6 or table 9 is applicable until good canopy cover is attained. The combined effects of vegetative mulch and low-growing canopy are given in figure 7. When grass is established in small grain, it can usually be evaluated as established meadow about 2 mo after the grain is cut.

C Values for Pasture, Range, and Idle Land

Factor **C** for a specific combination of cover conditions on these types of land may be obtained from table 10 (57). The cover characteristics that must be appraised before consulting this table are defined in the table and its footnotes. Cropstage periods and **EI** monthly distribution data are generally not necessary where perennial vegetation has become established and there is no mechanical disturbance of the soil.

Available soil loss data from undisturbed land were not sufficient to derive table 10 by direct comparison of measured soil loss rates, as was done for development of table 5. However, analyses of the assembled erosion data showed that the research information on values of **C** can be extended to completely different situations by combining subfactors that evaluate three separate and distinct, but interrelated, zones of influence: (a) vegetative cover in direct contact with the soil surface, (b) canopy cover, and (c) residual and tillage effects.

Subfactors for various percentages of surface cover by mulch are given by the upper curve of

TABLE 10.—*Factor* **C** *for permanent pasture, range, and idle land*[1]

Vegetative canopy		Cover that contacts the soil surface						
			Percent ground cover					
Type and height[2]	Percent cover[3]	Type[4]	0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	.043	.011
Tall weeds or short brush with average drop fall height of 20 in	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, with average drop fall height of 6½ ft	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

[1] The listed **C** values assume that the vegetation and mulch are randomly distributed over the entire area.

[2] Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 ft.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[4] G: cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 in deep.

W: cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface) or undecayed residues or both.

TABLE 11.—*Factor **C** for undisturbed forest land*[1]

Percent of area covered by canopy of trees and undergrowth	Percent of area covered by duff at least 2 in deep	Factor C[2]
100-75	100-90	.0001-.001
70-45	85-75	.002-.004
40-20	70-40	.003-.009

[1] Where effective litter cover is less than 40 percent or canopy cover is less than 20 percent, use table 6. Also use table 6 where woodlands are being grazed, harvested, or burned.

[2] The ranges in listed **C** values are caused by the ranges in the specified forest litter and canopy covers and by variations in effective canopy heights.

figure 6. Subfactors for various heights and densities of canopy cover are given in figure 5. The subfactor for residual effects of permanent pasture, range, idle land, or grazed or harvested woodland has been estimated to vary from 0.45 to 0.10 (57). Major influences on this subfactor are plant roots, organic matter buildup in the topsoil, reduced soil compaction, and surface stabilization after long periods without soil disturbance. The **C** values given in table 10 were derived by combining subfactors for specified combinations of type, height, and density of canopy cover; type and density of cover at the soil surface; and probable residual effects of longtime existence of the specified cover on the land. They are compatible with the rather scarce existing soil loss data from undisturbed land areas.

C Values for Woodland

Three categories of woodland are considered separately: (1) undisturbed forest land; (2) woodland that is grazed, burned, or selectively harvested; and (3) forest lands which have had site preparation treatments for re-establishment after harvest.

In undisturbed forests, infiltration rates and organic matter content of the soil are high, and much or all of the surface is usually covered by a layer of compacted decaying forest duff or litter several inches thick. Such layers of duff shield the soil from the erosive forces of runoff and of drop impact and are extremely effective against soil erosion. Where cover by trees and litter is incomplete, the spots with little or no litter cover are partially protected by undergrowth canopy. Factor **C** for undisturbed forest land may be obtained from table 11. These estimated **C** values are supported by the quite limited existing data and also by the subfactor-evaluation procedure discussed in the preceding subsection.

Woodland that is grazed or burned, or has been recently harvested, does not merit the extremely low **C** values of table 11. For these conditions, **C** is obtained from table 10. However, the buildup of organic matter in the topsoil under permanent woodland conditions is an added factor that should be accounted for by a reduction in the **C** value read from table 10. An earlier publication (57) recommended a factor of 0.7 for this purpose.

Site preparation treatments for re-establishing trees on harvested forest land usually alter the erosion factors substantially. Canopy effect is initially greatly reduced or lost entirely, and its restoration is gradual. Some of the forest litter is incorporated in the soil, and it may be entirely removed from portions of the area. A surface roughness factor is introduced. Windrowed debris, if across slope, may function as terraces by reducing effective slope length and inducing deposition above and in the windrows. The amount of residual effect retained depends on the amount and depth of surface scalping. Some of the changes are analogous to cropland situations. Some of the relationships available from tables 5 and 10 can be used to evaluate **C** for these conditions, but neither table is directly applicable.

Table 12 presents **C** values computed for Southern Pine Forests that have had site preparation treatments after harvesting. This table was jointly developed (in 1977) by representatives of SEA, SCS, and Forest Service, using factor relationships from tables 5, 10, and 11 as basic guides. Its application on forest lands in other climatic regions may require some modifications of factor values. Research designed to refine and improve tables 10, 11, and 12 is underway.

Tree plantings on converted cropland should, in the initial years, be evaluated similarly to cropland because the forest residual effect which underlies tables 10 to 12 will not be applicable. The subfactor for residual effects may be estimated by selecting from lines 1 to 16 of table 5 the line that most nearly describes the condition of the converted cropland and assuming a residual subfactor equal to the seedbed-period value given in that line. If the cropland has most recently been in

TABLE 12.—*Factor* **C** *for mechanically prepared woodland sites*

Site preparation	Mulch cover[1]	Soil condition[2] and weed cover[3]							
		Excellent		Good		Fair		Poor	
		NC	WC	NC	WC	NC	WC	NC	WC
	Percent								
Disked, raked, or bedded[4]	None	0.52	0.20	0.72	0.27	0.85	0.32	0.94	0.36
	10	.33	.15	.46	.20	.54	.24	.60	.26
	20	.24	.12	.34	.17	.40	.20	.44	.22
	40	.17	.11	.23	.14	.27	.17	.30	.19
	60	.11	.08	.15	.11	.18	.14	.20	.15
	80	.05	.04	.07	.06	.09	.08	.10	.09
Burned[5]	None	.25	.10	.26	.10	.31	.12	.45	.17
	10	.23	.10	.24	.10	.26	.11	.36	.16
	20	.19	.10	.19	.10	.21	.11	.27	.14
	40	.14	.09	.14	.09	.15	.09	.17	.11
	60	.08	.06	.09	.07	.10	.08	.11	.08
	80	.04	.04	.05	.04	.05	.04	.06	.05
Drum chopped[5]	None	.16	.07	.17	.07	.20	.08	.29	.11
	10	.15	.07	.16	.07	.17	.08	.23	.10
	20	.12	.06	.12	.06	.14	.07	.18	.09
	40	.09	.06	.09	.06	.10	.06	.11	.07
	60	.06	.05	.06	.05	.07	.05	.07	.05
	80	.03	.03	.03	.03	.03	.03	.04	.04

[1] Percentage of surface covered by residue in contact with the soil.

[2] *Excellent* soil condition—Highly stable soil aggregates in topsoil with fine tree roots and litter mixed in.

Good—Moderately stable soil aggregates in topsoil or highly stable aggregates in subsoil (topsoil removed during raking), only traces of litter mixed in.

Fair—Highly unstable soil aggregates in topsoil or moderately stable aggregates in subsoil, no litter mixed in.

Poor—No topsoil, highly erodible soil aggregates in subsoil, no litter mixed in.

[3] NC—No live vegetation.

WC—75 percent cover of grass and weeds having an average drop fall height of 20 in. For intermediate percentages of cover, interpolate between columns.

[4] Modify the listed **C** values as follows to account for effects of surface roughness and aging:

First year after treatment: multiply listed **C** values by 0.40 for rough surface (depressions >6 in); by 0.65 for moderately rough; and by 0.90 for smooth (depressions <2 in).

For 1 to 4 years after treatment: multiply listed factors by 0.7.

For 4+ to 8 years: use table 6.

More than 8 years: use table 7.

[5] For first 3 years: use **C** values as listed.

For 3+ to 8 years after treatment: use table 6.

More than 8 years after treatment: use table 7.

meadow, the selected seedbed soil loss ratio is multiplied by a factor from table 5-D. If mulch is applied, a subfactor read from the upper curve of figure 6 is multiplied by the residual subfactor to obtain **C.** When canopy develops, a canopy subfactor from figure 5 is also included.

SUPPORT PRACTICE FACTOR (P)

In general, whenever sloping soil is to be cultivated and exposed to erosive rains, the protection offered by sod or close-growing crops in the system needs to be supported by practices that will slow the runoff water and thus reduce the amount of soil it can carry. The most important of these supporting cropland practices are contour tillage, stripcropping on the contour, and terrace systems. Stabilized waterways for the disposal of excess rainfall are a necessary part of each of these practices.

By definition, factor **P** in the USLE is the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down-slope culture. Improved tillage practices, sod-based rotations, fertility treatments, and greater quantities of crop residues left on the field contribute materially to erosion control and frequently provide the major control in a farmer's field. However, these are considered conservation cropping and management practices, and the benefits derived from them are included in **C.**

Contouring

The practice of tillage and planting on the contour, in general, has been effective in reducing erosion. In limited field studies, the practice provided almost complete protection against erosion from storms of moderate to low intensity, but it provided little or no protection against the occasional severe storms that caused extensive breakovers of the contoured rows. Contouring appears to be the most effective on slopes in the 3- to 8-percent range. As land slope decreases, it approaches equality with contour row slope, and the soil loss ratio approaches 1.0. As slope increases, contour row capacity decreases and the soil loss ratio again approaches 1.0.

Effectiveness of contouring is also influenced by the slope length. When rainfall exceeds infiltration and surface detention in large storms, breakovers of contour rows often result in concentrations of runoff that tend to become progressively greater with increases in slope length. Therefore, on slopes exceeding some critical length the amount of soil moved from a contoured field may approach or exceed that from a field on which each row carries its own runoff water down the slope. At what slope length this could be expected to occur would depend to some extent on gradient, soil properties, management, and storm characteristics.

P Values for Contouring

A joint SEA and SCS workshop group, meeting at Purdue University in 1956, adopted a series of contour **P** values that varied with percent slope. The **P** values were based on available data and field observations supplemented by group judgment. Subsequent experience indicated only a few minor changes. Current recommendations are given in table 13. They are average values for the factor on the specified slopes. Specific-site values may vary with soil texture, type of vegetation, residue management, and rainfall pattern, but data have not become available to make the deviations from averages numerically predictable.

Full contouring benefits are obtained only on fields relatively free from gullies and depressions other than grassed waterways. Effectiveness of this practice is reduced if a field contains numerous small gullies and rills that are not obliterated by normal tillage operations. In such instances, land smoothing should be considered before contouring. Otherwise, a judgment value greater than shown in table 13 should be used when computing the benefits for contouring.

TABLE 13.—**P** *values and slope-length limits for contouring*

Land slope percent	P value	Maximum length[1]
		Feet
1 to 2	0.60	400
3 to 5	.50	300
6 to 8	.50	200
9 to 12	.60	120
13 to 16	.70	80
17 to 20	.80	60
21 to 25	.90	50

[1] Limit may be increased by 25 percent if residue cover after crop seedlings will regularly exceed 50 percent.

Slope-Length Limits

After the 1956 workshop, the SCS prepared reference tables for use with the Corn Belt slope-practice procedure. They included guides for slope-length limits for effective contouring, based largely on judgment. These limits, as modified with later data and observations (*16*, *42*), are also given in table 13. Data to establish the precise limits for specific conditions are still not available. However, the **P** values given in table 13 assume slopes short enough for full effectiveness of the practice. Their use for estimating soil loss on unterraced slopes that are longer than the table limits specified is speculative.

Contour Listing

Contour listing, with corn planted in the furrows, has been more effective than surface planting on the contour (*29*). However, the additional effectiveness of the lister ridges applies only from the date of listing until the ridges have been largely obliterated by two corn cultivations. Therefore, it can be more easily credited through **C** than through **P**. This is done by a 50-percent reduction in the soil loss ratios (table 5) that apply to the time interval during which the ridges are intact. The standard **P** value for contouring is applicable in addition to the **C** value reduction.

Potato rows on the contour present a comparable condition from lay-by time until harvest. However, this ridging effect has been already credited in table 5, line 160, and should not be duplicated.

Controlled-Row Grade Ridge Planting

A method of precise contouring has been developed that provides effective conservation on farm fields where the land slope is nearly uniform, either naturally or by land smoothing, and runoff from outside the field can be diverted. The practice uses ridge planting with undiminished channel capacity to carry water maintained throughout the year. It is being studied in Texas (*36*), Arkansas, Mississippi (*8*), and Iowa (*30*). In Texas, the channel cross section, with 40-in row spacing, was nearly 0.5 ft^2, and row grades varied from nearly zero at the upper end to 1 percent at the lower end of a 1,000-ft length. Measured soil loss compared favorably with that from an adjacent terraced watershed. Soil loss measurements in Mississippi and Iowa showed similar effectiveness during the test periods.

Because each furrow functions as an individual terrace, **P** values similar to those for terracing seem appropriate. Slope-length limits for contouring would then not apply, but the length limits would be applicable if the channel capacity were only sufficient for a 2-year design storm.

Contoured-Residue Strips

Contoured strips of heavy crop-residue mulch, resembling contour stripcropping without the sod, may be expected to provide more soil loss reduction than contouring alone. **P** values equal to about 80 percent of those for contouring are recommended if fairly heavy mulch strips remain throughout the year. If the strips are maintained only from harvest until the next seedbed preparation, the credit should be applied to the soil loss ratio for cropstage 4 rather than the **P** value.

Contour Stripcropping

Stripcropping, a practice in which contoured strips of sod are alternated with equal-width strips of row crops or small grain, is more effective than contouring alone. Alternate strips of grain and meadow year after year are possible with a 4-year rotation of corn-wheat with meadow seeding-meadow-meadow. This system has the added advantage of a low rotation **C** value. A stripcropped rotation of corn-corn-wheat-meadow is less effective. Alternate strips of winter grain and row crop were effective on flat slopes in Texas (*14*), but alternate strips of spring-seed grain and corn on moderate to steep slopes have not provided better erosion control than contouring alone.

Observations from stripcrop studies showed that much of the soil eroded from a cultivated strip was filtered out of the runoff as it was slowed and spread within the first several feet of the adjacent sod strip. Thus the stripcrop factor, derived from soil loss measurements at the foot of the slope, accounts for off-the-field soil movement but not for all movement within the field.

P Values, Strip Widths, and Length Limits

Recommended **P** values for contour stripcropping are given in table 14. The system to which each column of factors applies is identified in the table footnotes. The strip widths given in column 5 are essentially those recommended by the 1956 slope-practice workshop and are to be considered approximate maximums. Reasonable adjustments to accommodate the row spacing and row multiple of the planting and harvesting equipment are permissible. Slope-length limit is generally not a critical factor with contour stripcropping except on extremely long or steep slopes. The lengths given in column 6 are judgment values based on field experience and are suggested as guides.

Buffer Stripcropping

This practice consists of narrow protective strips alternated with wide cultivated strips. The location of the protective strips is determined by the width and arrangement of adjoining strips to be cropped in the rotation and by the location of steep, severely eroded areas on slopes. Buffer strips usually occupy the correction areas on sloping land and are seeded to perennial grasses and legumes. This type of stripcropping is not as effective as contour stripcropping (*4*).

TABLE 14.—**P** *values, maximum strip widths, and slope-length limits for contour stripcropping*

Land slope percent	P values[1] A	P values[1] B	P values[1] C	Strip width[2]	Maximum length
				Feet	Feet
1 to 2	0.30	0.45	0.60	130	800
3 to 5	.25	.38	.50	100	600
6 to 8	.25	.38	.50	100	400
9 to 12	.30	.45	.60	80	240
13 to 16	.35	.52	.70	80	160
17 to 20	.40	.60	.80	60	120
21 to 25	.45	.68	.90	50	100

[1] **P** values:

A For 4-year rotation of row crop, small grain with meadow seeding, and 2 years of meadow. A second row crop can replace the small grain if meadow is established in it.

B For 4-year rotation of 2 years row crop, winter grain with meadow seeding, and 1-year meadow.

C For alternate strips of row crop and small grain.

[2] Adjust strip-width limit, generally downward, to accommodate widths of farm equipment.

Terracing

The most common type of terrace on gently sloping land is the broadbase, with the channel and ridge cropped the same as the interterrace area. The steep backslope terrace is most common on steeper land. Difficulty in farming point rows associated with contoured terraces led to developing parallel terracing techniques (*16*). Underground outlets, landforming, and variable channel grades help establish parallel terraces. The underground outlets are in the low areas along the terrace line. The ridge is constructed across these areas. Another type of terrace, using a level and broad channel with either open or closed ends, was developed to conserve moisture in dryland farming areas.

Terraces with underground outlets, frequently called impoundment terraces, are highly effective for erosion control. Four-year losses from four such terrace systems in Iowa (*17*) averaged less than 0.4 t/A/year, which was less than 5 percent of the calculated soil movement to the channel. Comparable losses were measured from installations in Nebraska.

Terracing combined with contour farming and other conservation practices is more effective than those practices without the terraces because it positively divides the slope into segments equal to the horizontal terrace interval. The horizontal terrace interval for broadbase terraces is the distance from the center of the ridge to the center of the channel for the terrace below. For steep backslope terraces with the backslope in sod, it is the distance from the point where cultivation begins at the base of the ridge to the base of the frontslope of the terrace below (*44*). With terracing, the slope length is this terrace interval; with stripcropping or contouring alone, it is the entire field slope length.

P Values

Values of **P** for contour farming terraced fields are given in table 15. These values apply to contour farmed broadbase, steep backslope, and level terraces. However, recognize that the erosion control benefits of terraces are much greater than indicated by the **P** values. As pointed out earlier, soil loss per unit area on slopes of 5 percent or steeper is approximately proportional to the square root of slope length. Therefore, dividing a field slope into **n** approximately equal horizontal terrace intervals divides the average soil loss per unit area by the square root of **n**. This important erosion control benefit of terracing is not included in **P** because it is brought into the USLE computation through a reduced **LS** factor obtained by using the horizontal terrace interval as the slope length when entering figure 4 or table 3.

Erosion control between terraces depends on the crop system and other management practices evaluated by **C**. The total soil movement within a contour-farmed terrace interval may be assumed equal to that from the same length of an identical slope that is contoured only. Therefore, if a control level is desired that will maintain soil movement between the terraces within the soil loss tolerance limit, the **P** value for a contour-farmed terraced field should equal the contour factor (col. 2, table 15), and use of these values for farm planning purposes is generally recommended.

With contour stripcropping, the soil deposited in the grass strips is not considered lost because it remains on the field slope. With terraces, most of the deposition occurs in the terrace channels, but research measurements have shown that this deposition may equal 80 percent of the soil moved from the contour-farmed slopes between the terraces (*67*). Use of the contour factor as the **P** value for terracing assumes that all of the eroded soil deposited in the terrace channels is lost from the productive areas of the field. With broadbase terraces, the channels and ridges are cropped the same as

TABLE 15.—**P** *values for contour-farmed terraced fields*[1]

Land slope (percent)	Farm planning		Computing sediment yield[3]	
	Contour factor[2]	Stripcrop factor	Graded channels sod outlets	Steep backslope underground outlets
1 to 2	0.60	0.30	0.12	0.05
3 to 8	.50	.25	.10	.05
9 to 12	.60	.30	.12	.05
13 to 16	.70	.35	.14	.05
17 to 20	.80	.40	.16	.06
21 to 25	.90	.45	.18	.06

[1] Slope length is the horizontal terrace interval. The listed values are for contour farming. No additional contouring factor is used in the computation.

[2] Use these values for control of interterrace erosion within specified soil loss tolerances.

[3] These values include entrapment efficiency and are used for control of offsite sediment within limits and for estimating the field's contribution to watershed sediment yield.

the interterrace slopes, and some of the material deposited in the channels is moved to the ridges in terrace maintenance. The 1956 slope-practice group felt that some of the deposition should be credited as soil saved and recommended use of a terracing practice factor equal to the stripcrop factor (*64*). However, the more conservative values given in column 2 are now commonly used in conservation planning.

When the USLE is used to compute a terraced field's contribution to offsite sediment or watershed gross erosion, the substantial channel deposition must be credited as remaining on the field area. For this purpose, the **P** values given in the last two columns of table 15 are recommended unless an overland flow deposition equation based on transport relationships is used with the USLE.

With widespread use of large multirow equipment, farming with field boundaries across nonparallel terraces is not uncommon in some regions. When terraces are not maintained and overtopping is frequent, **P** = 1 and the slope length is the field slope length. However, if the terraces are periodically maintained so that overtopping occurs only during the most severe storms, **LS** is based on the horizontal terrace interval. If farming across terraces is at an angle that approximates contour farming, **P** values less than 1.0 but greater than the contour factors would be appropriate.

Soil Loss Terrace Spacing

Traditionally, terrace spacing has been based on slope gradient; however, some recent spacing guides have included modifying factors for severity of rainfall and for favorable soil and tillage combinations. A major objective of cropland conservation planning is to hold the productive topsoil in place. Extending this objective to terrace system design suggests limiting slope lengths between terraces sufficiently so that specified erosion tolerances will not be exceeded. Using the USLE in developing spacing guides will make this possible.

The USLE may be written as **LS = T/RKCP,** where **T** is the tolerance limit. If **T/RKP = Z,** then **LS = Z/C,** and **C = Z/LS.** The values **T, R, K** and **P** are constant for a given location and can be obtained from handbook tables and charts as illustrated in the section **Predicting Cropland Soil Losses.** Factor **C** can be selected as the **C** value of the most erosion-vulnerable crop system that a farmer is likely to use on the terraced field. **LS** can be computed by solving the equation as written above and, with the percent slope known, the maximum allowable length can be read from the slope-effect chart, figure 4.

To illustrate the procedure, assume a 6-percent slope at a location where **R** = 175, **K** = 0.32, **T** = 5, **P** = 0.5, and the most erodible crop expected to occur on the field has a **C** value of 0.24. (An assumption that the field will always be in a sod based rotation or that the operator will always make the best possible use of the crop residues would be too speculative to serve as a guide for terrace spacing.) With these assumptions, **Z** = 5/175 (0.32)(0.5) = 0.179 and **LS** = 0.179/0.24, or 0.744. Enter the slope-effect chart, figure 4, on the **LS** scale with a value of 0.744, move horizontally to intersect the 6 percent-slope line and read the corresponding slope length, 120 ft, on the horizontal scale. Add to this value the width of the terrace frontslope and compute the vertical interval: $\left(\frac{120 + 12}{100}\right)6 = 7.9$ ft. However, the horizontal interval should not exceed the slope-length limit for effectiveness of contouring. From table 13 the length limit for contouring on a 6-percent slope is 200 ft, so the computed terrace interval is satisfactory. A small modification in spacing may be made to adjust to an even multiple of machinery width.

The maximum **C** value that will allow a horizontal terrace spacing equal to the length limit for effective contouring on the given slope can also be determined by using figure 4 and table 13. For the conditions in the illustration above, **C** = 0.179/**LS.** The maximum acceptable length for contouring is 200 ft. From figure 4, the **LS** value for a 200-ft length of 6-percent slope is 0.95. Therefore, the maximum allowable **C** = 0.179/0.95, which is 0.188. With terraces spaced at 200-ft intervals, any cropping and management system with a **C** value of less than 0.188 should provide the level of conservation prescribed by the assumed soil loss tolerance limit of 5 t/A/year.

One additional consideration is important. For a terrace to function satisfactorily, the channel capacity must be sufficient to carry the runoff safely to a stabilized outlet without excessive channel scour or overtopping of the ridge. SCS engineering practice standards specify a capacity sufficient to control the runoff from a 10-year-frequency, 24-hour storm without overtopping. Some SCS practice standards may require a shorter terrace interval than would be indicated by the foregoing procedure.

The discussion of the topographic factor pointed out that the erosion rate increases as slope length increases. Table 4 lists the relative soil losses for successive equal-length increments of a uniform slope divided into 2, 3, 4, or 5 segments. The third column of table 4 shows that if a uniform 6-percent slope were controlled at a tolerance of 5 t average soil loss, the average loss per unit area from the lower third of the slope would exceed the tolerance by about 38 percent. Soil loss from the upper third would be 43 percent less than the tolerance limit. To have an average rate of 5 t from the lower third, the **T** values used in the spacing calculation would need to be 1/1.38 times the 5-t tolerance, or 3.6 t. This is an approach that can be used to calculate terrace spacings for a higher level of conservation.

Effect of Terraces on Amount and Composition of Offsite Sediment

By reducing runoff velocity and inducing deposition of sediment in the channels, terraces have a profound effect on the amount and composition of offsite sediments from cultivated fields. The type of terrace, the channel grade, and the type of outlet influence the magnitude of the effect.

The greatest reduction in sediment is attained with the impoundment type terrace systems that use underground outlets. With the outlets in the lower areas of the field and terrace ridges built across these areas, temporary ponds are created around the risers of the outlet tile. The outlets are designed to drain the impounded runoff in 1 to 2 days. Thus, the ponds provide a maximum stilling effect, and only the smallest and lightest soil particles are carried off the field in the runoff water. The increased time for infiltration also reduces runoff.

Sediments collected from four impoundment terrace systems over 4 years in Iowa (*17*) showed the following percentages of fine materials:

Soil type	< 0.002 mm	< 0.008 mm
	Percent	*Percent*
Fayette silt loam	78	91
Sharpsburg silty clay loam	68	96
Floyd loam	31	82
Clarion loam	35	78

Sediment concentrations in the runoff ranged from about 1,300 p/m on the Fayette soil to 6,300 p/m on the Clarion. Average annual sediment from the outlets was less than 800 lb/A for all four systems.

Farm chemical losses in runoff vary with type and formulation, amount, placement, and time of rainfall in relation to time of application, as well as with the usual runoff and erosion factors. Principal chemicals are the fertilizers, insecticides, fungicides, and herbicides. Losses are by solution and by suspension of chemical granules or adsorption on soil particles suspended in the runoff water.

Terracing exerts its greatest influence in reducing offsite pollution from those chemicals that are adsorbed on soil particles. Examples of these are the phosphates, organic nitrogen, and persistent organochlorine insecticides. Reductions in offsite *sediment* by terrace systems with contouring are estimated to range from 82 to 95 percent. However, the reductions in chemical transport are generally not proportional to reductions in soil loss because of an enrichment process that applies to the suspensions. The nutrient content of sediments is often 50 percent greater than that of the soil. Offsite delivery of sediment is also affected by watershed characteristics, particularly size of the drainage area. This reduction is measured by a "delivery ratio" that ranges from 0.33 for an area of one-half square mile to 0.08 for a 200-mi^2 area (*45*).

Terracing has the least effect on offsite pollution from those chemicals transported primarily in solution. Annual runoff reductions by terracing and contour farming, at 21 locations throughout the United States, have been estimated to vary only from 9 to 37 percent (*42*). Examples of farm chemicals transported primarily in solution are the nitrates and some herbicides such as 2,4-D ((2,4-dichlorophenoxy) acetic acid). The predominate transport modes for an extensive list of pesticides are listed in volumes 1 and 2 of "Control of Water Pollution From Cropland" (*42*).

APPLYING THE SOIL LOSS EQUATION

The major purpose of the soil loss prediction procedure is to supply specific and reliable guides for selecting adequate erosion control practices for farm fields and construction areas. The procedure is also useful for computing the upland erosion phase of sediment yield as a step in predicting rates of reservoir sedimentation or stream loading, but the USLE factors are more difficult to evaluate for large mixed watersheds. Specific applications of the soil loss equation are discussed and illustrated below.

Predicting Cropland Soil Losses

The USLE is designed to predict longtime-average soil losses for specified conditions. This may be the average for a rotation or for a particular crop year or cropstage period in the rotation. Where the term "average loss" is used below, it denotes the average for a sufficient number of similar events or time intervals to cancel out the plus and minus effects of short-time fluctuations in uncontrolled variables.

Rotation Averages

To compute the average annual soil loss from a particular field area, the first step is to refer to the charts and tables discussed in the preceding sections and select the values of **R, K, LS, C,** and **P** that apply to the specific conditions on that field. For example, assume a field on Russell silt loam soil in Fountain County, Ind. The dominant slope is about 8 percent with a length of 200 ft. Fertility and crop management on this field are such that crop yields are rarely less than 85 bu corn, 40 bu wheat, or 4 t alfalfa-brome hay. The probability of meadow failure is slight.

Factor **R** is taken from the isoerodent map (fig. 1). Fountain County, in west-central Indiana, lies between isoerodents of 175 and 200. By linear interpolation, **R** = 185. **K** is taken from a table of **K** values that were derived either by direct research measurement or by use of the soil erodibility nomograph (fig. 3). For the Russell silt loam soil, **K** = 0.37. The slope-effect chart, figure 4, shows that an 8 percent slope 200 ft long has an **LS** of 1.41. If the field were continuously in clean-tilled fallow, the average annual soil loss from the dominant slope would equal the product **RKLS**; that is, 185(0.37)(1.41) = 96.5 t/A.

Next, we need to know the effect of the cropping and management system and support practices existing on the field. This effect is represented by factors **C** and **P**. The **C** value for the field may either be derived by the procedure previously presented, using data from tables 5 and 6, or it may be obtained from a centrally prepared **C** value table available from the SCS. For convenience, assume the same crop system and management as were assumed for the problem illustrating the derivation of locality **C** values. From table 8, **C** then equals 0.085. If rows and tillage are in the direction of the land slope, factor **P** = 1.0. The computed average soil loss is then 96.5(0.085)(1.0) = 8.2 t/A/year.

From table 13, contour farming on 8 percent slopes not exceeding 200 ft in length has a **P** value of 0.5. Therefore, if farming were on the contour, the computed average soil loss for the field would be 96.5(0.085)(0.5) = 4.1 t. If the length of 8-percent slope was appreciably greater than 200 ft, the effectiveness of contouring could not be assumed, and the **P** value of 0.5 would not be applied unless the slope length was broken by terraces or diversions. Any change in either the crop sequence or the management practices would likely increase or decrease soil loss. This would be reflected in the USLE solution through a change in the **C** value.

When **C** is used at its average annual value for a rotation that includes a sod crop, as was done in the example given in table 8, the heavier losses experienced during row crop years are diluted by trivial losses in the meadow year(s). For holding longtime-average soil losses below some prescribed tolerance limit, this dilution poses no problem. But from the viewpoint of offsite water quality, it may not be desirable. The USLE may also be used to compute the average soil loss for each crop in the rotation or for a particular cropstage period.

Crop-Year Averages

The subtotals in column 9 of table 8 show that with the assumed management system, **C** for the first-year corn would be 0.130 and for the second-year, 0.138. For the second-year corn, without contouring, the expected average soil loss would equal 185(0.37)(1.41)(0.138), or 13.3 t. If, in the same crop system, the corn residues were plowed down in fall, the **C** value for second-year corn would be 0.29, and the soil loss would average 28 t. On the other hand, no-till planting the second-year corn in a 70-percent cover of shredded cornstalks would reduce the **C** value for this crop to 0.08 and the soil loss to about 8 t. This would also reduce the rotation average for straight row farming to 7 t. Killing the meadow instead of turning it under, and no-till planting, would reduce the **C** value for the first-year corn to 0.01 and the soil loss to less than 1 t. Thus, crop-year **C** values can be helpful for sediment control planning.

Cropstage Averages

Additional information can be obtained by computing the average annual soil loss for each cropstage period. First, the computed cropstage soil losses will show in which portions of the crop year (or rotation cycle) improved management practices would be most beneficial. Second, they provide information on the probable seasonal distribution of sediment yields from the field. When a tabulation like table 8 has been prepared, the values in column 8 will be directly proportional to the cropstage soil losses. They can be converted to tons per acre for a specific field by multiplying them by the product of factors **R**, **K**, **LS**, and **P**.

To estimate the average soil loss for a particular cropstage when such a table has not been prepared, the cropstage soil loss ratio from table 5 is used as **C**. The annual **EI** fraction that is applicable to the selected period is obtained from table 6 and is multiplied by the location's annual erosion index value (fig. 1) to obtain the relevant **R** value. **K**, **LS**, and **P** will usually be assumed to have the same values as for computation of average annual soil losses.

Suppose, for example, that one wishes to predict the average soil loss for the seedbed and establishment periods of corn that is conventionally planted about May 15 on spring plowed soybean land in southwestern Iowa (area No. 13, fig. 9). Suppose also that the corn is on a field for which the combined value of factors **K**, **LS**, and **P** is 0.67 and the fertility and crop management are such that corn planted by May 15 usually develops a 10 percent canopy cover by June 5, 50 percent by June 25, and a final canopy cover of more than 95 percent. Interpolating between values in line 13 of table 6 shows cumulative **EI** percentages of 12, 23, and 43 for these three dates. Therefore, on the average, 11 percent of the annual **EI** would occur in the seedbed period, and 20 percent would occur in the establishment period. From line 109 of table 5, the soil loss ratios for these two cropstage periods under the assumed management are 0.72 and 0.60. From figure 1, the average annual **EI** is 175. The soil loss would be expected to average $0.11(175)(0.72)(0.67) = 9.3$ t/A in the seedbed period and $0.20(175)(0.60)(0.67) = 14$ t in the establishment period. The cropping assumed for this example represents an extremely erodible condition. For second-year corn with good residue management, the applicable soil loss ratios and the predicted soil losses would be much lower.

Individual Storm Soil Losses

The USLE factors derived from tables and charts presented herein compute longtime-average soil losses for specified cover and management on a given field. The USLE is not recommended for prediction of specific soil loss events.

If it is applied to a specific rainstorm, using the storm **EI** for **R** and the relevant cropstage soil loss ratio for **C**, it will estimate the *average* soil loss for a large number of storms of this size occurring on that field and in that cropstage period. However, the soil loss from any one of these events may differ widely from this average because of interactions with variables whose values fluctuate randomly over time (*56*).

When rain falls on relatively dry, freshly tilled soil, most of the water may infiltrate before runoff begins, resulting in a low-average soil loss per unit of **EI** for that storm. When rain falls on presaturated soil, runoff begins quickly, and most of the rain becomes runoff. Such rains usually produce above-average soil loss per **EI** unit. Some rains are accompanied by high winds that increase the impact energy of raindrops; others occur in a fairly calm atmosphere. Some storms begin with a high intensity and seal the surface quickly so that trailing lower intensities encounter a low infiltration rate. In other storms the moderate intensities precede the high ones. In some seasons the soil is cultivated when wet and remains cloddy; in other seasons it is cultivated when soil moisture is ideal for fine pulverization. A claypan or fragipan subsoil may substantially influence permeability in early spring or in a wet growing season and yet have no significant effect on infiltration rates during intense thunderstorms on dry soil.

The soil loss ratios of table 5 are averages for cropstage periods that cover several weeks to several months. Early in a cropstage period, the ratio will usually be higher than the average because the development of cover is gradual. Later in the period it will be lower than average. In a poor growing season the ratio will be above average because cover and water use by transpiration are below normal. In a favorable growing season, the ratio will be below average. Cover effect in a specific year may be substantially influenced by abnormal rainfall. A crop canopy or conservation tillage practice may delay the start of runoff long enough to be 100 percent effective for moderate storms on a given field and yet allow substantial erosion by prolonged runoff periods.

The irregular fluctuations in these and other variables can greatly influence specific-storm soil losses. However, they do not invalidate the USLE for predicting long-term-average soil losses for specific land areas and management conditions. Their positive and negative effects tend to balance over a longtime period, and their average effects are reflected in the factor-evaluation tables and charts.

Two recent research reports are recommended references for those who find it necessary to estimate specific-storm soil losses (*34*, *10*). The authors present modifications of **R** and **LS** that are designed to account for some random effects discussed.

Specific-Year Soil Losses

In any given year, both the annual **EI** and its monthly distribution may differ substantially from the location averages. Therefore, **R** values from figure 1 and **EI** distribution data from table 6 will not correctly reflect specific-year values of these variables. The most accurate procedure is to compute the **EI** value for each storm from a recording-rain gage record for the location and year by the method given in the appendix. The storm values are summed for each cropstage period, and the subtotals are combined with soil loss ratios from table 5 to estimate the soil loss for each cropstage period. The sum of the cropstage soil losses then reflects the effects of possible abnormal **EI** distribution, as well as the corrected **R** value for the specific year. However, the irregular fluctuations in variables discussed in the preceding subsection are often related to abnormalities in rainfall. The plus and minus effects on soil loss may not average out within 1 year but may appreciably bias specific-year soil losses. These biases will not be evaluated by the USLE. Therefore, specific-year estimates of soil loss will be less accurate than USLE estimates of long-term, crop-year averages.

Soil Loss Probabilities

Soil loss probabilities are a function of the combination of the probabilities for annual **EI**, seasonal distribution of the erosive rains, abnormal antecedent soil moisture conditions, favorable or unfavorable conditions for soil tillage and crop development, and other factors. The section on the **Rainfall Erosion Index** pointed out that a location's annual and maximum storm **EI** values tend to follow log-normal frequency distributions and that specific probability values are listed in tables 17 and 18 for 181 key locations. When these probabilities of **EI** are used for **R** in the USLE, the equation will estimate the soil loss that would occur if all the other factors were at their normal levels. However, the seasonal distribution of erosive rains, and the surface conditions in the field, may also be abnormal in years of rainfall extremes. Deriving probable relationships of these variables to extremes in annual **EI** would require longer records than were available.

Stochastic modeling techniques (*66*) are available that could be used to generate synthetic data having the same statistical properties as historical data. Such data could be used to estimate the probable range in specific-year soil losses in a particular rainfall area.

Determining Alternative Land Use and Treatment Combinations

The soil loss prediction procedure supplies the practicing conservationist with concise reference tables from which he can ascertain, for each particular situation encountered, which specific land use and management combinations will provide the desired level of erosion control. A number of possible alternatives are usually indicated. From these, the farmer will be able to make a choice in line with his desires and financial resources.

Management decisions generally influence erosion losses by affecting the factor **C** or **P** in the erosion equation. **L** is modified only by constructing terraces, diversions, or contour furrows with sufficient capacity throughout the year to carry the runoff water from the furrow area above. **R, K,** and **S** are essentially fixed as far as a particular field is concerned.

When erosion is to be limited within a predetermined tolerance, **T,** the term **A** in the equation is replaced by **T,** and the equation is rewritten in the form **CP** = **T/RKLS.** Substituting the site values of the fixed factors in this equation and solving for **CP** give the maximum value that the product **CP** may assume under the specified field conditions. With no supporting practices, **P** = 1, and the most intensive cropping plan that can be safely used on the field is one for which **C** just equals this value. When a supporting practice like contouring or stripcropping is added, the computed value of **T/RKLS** is divided by the practice factor, **P,** to obtain the maximum permissible cover and management factor value. Terracing increases the value of **T/RKLS** by decreasing the value **L.**

A special USLE calculator, originally designed in Tennessee (*41*) and recently updated, enables rapid and systematic calculation of either average annual soil loss or **T/RKLS** for any specific situation.

Many practicing conservationists prefer to use handbook tables. **C**-value tables for specific geographic areas (fig. 9) are centrally prepared by persons who are experienced in the procedures outlined in a preceding section and who obtain the needed data from tables 5 and 6. Values of **T/RKLS** are also centrally computed and arranged in two-way classification as illustrated in table 16 for **R** = 180, **K** = 0.32, and **T** = 5. Similar tables are prepared for other combinations of **R, K,** and **T.**

A conservationist working in the field usually carries a pocket-sized handbook which includes the **R** value(s), **T** and **K** soil values, applicable tables of **T/RKLS** values, and a table of **C** values for the area. These items will provide all the information needed to use this procedure as a guide for selecting conservation practices in each field. Solving the equation or performing field computations rarely will be necessary.

TABLE 16.—*Maximum permissible* **C** *values* (**T/RKLS**) *for* **R** = *180,* **K** = *0.32 and* **T** = *5*

Gradient percent	Values for slope lengths (feet)							
	50	75	100	150	200	250	300	400
	STRAIGHT ROW							
2 ..	0.53	0.47	0.43	0.38	0.35	0.33	0.31	0.28
4 ..	.29	.24	.22	.18	.16	.15	.14	.12
6 ..	.18	.15	.13	.11	.091	.082	.074	.064
8 ..	.12	.10	.087	.072	.062	.055	.050	.044
10 ..	.090	.073	.063	.052	.045	.040	.037	.032
12 ..	.068	.056	.048	.039	.034	.030	.028	.024
14 ..	.054	.044	.038	.031	.027	.024	.022	.019
16 ..	.043	.035	.030	.025	.022	.019	.018	.015
	CONTOURED[1]							
2 ..	0.89	0.78	0.72	0.64	0.58	0.55	0.52	0.47
4 ..	.57	.49	.43	.37	.33	.30	.28	.25
6 ..	.36	.30	.26	.21	.18	.16	([2])	—
8 ..	.25	.20	.17	.14	.12	.11	—	—
10 ..	.15	.12	.11	.086	([2])	—	—	—
12 ..	.11	.093	.080	.065	—	—	—	—
14 ..	.077	.062	.054	([2])	—	—	—	—
16 ..	.062	.050	.044	—	—	—	—	—

[1] The values for contour farming are **T/RKLSP**, where **P** is dependent on percent slope (see table 13).

[2] Omission of values indicates that the slope-lengths exceed the limits for effectiveness of contouring. Use corresponding values from upper half of table.

Example. The first step is to ascertain the soil type, percent slope, and slope length for the field being planned. From his handbook data, the conservationist can then obtain the values of **R, K,** and **T.** To complete the illustration, assume that **R** = 180, **K** = 0.32, **T** = 5, and the field slope is 400 ft long with a nearly uniform gradient of 6 percent. For this combination, the **T/RKLS** table shows a value of 0.064 for straight-row farming with the land slope (table 16). This is the maximum **C** value that will hold the average annual soil loss from that field within the 5-t tolerance limit, if no supporting practices are used. Consulting the **C** value table will show that a **C** as low as 0.064 can be attained only with well-managed, sod-based crop systems, or with no-till planting in residue covers of at least 70 percent.

A logical improvement is to add contouring. Table 13 shows a slope-length limit of 200 ft (250 ft if residue cover after seeding exceeds 50 percent) for contouring on 6-percent slope. Therefore, the **P** value of 0.5 for contouring will not be applicable on the 400-ft slope without terracing. Construction of three, equally spaced terraces across the slope would divide it into four 100-ft slope lengths. Shortening the slope lengths to 100 ft will assure contour effectiveness and will also reduce the site value of **L**. For a 100-ft length of 6-percent slope farmed on the contour, table 16 shows a **T/RKLSP** value of 0.26. Any combination of cropping and management practices having a **C** value less than 0.26 will now be acceptable. Consulting the table of **C** values will show that with the terraces and contouring, the conservationist can recommend a range of possibilities for land use and management. If a system with a **C** value appreciably less than 0.26 is selected, a higher level of conservation will be attained than required by the 5-t tolerance limit.

Had the slope length in the example been only 200 ft, the contour **P** value of 0.5 (table 13) would have been applicable without the terraces. Table 16 shows that this combination would have permitted use of any system having a **C** value less than 0.18.

Thus, by this procedure a conservationist can list all the alternative crop system and management combinations that would control erosion on a field at an acceptable level. Study of this list will show how an erosion control program can be improved and still increase crop yields or decrease labor and fuel costs. In making a selection from this list, practices needed for control of nutrient and pesticide losses in the runoff (*42*) should also be considered.

Construction Sites

Procedures and data have been presented for predicting erosion losses from specific cropland areas and logically determining alternative ways in which the losses from each field may be held below given tolerance limits. These procedures and data can also be adapted to conditions on highway, residential, and commercial developing areas. The USLE will show under which development plan the area will produce the least sediment, and it will also show about how much sediment the developer will need to trap in sediment basins (*46*) during construction to prevent excessive soil movement to streams or reservoirs.

Evaluating the erosion factors for construction site conditions is discussed below. However, those primarily concerned with this particular phase of sediment control should also read the preceding discussions of the USLE factors and the procedures for predicting cropland soil losses.

Factor R. For a construction project extending over several years, the average annual **R** value for the site is obtained directly from figure 1. Probabilities of **EI** values greater than average are given in table 17. Using **EI** probabilities for **R** was discussed in the subsection **Soil Loss Probabilities.**

For construction periods of less than 1 year, the procedure outlined for predicting cropland soil losses for specific cropstage periods is appropriate. The portion of the annual **R** value that is applicable to the construction period is obtained from table 6 as illustrated on p. 41 for cropstage averages.

Factor K. Because the soil surface is often unprotected during construction, this factor assumes even greater importance than for cropland. The soil erodibility nomograph (fig. 3) can be especially helpful for sediment prediction and erosion control planning on construction sites because it can predict the changes in erodibility when various subsoil horizons are exposed in the reshaping process. Some subsoils are substantially more erodible than the original topsoil, and others are less erodible. The planner can usually obtain a detailed description of the successive horizons of his soil from published soil survey data. By using the data for each soil horizon separately to follow the steps of the nomograph solution, the **K** value can be determined after various depths of desurfacing. Soil losses from the successive soil horizons, if exposed on similar slopes, would be directly proportional to the horizon **K** values. Information on the subsoil **K** values not only shows the depths of cut that would result in the most or the least soil erosion but also indicates whether return of stockpiled topsoil on the exposed subsoil would be profitable on the particular site.

When a chemical soil additive is used that stabilizes the soil and makes it less erodible, the **K** value is the nomograph solution times a factor for the effectiveness of the chemical additive.

Factor LS. Within limits, the **LS** value for a given length and steepness of uniform slope can be obtained directly from figure 4 or table 3. When the slope is concave or convex, the figure 4 value needs to be adjusted by the procedure outlined for irregular slopes in the section on **The Topographic Factor**.

Development planning may include measures designed to reduce sediment yield by lowering **LS**. The effect of shortening slope lengths by diversions or stabilized drainageways is credited by entering figure 4 with the reduced slope length. A slope graded to flatten toward the bottom (concave) will lose less soil than an equivalent uniform slope whereas one that steepens toward the bottom (convex) will lose more. Reduction or increase in soil loss can be predicted by the procedure illustrated in the subsection **Irregular Slopes**.

Data are not available to evaluate **LS** on very steep slopes, like 2:1 and 3:1 roadbank slopes, in relation to soil and rainstorm characteristics. The best presently available estimates of **LS** for these slopes can be obtained by the **LS** equation presented earlier. However, values projected by this equation for steep slopes are speculative because the equation was derived from data obtained on slopes of less than 20 percent.

Factor C. Procedures for selecting **C** values for construction sites were given in the **Cover and Management Factor** section.

Factor P. This factor as used for soil conservation planning on cropland would rarely have a counterpart during construction on development areas, and **P** will usually equal 1.0. Erosion-reducing effects of shortening slopes or reducing slope gradients are accounted for through the **LS** factor.

If the lower part of a grass or woodland slope on a development area can be left undisturbed while the upper part is being developed, the procedure outlined for computing the value of **LSC** on irregular slopes is applicable, and sediment deposition on the undisturbed strip must be accounted for separately. For prolonged construction periods, buffer strips of grass, small grain, or high rates of anchored mulch may also be feasible to induce deposition within the area. Such deposition is important for water quality or offsite sediment control, but it should be evaluated from soil-transport factors rather than by a **P** factor.

Alternative plans. When appropriate numerical values of the six erosion factors are combined, their product is the soil loss estimate for the particular area in tons per acre and for the time interval for which **R** was evaluated. With the information supplied by the tables and charts in this handbook, the six factor values can be derived for each feasible alternative plan. Successive solutions of the equation will then provide comparative soil loss estimates to help guide decisions by the developer.

Estimating Upslope Contributions to Watershed Sediment Yield

The importance of predicting watershed sediment yields and identifying the major sediment sources was increased by the Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500. Sources, causes, and potentials of sediment, nutrient, and pesticide losses from cropland, and measures that may be necessary to control these pollutants, are dealt with in depth in a two-volume manual developed by SEA and the Environmental Protection Agency (EPA) (*42*). Volume II, "An Overview," also includes an extensive list of other relevant publications. Only sediment yield prediction will be considered here.

Estimates show that about one-fourth of the amount of sediment moved by flowing water in the United States annually reaches major streams (*42*). The USLE can be used to compute average sheet and rill erosion in the various parts of a watershed, but deposition and channel-type erosion must be estimated by other means. A fully tested equation for sediment transport to use on agricultural land is not now available. One presented by Neibling and Foster (*32*) is perhaps the best now available for use with the USLE. It estimates transport capacity for sand and large silt-sized particles and does not consider the transport of clay particles.

Of the several methods now used for estimating sediment yield, the Gross Erosion-Sediment Delivery Method uses the USLE. A brief description of this method follows. More details are available from the SCS National Engineering Handbook (*45*). The equation is

$$Y = E(DR)/W_s \qquad (6)$$

where **Y** is sediment yield per unit area,
E is the gross erosion,
DR is the sediment delivery ratio, and
W_s is the area of the watershed above the point for which the sediment yield is being computed.

Gross Erosion

Gross erosion is the summation of erosion from all sources within the watershed. It includes sheet and rill erosion from tilled cropland, meadows, pastures, woodlands, construction sites, abandoned acreages, and surface-mined areas; gully erosion from all sources; and erosion from streambeds and streambanks. The relative importance of each of these sources of gross erosion will vary between watersheds.

The USLE can be used to estimate the sediment generated by sheet and rill erosion that is usually, but not always, the major portion of a watershed's gross erosion. Sediment from gully, streambank and streambed erosion, and from uncontrolled roadsides must be added to the USLE estimates. Methods for estimating sediment yields from these sources are discussed in Section 3 of the SCS National Engineering Handbook (*45*).

For small areas like farm fields or construction sites, the six USLE factors can usually be evaluated directly from the information presented in this handbook. For a large heterogeneous watershed, the factors are more difficult to define. Several methods of computing the average slope length and gradient for a large drainage area are available. Using **LS** values based on such averages, together with estimated watershed-average soil and cover factors, simplifies the computing procedure, but the saving in time is at the expense of substantial loss in accuracy. Erosion hazards are highly site specific. The parameters that determine the USLE factor values vary within a large watershed, and the variations are often not interrelated. Combining overall averages in the equation does not reflect the particular way in which the factors are actually combined in different parts of the watershed. Neither does it show which portions of the drainage area are contributing most of the sediment.

A more accurate procedure is to divide the heterogeneous drainage area into subareas for which representative soil type, slope length, gradient, cover, and erosion-control practice factors can be defined. The USLE is then used to compute the sheet and rill erosion on each subarea. For this purpose, eroded soil that is entrapped within the field area by terrace systems is not soil loss. An estimate of the entrapped sediment can be excluded from the USLE soil loss estimates by using values from the last two columns of table 15 as the **P** values. An alternate procedure is to estimate the channel deposition by sediment-transport relationships and subtract this amount from the soil loss computed by using the standard terracing factor (col. 2, table 15) in the USLE. By this procedure, the subarea soil loss computations identify the portions of the drainage area that contribute most of the sediment and also show how much of the sediment derives from tracts that receive heavy applications of agricultural chemicals.

Procedures for computing soil losses from cropped, idle, pasture, range, or wooded areas and from construction or development areas were outlined in the preceding sections. Factor values derived by the prescribed procedures are assumed applicable also for surface-mined areas. However, the effect of mining processes on soil erodibility, **K**, has not been determined. Length and percent slope and deposition within the area also are hard to determine for rugged strip mine spoils. Sometimes nearly all the sediment may be trapped within the bounds of the area. The USLE can be quite useful for predicting the effectiveness of each feasible reclamation plan for such areas.

Sediment Delivery Ratio

Eroded soil materials often move only short distances before a decrease in runoff velocity causes their deposition. They may remain in the fields where they originated or may be deposited on more level slopes that are remote from the stream system. The ratio of sediment delivered at a given location in the stream system to the gross erosion from the drainage area above that location is the sediment delivery ratio for that drainage area. A general equation for computing watershed delivery ratios is not yet available, but the ratios for some specific drainage areas have been computed directly from local data. Helpful guides for estimating this factor for other drainage areas were published by SCS in Section 3 of their National Engineering Handbook (*45*), and most of these guides were also included in a publication by SEA and EPA (*42*). Therefore, the relationships involved will be only briefly summarized here.

Available watershed data indicate that the delivery ratio varies approximately as the 0.2 power of drainage-area size, with representative values of about 0.33 for 0.5 mi^2; 0.18 for 10 mi^2; and 0.10 for 100 mi^2. There were indications that the exponent in this relationship may be as small as 0.1 for very large areas. But the ratio may vary substantially for any given size of drainage area. Other important factors include soil texture, relief, type of erosion, sediment transport system, and areas of deposition within the watershed. Fine soil texture, high channel density, and high stream gradients generally indicate delivery ratios that are above average for the drainage-area size.

A substantial reduction in sediment delivered to a stream may sometimes result in a compensatory increase in channel erosion. Channel erosion produces sediment that is immediately available to the transport system and that may remain in motion as bedload and suspended sediment. The composition of sediment derived from channel erosion will usually differ substantially from that derived from cropland erosion. This is particularly important from the viewpoint of transported chemical pollutants.

With reference to a field-sized area, the delivery ratio can closely approach 1.0 if the runoff drains directly into a lake or stream system with no intervening obstructions or flattening of the land slope. On the other hand, a substantial width of forest litter or dense vegetation below the eroding area may cause deposition of essentially all the sediment except colloidal material. Anything that reduces runoff velocity (such as reduction in gradient, physical obstructions, vegetation, and ponded water) reduces its capacity to transport sediment. When the sediment load exceeds the transport capacity of the runoff, deposition occurs.

From analysis of runoff and soil loss data from small single-cropped watersheds, Williams (*48*) concluded that the need for a sediment delivery ratio could be eliminated by using the watershed runoff times peak rate as the storm **R** value in the USLE.

Accuracy of USLE Predictions

Soil losses computed with the USLE are best available estimates, not absolutes. They will generally be most accurate for medium-textured soils, slope lengths of less than 400 ft, gradients of 3 to 18 percent, and consistent cropping and management systems that have been represented in the erosion plot studies. The farther these limits are exceeded, the greater will be the probability of significant extrapolation error.

An indication of the accuracy of the equation, tables, and charts presented herein was obtained by using them to compute longtime average soil losses for plots in past erosion studies and comparing these with the actually measured losses on each plot. About 53 percent of the differences were less than 1 t/A, 84 percent were less than 2 t, and 5 percent were as much as 4.6 t (*53*). The mean annual soil loss for this 2,300 plot-year sample was 11.3 t. Of those differences that exceeded 1 t/A, 67 percent were from comparisons with plot records whose duration was less than half of a normal 22-year rainfall cycle (*33*). Such short records are subject to bias by cyclical effects and random fluctuations in uncontrolled variables whose effects are averaged in the USLE factor values (*56*). Testing the complete equation against the assembled plot data was statistically valid because the equation for each factor, as a function of several parameters, was independently derived from only selected portions of the data.

The accuracy of a predicted soil loss will depend on how accurately the physical and management conditions on the particular piece of land are described by the parameter values used to enter the factor-evaluation tables and charts. An error in the selection of a factor value will produce an equivalent percentage error in the soil loss estimate. Large-scale averaging of parameter values on mixed drainage areas will usually also reduce accuracy. For reasons previously pointed out and discussed in depth in another publication (*56*), specific-storm or specific-year soil losses and short-term averages may differ substantially from the longtime average predicted by the USLE for the specified physical and management conditions.

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APPENDIX

Estimating Percentages of Canopy and Mulch Covers

"Percent canopy cover" is the percentage of the field area that could not be hit by vertically falling raindrops because of canopy interception. It is the portion of the soil surface that would be covered by shadows if the sun were directly overhead. Because the blades from adjacent rows intertwine does not necessarily indicate 100 percent canopy cover.

"Percent mulch cover" is the percentage of the field area that is covered by pieces of mulch lying on the surface. Researchers in Indiana attempted to relate percent cover to mulch rate by photographing numerous small, equal-sized areas in harvested corn fields. The residues on the photographed areas were carefully picked up, dried, and weighed to measure mulch rates, and the photographs were projected on grids to determine percent cover. The indicated average relation of percent cover to dry weight of well-distributed corn stover mulch is shown by the solid-line curve in figure 10. However, observed differences between samples were appreciable. The average relation of percent cover to dry weight of straw mulch uniformly distributed over research plots is shown by the broken-line curve.

A simple method of estimating percent mulch cover on a field is with a cord, preferably not shorter than 50 ft, that has 100 equally spaced knots or other readily visible markings. The cord is stretched diagonally across several rows, and the knots that contact a piece of mulch are counted. This procedure is repeated at randomly selected spots on the field, and the data are averaged to obtain a representative value for the field.

Probability Values of **EI** in the United States

The annual and maximum-storm values of **EI** at any given location differ substantially from year to year. The observed ranges and 50 percent, 20 percent and 5 percent probabilities of annual **EI** values from 22-year precipitation records at 181 locations in 44 States are listed in table 17. Other probabilities can be derived by plotting the 50 percent and 5 percent values on log-probability paper and joining the two points by a straight line. Annual maxima storm probabilities for the same locations are given in table 18.

Computing the Erosion Index from Recording-Rain Gage Records

Soil loss prediction by the method presented in this handbook does not require computation of **EI** values by application personnel, but the procedure is included here for the benefit of those who may wish to do so.

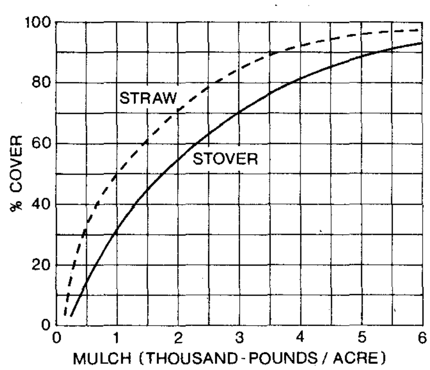

FIGURE 10.—Relation of percent cover to dry weight of uniformly distributed residue mulch.

The kinetic energy of a given amount of rain depends on the sizes and terminal velocities of the raindrops, and these are related to rainfall intensity. The computed energy per inch of rain at each intensity is shown in table 19. The energy of a given storm depends on all the intensities at which the rain occurred and the amount that occurred at each intensity. A recording-rain gage record of the storm will provide this information. Clock time and rain depth are read from the chart at each point where the slope of the pen line changes and are tabulated as shown in the first two columns of the sample computation below. Clock times (col. 1) are subtracted to obtain the time intervals given in column 3, and the depths (col. 2) are subtracted to obtain the incremental amounts tabulated in column 4. The intensity for each increment (col. 5) is the incremental amount times 60, divided by column 3.

Chart readings		For each increment			Energy	
Time	Depth (inch)	Duration (minute)	Amount (inch)	Intensity (in/hr)	Per inch	Total
4:00	0					
:20	0.05	20	0.05	0.15	643	32
:27	.12	7	.07	.60	843	59
:36	.35	9	.23	1.53	977	225
:50	1.05	14	.70	3.00	1074	752
:57	1.20	7	.15	1.29	953	143
5:05	1.25	8	.05	.38	777	39
:15	1.25	20	0	0	0	0
:30	1.30	15	.05	.20	685	34
Totals		90	1.30			1,284

Kinetic energy of the storm $= 1{,}284(10^{-2}) = 12.84$

The energy per inch of rain in each interval (col. 6) is obtained by entering table 19 with the intensity given in column 5. The incremented energy amounts (col. 7) are products of columns 4 and 6. The total energy for this 90-minute rain is 1,284 foot-tons per acre. This is multiplied by a constant factor of 10^{-2} to convert the storm energy to the dimensions in which **EI** values are expressed.

The maximum amount of rain falling within 30 consecutive minutes was 1.08 in, from 4:27 to 4:57. I_{30} is twice 1.08, or 2.16 in/h. The storm **EI** value is $12.84(2.16) = 27.7$. When the duration of a storm is less than 30 minutes, I_{30} is twice the amount of the rain.

The **EI** for a specified time is the sum of the computed values for all significant rain periods within that time. The average annual erosion index for a specific locality, as given in figures 1 and 2, is the sum of all the significant storm **EI** values over 20 to 25 years, divided by the number of years. For erosion index calculations, 6 h or more with less than 0.5 in of precipitation was defined as a break between storms. Rains of less than 0.5 in, separated from other showers by 6 h or more, were omitted as insignificant unless the maximum 15-min intensity exceeded 0.95 in/h.

Recent studies showed that the median dropsize of rain does not continue to increase for intensities greater than about 2.5 to 3 in/h (*7*, *15*). Therefore, energy per unit of rainfall also does not continue to increase, as was assumed in the derivation of the energy-intensity table published in 1958 (*62*). The value given in table 19 for rain at 3 in/h (7.6 cm/h in table 20) should be used for all greater intensities. Also, analysis of the limited soil loss data available for occasional storms with 30-min intensities greater than 2.5 in/h showed that placing a limit of 2.5 in (6.35 cm)/h on the I_{30} component of **EI** improved prediction accuracy for these storms. Both of these limits were applied in the development of figure 1. They slightly lowered previously computed erosion index values in the Southeast, but average-annual **EI** values for the U.S. mainland other than the Southeast were not significantly affected by the limits because they are rarely exceeded.

Conversion to Metric System

Metric equivalents were not included in the procedures and tables presented in this handbook because direct conversion of each English unit would produce numbers that would be awkward and undesirable. Converting the USLE as a whole is more appropriate. Metric units can then be selected so that each of the interdependent factors will have a metric counterpart whose values will be expressed in numbers that are easy to visualize and to combine in computations.

A convenient unit for measuring cropland soil losses is metric tons per hectare per year. **EI** values of convenient magnitude can be obtained by expressing rainfall energy in metric ton-meters per hectare, expressing intensities in centimeters per hour, and retaining the constant factor of 10^{-2} that has been used consistently for **EI** calculations in English units. Factor **K** will then be in metric tons per hectare per metric **EI** unit. If 22 meters is taken as the basic slope length and 9 percent is retained as the basic slope gradient, the **LS** factor will not be significantly affected. Using these units is recommended and is assumed in the following paragraphs.

The USLE factors will normally be derived directly in these units by procedures outlined below. However, the following conversion factors will facilitate comparisons of the metric factor values with the English values published in this handbook. Factors expressed in the recommended metric units are identified by the subscript, **m**.

Text continues on page 56.

TABLE 17.—*Observed range and 50-, 20-, and 5- percent probability values of erosion index at each of 181 key locations*

Location	Values of erosion index (*EI*)			
	Observed 22-year range	50-percent probability	20-percent probability	5-percent probability
Alabama:				
Birmingham	179-601	354	461	592
Mobile	279-925	673	799	940
Montgomery	164-780	359	482	638
Arkansas:				
Fort Smith	116-818	254	400	614
Little Rock	103-625	308	422	569
Mountain Home	98-441	206	301	432
Texarkana	137-664	325	445	600
California:				
Red Bluff	11-240	54	98	171
San Luis Obispo	5-147	43	70	113
Colorado:				
Akron	8-247	72	129	225
Pueblo	5-291	44	93	189
Springfield	4-246	79	138	233
Connecticut:				
Hartford	65-355	133	188	263
New Haven	66-373	157	222	310
District of Columbia	84-334	183	250	336
Florida:				
Apalachicola	271-944	529	663	820
Jacksonville	283-900	540	693	875
Miami	197-1225	529	784	1136
Georgia:				
Atlanta	116-549	286	377	488
Augusta	148-476	229	308	408
Columbus	215-514	336	400	473
Macon	117-493	282	357	447
Savannah	197-886	412	571	780
Watkinsville[1]	182-544	278	352	441
Illinois:				
Cairo	126-575	231	349	518
Chicago	50-379	140	212	315
Dixon Springs[1]	89-581	225	326	465
Moline	80-369	158	221	303
Rantoul	73-286	152	201	263
Springfield	38-315	154	210	283
Indiana:				
Evansville	104-417	188	263	362
Fort Wayne	60-275	127	183	259
Indianapolis	60-349	166	225	302
South Bend	43-374	137	204	298
Terre Haute	81-413	190	273	389
Iowa:				
Burlington	65-286	162	216	284
Charles City	39-308	140	205	295
Clarinda[1]	75-376	162	220	295
Des Moines	30-319	136	198	284
Dubuque	54-389	175	251	356
Sioux City	56-336	135	205	308
Rockwell City	40-391	137	216	335
Kansas:				
Burlingame	57-447	176	267	398
Coffeyville	66-546	234	339	483
Concordia	38-569	131	241	427
Dodge City	16-421	98	175	303
Goodland	10-166	76	115	171
Hays[1]	66-373	116	182	279
Wichita	42-440	188	292	445
Kentucky:				
Lexington	54-396	178	248	340
Louisville	84-296	168	221	286
Middlesboro	107-301	154	197	248
Louisiana:				
Lake Charles	200-1019	572	786	1063
New Orleans	273-1366	721	1007	1384
Shreveport	143-707	321	445	609
Maine:				
Caribou	26-120	58	79	106
Portland	36-241	91	131	186
Skowhegan	39-149	78	108	148
Maryland:				
Baltimore	50-388	178	263	381
Massachusetts:				
Boston	39-366	99	159	252
Washington	65-229	116	153	198
Michigan:				
Alpena	14-124	57	85	124
Detroit	56-179	100	134	177
East Lansing	35-161	86	121	166
Grand Rapids	33-203	84	123	178
Minnesota:				
Alexandria	33-301	88	147	240
Duluth	7-227	84	127	189
Fosston	22-205	62	108	184
Minneapolis	19-173	94	135	190
Rochester	46-338	142	207	297
Springfield	37-290	96	154	243
Mississippi:				
Meridian	216-820	416	557	737
Oxford	131-570	310	413	543
Vicksburg	165-786	365	493	658
Missouri:				
Columbia	98-419	214	297	406
Kansas City	28-361	170	248	356
McCredie[1]	64-410	189	271	383
Rolla	105-415	209	287	387
Springfield	97-333	199	266	352
St. Joseph	50-359	178	257	366
St. Louis	59-737	168	290	488
Montana:				
Billings	2-82	12	26	50
Great Falls	3-62	13	24	44
Miles City	1-101	21	40	72
Nebraska				
Antioch	18-131	60	86	120
Lincoln	44-289	133	201	299
Lynch	34-217	96	142	205
North Platte	14-236	81	136	224
Scribner	69-312	154	205	269
Valentine	4-169	64	100	153

See footnote at end of table.

TABLE 17.—*Observed range and 50-, 20-, and 5- percent probability values of erosion index at each of 181 key locations*—Continued

Location	Values of erosion index (*EI*)			
	Observed 22-year range	50-percent probability	20-percent probability	5-percent probability
New Hampshire:				
Concord	52-212	91	131	187
New Jersey:				
Atlantic City	71-318	166	229	311
Marlboro[1]	58-331	186	254	343
Trenton	37-382	149	216	308
New Mexico:				
Albuquerque	0-46	10	19	35
Roswell	5-159	41	73	128
New York:				
Albany	40-172	81	114	159
Binghamton	20-151	76	106	146
Buffalo	20-148	66	96	139
Geneva[1]	33-180	73	106	152
Marcellus[1]	24-241	74	112	167
Rochester	22-180	66	101	151
Salamanca	31-202	70	106	157
Syracuse	8-219	83	129	197
North Carolina:				
Asheville	76-238	135	175	223
Charlotte	113-526	229	322	443
Greensboro	102-357	184	244	320
Raleigh	152-569	280	379	506
Wilmington	196-701	358	497	677
North Dakota:				
Bismarck	9-189	43	73	120
Devils Lake	21-171	56	90	142
Fargo	5-213	62	113	200
Williston	4-71	30	45	67
Ohio:				
Cincinnati	66-352	146	211	299
Cleveland	21-186	93	132	185
Columbiana	29-188	96	129	173
Columbus	45-228	113	158	216
Coshocton[1]	72-426	158	235	343
Dayton	56-245	125	175	240
Toledo	32-189	83	120	170
Oklahoma:				
Ardmore	100-678	263	395	582
Cherokee[1]	49-320	167	242	345
Guthrie[1]	69-441	210	316	467
McAlester	105-741	272	411	609
Tulsa	19-584	247	347	478
Oregon:				
Pendleton	2-28	4	8	16
Portland	16-80	40	56	77
Pennsylvania:				
Erie	11-534	96	181	331
Franklin	50-228	97	135	184
Harrisburg	48-232	105	146	199
Philadelphia	72-361	156	210	282
See footnote at end of table.				
Pittsburgh	43-201	111	148	194
Reading	84-308	144	204	285
Scranton	52-198	104	140	188
Puerto Rico:				
San Juan	203-577	345	445	565
Rhode Island:				
Providence	53-225	119	167	232
South Carolina:				
Charleston	174-1037	387	559	795
Clemson[1]	138-624	280	384	519
Columbia	81-461	213	298	410
Greenville	130-589	249	350	487
South Dakota:				
Aberdeen	19-295	74	129	219
Huron	18-145	60	91	136
Isabel	16-141	48	78	125
Rapid City	10-140	37	64	108
Tennessee:				
Chattanooga	163-468	269	348	445
Knoxville	64-370	173	239	325
Memphis	139-595	272	384	536
Nashville	116-381	198	262	339
Texas:				
Abilene	27-554	146	253	427
Amarillo	33-340	110	184	299
Austin	59-669	270	414	624
Brownsville	46-552	267	386	549
Corpus Christi	124-559	237	330	451
Dallas	93-630	263	396	586
Del Rio	19-405	121	216	374
El Paso	4-85	18	36	67
Houston	176-1171	444	674	1003
Lubbock	17-415	82	158	295
Midland	35-260	82	139	228
Nacogdoches	153-769	401	571	801
San Antonio	77-635	220	353	556
Temple[1]	81-644	261	379	542
Victoria	108-609	265	385	551
Wichita Falls	79-558	196	298	447
Vermont:				
Burlington	33-270	72	114	178
Virginia:				
Blacksburg[1]	81-245	126	168	221
Lynchburg	64-366	164	232	324
Richmond	102-373	208	275	361
Roanoke	78-283	129	176	237
Washington:				
Pullman[1]	1-30	6	12	21
Spokane	1-19	7	11	17
West Virginia:				
Elkins	43-223	118	158	209
Huntington	56-228	127	173	233
Parkersburg	69-303	120	165	226
Wisconsin:				
Green Bay	17-148	77	107	147
LaCrosse[1]	61-385	153	228	331
Madison	38-251	118	171	245
Milwaukee	31-193	93	139	202
Rice Lake	24-334	122	202	327
Wyoming:				
Casper	1-24	9	15	26
Cheyenne	8-66	28	43	66

[1] Computations based on SEA rainfall records. All others are based on Weather Bureau records.

TABLE 18.—*Expected magnitudes of single-storm erosion index values*

Location	Index values normally exceeded once in—				
	year 1	years 2	years 5	years 10	years 20
Alabama:					
Birmingham	54	77	110	140	170
Mobile	97	122	151	172	194
Montgomery	62	86	118	145	172
Arkansas:					
Fort Smith	43	65	101	132	167
Little Rock	41	69	115	158	211
Mountain Home	33	46	68	87	105
Texarkana	51	73	105	132	163
California:					
Red Bluff	13	21	36	49	65
San Luis Obispo	11	15	22	28	34
Colorado:					
Akron	22	36	63	87	118
Pueblo	17	31	60	88	127
Springfield	31	51	84	112	152
Connecticut:					
Hartford	23	33	50	64	79
New Haven	31	47	73	96	122
District of Columbia	39	57	86	108	136
Florida:					
Apalachicola	87	124	180	224	272
Jacksonville	92	123	166	201	236
Miami	93	134	200	253	308
Georgia:					
Atlanta	49	67	92	112	134
Augusta	34	50	74	94	118
Columbus	61	81	108	131	152
Macon	53	72	99	122	146
Savannah	82	128	203	272	358
Watkinsville	52	71	98	120	142
Illinois:					
Cairo	39	63	101	135	173
Chicago	33	49	77	101	129
Dixon Springs	39	56	82	105	130
Moline	39	50	89	116	145
Rantoul	27	39	56	69	82
Springfield	36	52	75	94	117
Indiana:					
Evansville	26	38	56	71	86
Fort Wayne	24	33	45	56	65
Indianapolis	29	41	60	75	90
South Bend	26	41	65	86	111
Terre Haute	42	57	78	96	113
Iowa:					
Burlington	37	48	62	72	81
Charles City	33	47	68	85	103
Clarinda	35	48	66	79	94
Des Moines	31	45	67	86	105
Dubuque	43	63	91	114	140
Rockwell City	31	49	76	101	129
Sioux City	40	58	84	105	131
Kansas:					
Burlingame	37	51	69	83	100
Coffeyville	47	69	101	128	159
Concordia	33	53	86	116	154
Dodge City	31	47	76	97	124
Goodland	26	37	53	67	80
Hays	35	51	76	97	121
Wichita	41	61	93	121	150
Kentucky:					
Lexington	28	46	80	114	151
Louisville	31	43	59	72	85
Middlesboro	28	38	52	63	73
Louisiana:					
New Orleans	104	149	214	270	330
Shreveport	55	73	99	121	141
Maine:					
Caribou	14	20	28	36	44
Portland	16	27	48	66	88
Skowhegan	18	27	40	51	63
Maryland:					
Baltimore	41	59	86	109	133
Massachusetts:					
Boston	17	27	43	57	73
Washington	29	35	41	45	50
Michigan:					
Alpena	14	21	32	41	50
Detroit	21	31	45	56	68
East Lansing	19	26	36	43	51
Grand Rapids	24	28	34	38	42
Minnesota:					
Duluth	21	34	53	72	93
Fosston	17	26	39	51	63
Minneapolis	25	35	51	65	78
Rochester	41	58	85	105	129
Springfield	24	37	60	80	102
Mississippi:					
Meridian	69	92	125	151	176
Oxford	48	64	86	103	120
Vicksburg	57	78	111	136	161
Missouri:					
Columbia	43	58	77	93	107
Kansas City	30	43	63	78	93
McCredie	35	55	89	117	151
Rolla	43	63	91	115	140
Springfield	37	51	70	87	102
St. Joseph	45	62	86	106	126
Montana:					
Great Falls	4	8	14	20	26
Miles City	7	12	21	29	38
Nebraska:					
Antioch	19	26	36	45	52
Lincoln	36	51	74	92	112
Lynch	26	37	54	67	82
North Platte	25	38	59	78	99
Scribner	38	53	76	96	116
Valentine	18	28	45	61	77

TABLE 18.—*Expected magnitudes of single-storm erosion index values*—Continued

Location	Index values normally exceeded once in—				
	year 1	years 2	years 5	years 10	years 20
New Hampshire:					
Concord	18	27	45	62	79
New Jersey:					
Atlantic City	39	55	77	97	117
Marlboro	39	57	85	111	136
Trenton	29	48	76	102	131
New Mexico:					
Albuquerque	4	6	11	15	21
Roswell	10	21	34	45	53
New York:					
Albany	18	26	38	47	56
Binghamton	16	24	36	47	58
Buffalo	15	23	36	49	61
Marcellus	16	24	38	49	62
Rochester	13	22	38	54	75
Salamanca	15	21	32	40	49
Syracuse	15	24	38	51	65
North Carolina:					
Asheville	28	40	58	72	87
Charlottte	41	63	100	131	164
Greensboro	37	51	74	92	113
Raleigh	53	77	110	137	168
Wilmington	59	87	129	167	206
North Dakota:					
Devils Lake	19	27	39	49	59
Fargo	20	31	54	77	103
Williston	11	16	25	33	41
Ohio:					
Cincinnati	27	36	48	59	69
Cleveland	22	35	53	71	86
Columbiana	20	26	35	41	48
Columbus	27	40	60	77	94
Coshocton	27	45	77	108	143
Dayton	21	30	44	57	70
Toledo	16	26	42	57	74
Oklahoma:					
Ardmore	46	71	107	141	179
Cherokee	44	59	80	97	113
Guthrie	47	70	105	134	163
McAlester	54	82	127	165	209
Tulsa	47	69	100	127	154
Oregon:					
Portland	6	9	13	15	18
Pennsylvania:					
Franklin	17	24	35	45	54
Harrisburg	19	25	35	43	51
Philadelphia	28	39	55	69	81
Pittsburgh	23	32	45	57	67
Reading	28	39	55	68	81
Scranton	23	32	44	53	63
Puerto Rico:					
San Juan	57	87	131	169	216
Rhode Island:					
Providence	23	34	52	68	83

Location	Index values normally exceeded once in—				
	year 1	years 2	years 5	years 10	years 20
South Carolina:					
Charleston	74	106	154	196	240
Clemson	51	73	106	133	163
Columbia	41	59	85	106	132
Greenville	44	65	96	124	153
South Dakota:					
Aberdeen	23	35	55	73	92
Huron	19	27	40	50	61
Isabel	15	24	38	52	67
Rapid City	12	20	34	48	64
Tennessee:					
Chattanooga	34	49	72	93	114
Knoxville	25	41	68	93	122
Memphis	43	55	70	82	91
Nashville	35	49	68	83	99
Texas:					
Abilene	31	49	79	103	138
Amarillo	27	47	80	112	150
Austin	51	80	125	169	218
Brownsville	73	113	181	245	312
Corpus Christi	57	79	114	146	171
Dallas	53	82	126	166	213
Del Rio	44	67	108	144	182
El Paso	6	9	15	19	24
Houston	82	127	208	275	359
Lubbock	17	29	53	77	103
Midland	23	35	52	69	85
Nacogdoches	77	103	138	164	194
San Antonio	57	82	122	155	193
Temple	53	78	123	162	206
Victoria	59	83	116	146	178
Wichita Falls	47	63	86	106	123
Vermont:					
Burlington	15	22	35	47	58
Virginia:					
Blacksburg	23	31	41	48	56
Lynchburg	31	45	66	83	103
Richmond	46	63	86	102	125
Roanoke	23	33	48	61	73
Washington:					
Spokane	3	4	7	8	11
West Virginia:					
Elkins	23	31	42	51	60
Huntington	18	29	49	69	89
Parkersburg	20	31	46	61	76
Wisconsin:					
Green Bay	18	26	38	49	59
LaCrosse	46	67	99	125	154
Madison	29	42	61	77	95
Milwaukee	25	35	50	62	74
Rice Lake	29	45	70	92	119
Wyoming:					
Casper	4	7	9	11	14
Cheyenne	9	14	21	27	34

> Note: These conversions are incorrect. Refer to the supplement for corrections.

$$\begin{aligned} 1\ \text{t/ha} &= 2.242 \text{ tons per acre} \\ 1\ \text{t-m/ha/cm} &= 0.269 \text{ ft-tons per acre per inch} \\ 1\ E_m &= 0.683\ E \\ 1\ I_{30m} &= 2.54\ I_{30} \\ 1\ (EI)_m &= 1.735\ EI \\ 1\ K_m &= 1.292\ K \end{aligned} \tag{7}$$

Factor R. The procedure for computing $(\mathbf{EI})_m$ for a given rain period is similar to that described in the preceding section for computation of **EI**, but the input data will be in different units. If the rain gage chart used for the preceding example had been calibrated in millimeters, the computation would have been as follows:

Chart readings		Storm increments			Energy	
Time	Depth (mm)	Duration (min)	Amount (cm)	Intensity (cm/h)	Per cm	For increment
4:00	0					
:20	1.2	20	0.12	0.36	175	21
:27	3.0	7	.18	1.54	226	41
:36	8.8	9	.58	3.87	263	153
:50	26.6	14	1.78	7.68	289	514
:57	30.4	7	.38	3.26	256	97
5:05	31.7	8	.13	.98	220	29
:15	31.7	10	0	0	0	0
:30	33.0	15	.13	.52	184	24
Totals		90	3.30			879

Kinetic energy of the storm $= 879(10^{-2}) = 8.79$

TABLE 19.—*Kinetic energy of rainfall expressed in foot-tons per acre per inch of rain*[1]

Intensity inch per hour	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	—	254	354	412	453	485	512	534	553	570
0.1	585	599	611	623	633	643	653	661	669	677
.2	685	692	698	705	711	717	722	728	733	738
.3	743	748	752	757	761	765	769	773	777	781
.4	784	788	791	795	798	801	804	807	810	814
.5	816	819	822	825	827	830	833	835	838	840
.6	843	845	847	850	852	854	856	858	861	863
.7	865	867	869	871	873	875	877	878	880	882
.8	884	886	887	889	891	893	894	896	898	899
.9	901	902	904	906	907	909	910	912	913	915
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	916	930	942	954	964	974	984	992	1000	1008
2	1016	1023	1029	1036	1042	1048	1053	1059	1064	1069
3	[2]1074									

[1] Computed by the equation, $E = 916 + 331 \log_{10} I$, where E = kinetic energy in foot-tons per acre per inch of rain, and I = rainfall intensity in inches per hour.

[2] The 1074 value also applies for all intensities greater than 3 in/h (see text).

TABLE 20.—*Kinetic energy of rainfall expressed in metric ton-meters per hectare per centimeter of rain*[1]

Intensity cm/h	.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0	121	148	163	175	184	191	197	202	206
1	210	214	217	220	223	226	228	231	233	235
2	237	239	241	242	244	246	247	249	250	251
3	253	254	255	256	258	259	260	261	262	263
4	264	265	266	267	268	268	269	270	271	272
5	273	273	274	275	275	276	277	278	278	279
6	280	280	281	281	282	283	283	284	284	285
7	286	286	287	287	288	288	[2]289			

[1] Computed by the equation $E = 210 + 89 \log_{10} I$,
where E = kinetic energy in metric-ton meters per hectare per centimeter of rain, and
I = rainfall intensity in centimeters per hour.

[2] The 289 value also applies for all intensities greater than 7.6 cm/h.

Values for column 6 are obtained by entering table 20 with the intensities listed in column 5, and their sum, 879, is the kinetic energy $(\mathbf{E}_m)$ of the 3.30 cm of rain expressed in metric ton-meters per hectare. The constant factor of 10^{-2} used for the English system should be applied here also so that storm $(\mathbf{EI})_m$ values will usually not exceed 100. The maximum amount of rain in any 30-minute period was 2.74 cm, from 4:27 to 4:57. Therefore $\mathbf{I}_{30m} = 2(2.74 = 5.48$ cm/h. $(\mathbf{EI})_m = 8.79(5.48) = 48.17$

The procedure for combining storm **EI** values for local erosion index values was fully described in the preceding section. For predicting average annual soil losses from rainfall and its associated runoff, **R** equals the erosion index. Where runoff from thaw, snowmelt, or irrigation is significant, an $\mathbf{R}_s$ factor must be added to the **EI** value as previously discussed.

Where adequate rainfall intensity data are not available, the erosion index cannot be estimated solely from annual precipitation data. It is a function of the sizes and intensities of the individual rainstorms, and these are not closely related to annual precipitation. Therefore a given annual rainfall will indicate only a broad range of possible values of the local erosion index. However, the United States data indicate that the range of likely values can be somewhat narrowed by knowledge of the general climatic conditions in the particular geographic area.

In the U.S. Northern and Northeastern States, the winter precipitation generally comes as snow and low-intensity rains, but erosive intensities occur during the spring and summer. There, the local erosion index values, $(\mathbf{EI})_m$, have ranged from **2P**-52 to 2.6**P**, where **P** is the average annual precipitation expressed in centimeters. In several Northwestern States, where rain intensities rarely exceed 2.5 cm/h, the annual $(\mathbf{EI})_m$ is generally less than **P**, but $\mathbf{R}_s$ values are high. Near the Gulf of Mexico and along the southern half of the Atlantic Coast, the rainfall characteristics are substantially influenced by coastal storms, 24-h rainfall exceeds 10 cm at least once in 2 years, on the average, and erosive rains occur in nearly every month of the year. There, erosion index values range between 4.2**P** and 6.7**P**. Values computed from the few long-term, recording-raingage records available for the islands of Hawaii and Puerto Rico were also within this range. In the large region between the northern and southern extremes mentioned above, the annual $(\mathbf{EI})_m$ values range from 2.5**P** to 4.5**P**. Brief, high-intensity thunderstorms are common in this region during the summer months, but general rains of longer duration also occur.

Where data are adequate to determine 2-year probabilities of 6-hour rainfall, these probabilities may provide more specific estimates of the local erosion index values. In the U.S. data, local erosion index values were approximately equal to the quantity 27.38 $\mathbf{P}^{2.17}$, where $\mathbf{P}$ = the 2-year, 6-hour precipitation in inches. Converted to the recommended metric units, $(\mathbf{EI})_m$ equals approximately 6.28$\mathbf{P}^{2.17}$, where **P** is expressed in centimeters. However, this estimating procedure should not be substituted for the standard erosion index calculation procedure where adequate intensity data are available.

Factor K. This factor is the average soil loss in metric tons per hectare per unit of $(\mathbf{EI})_m$, measured on unit plots of the given soil. A unit plot is a 22-m length of uniform 9 percent slope that has been in clean fallow for more than 2 years and is tilled to prevent vegetative growth and surface crusting during the period of soil loss measurement. If a gradient other than 9 percent must be used, the data are adjusted by an **LS** factor available from figure 11. If the soil-erodibility nomograph (fig. 3) is used to evaluate $\mathbf{K}_m$, the **K** value read from the nomograph is multiplied by a conversion factor of 1.292.

The most accurate direct measurement of **K** for a given soil is obtained by measuring soil losses from unit plots under natural rain for at least 5 years, beginning 2 years after the clean-fallow condition was established. This permits averaging the interactions of soil erodibility with antecedent soil moisture, storm size, and other randomly distributed variables. The fallow plots receive the same annual tillage as conventionally tilled row crops.

Using rainfall simulators to evaluate **K** is quicker and less costly, but it requires caution. A one-time simulator test, even though replicated on several plots, measures soil loss from only one storm size and rain intensity, on one set of antecedent conditions, and these may or may not represent natural rainfall patterns. When simulated rainfall is used to evaluate **K**, measuring the soil losses for four or five successive 30-minute periods is helpful so that the segmented data can be rearranged to represent small, intermediate, and large storms beginning at various antecedent soil moisture levels. These can be weighted according to their probability of occurrence in natural rainfall (*58*).

Factor LS. Selecting 22 m as the basic slope length and retaining 9 percent as the basic slope gradient leaves the **LS** values essentially unchanged from those used in the English system of units. For uniform slopes, **LS** may be obtained by entering figure 11 with the field slope length expressed in meters. For concave or convex slopes, the value read from figure 11 should be modified by the procedure given in the subsection **Irregular Slopes.**

Factors C and P. Soil loss ratios (table 5) and **P** values (tables 13, 14, 15) are not affected by the units selected for the other factors. However, in countries where crops and farming techniques are different from those reflected in table 5, measurements of soil loss reductions attainable with feasible changes in crop system, tillage methods, and residue management may merit priority over establishing **EI** and **K** values.

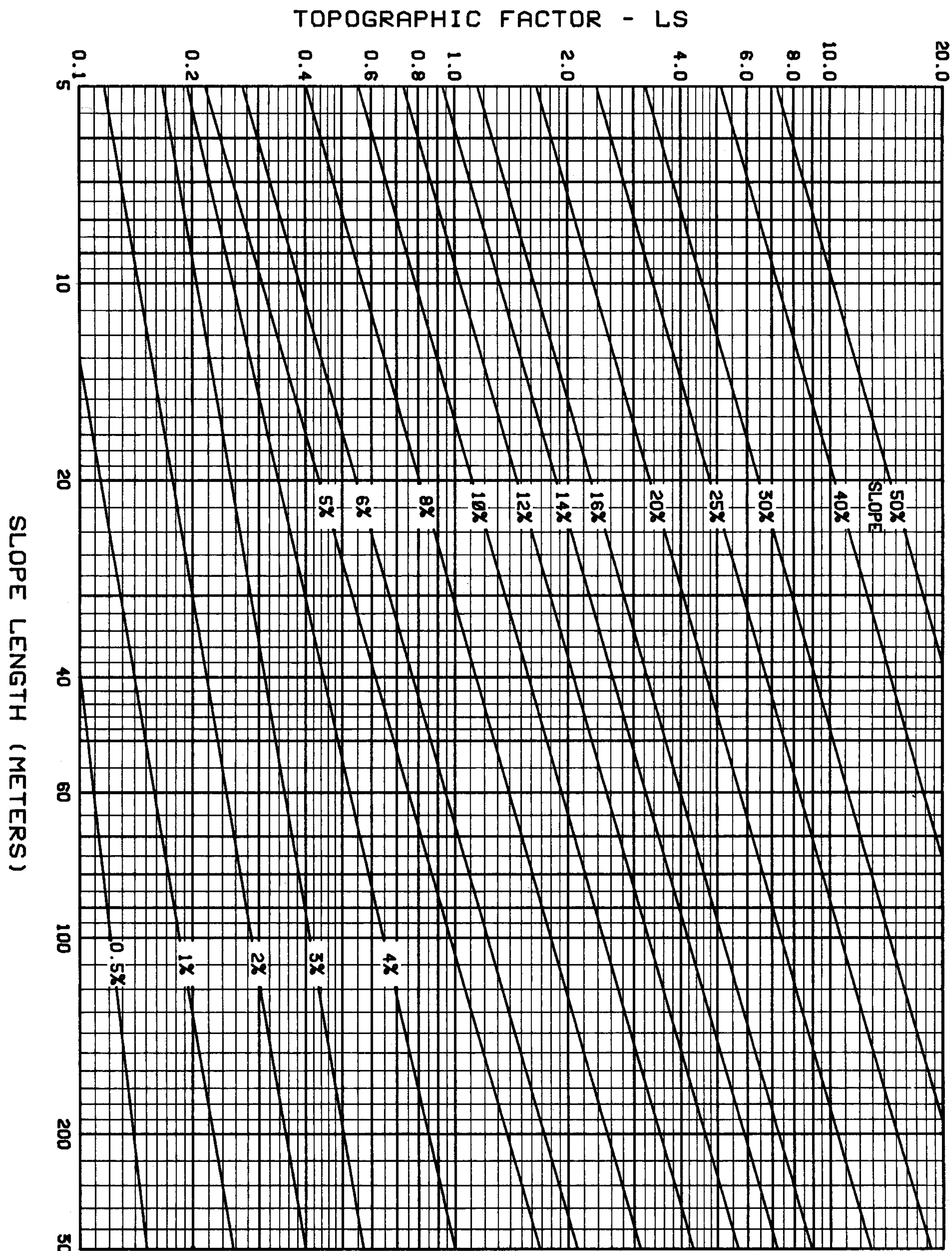

FIGURE 11.—Slope-effect chart for metric system.

☆U.S. GOVERNMENT PRINTING OFFICE: 1978 O—278-995/6583

AH-537, PREDICTING RAINFALL EROSION LOSSES—
A GUIDE TO CONSERVATION PLANNING

Note: **ERRATA** Jan. 1981

The following corrections and minor additions should be made with pen and ink in existing desk copies of AH-537. Corrected words or numbers have been identified by underlining. Additional footnotes that were added to clarify original content can be inserted in the lower margins of the indicated pages.

Page

4 Insert footnote symbol [4] after the definitions of **R** and **K** in column 1 and add footnote:

[4] The erosion index values in figures 1 and 2 and the EI values used in the text have the dimension 100 (foot-ton inch)/(acre hour). K values in tables 1 and 2 and figure 3 are in tons per acre per EI unit and have the dimensions 0.01 (ton acre hour)/(acre foot-ton inch).

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5 Equation (2) $\underline{e} = 916 + 331 \log_{10} \underline{i}$,

where $\underline{e}$ is kinetic energy in foot-tons per acre-inch and $\underline{i}$ is intensity in in/h (62). A limit of 3 in/h is imposed on $\underline{i}$ . . .

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9 column 2. Change footnote number from [4] to [5].

---

18 column 1. Change footnote number from [5] to [6].

---

19 column 1, last sentence. Insert footnote symbol [7] after "The expected effects of mulch and canopy combinations" and add footnote in lower margin:

[7] Figures 6 and 7 and table 5 assume that slope-length limits for full effectiveness of residue mulches at the stated rates are not exceeded. Beyond these limits, the subfactor for mulch effect approaches 1.0. The length limits vary inversely with mulch rate, runoff depth and velocity, but have not been precisely defined by research.

FIGURE 6 and 7. Change the ordinate labels from "SOIL-LOSS RATIO" to SUBFACTOR FOR EFFECT OF COVER.

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23 TABLE 5, line 160. Change 50 percent to 10 percent and reduce the ratio for cropstage 1 from 56 to 28.

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24 Add to footnote [4]: *See also* footnote [7], page 19.

Change footnote 13 to: Divide the winter-cover period into cropstages for the seeded cover and use lines 132-145.

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32 TABLE 10. Corrected title: *Factor* **C** *for permanent pasture, range, idle land, or grazed woodland*[1]

Change second category of vegetative canopy to: Tall grass, weeds or bushes with average drop fall height of less than 3 ft.[5]

Footnote [1]: The listed **C** values assume that the vegetation and mulch are randomly distributed over the entire area.

For grazed woodland with high buildup of organic matter in the topsoil under permanent forest conditions, multiply the table values by 0.7.

For areas that have been mechanically disturbed by root plowing, implement traffic or other means, use table 5 or 12.

Footnote [4], G: cover at surface is grass, grasslike plants, or decaying compacted duff. (Delete "or litter at least 2 in deep")

Add footnote [5]: [5] The portion of a grass or weed cover that contacts the soil surface during a rainstorm and interferes with water flow over the soil surface is included in "cover at the surface." The remainder is included in canopy cover. Use table 5-B for nearly complete grass covers.

TABLE 11. 33

Second column heading: Delete "at least 2 in deep."

Footnote [1]: The references to table 6 should be to table 10, and the following may be added: For sites that are mechanically treated following harvest, use table 12.

TABLE 12, footnotes [4] and [5]. The references to tables 6 and 7 should be to tables 10 and 11, respectively. 34

TABLE 13, footnote [1]. Change the word "seedlings" to plantings. 35

TABLE 14, footnote [1]. C For alternate strips of row crop and winter grain. 36

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column 2, line 6. 0.5 should be 0.05 in of precipitation . . . 51

centered heading. Insert footnote symbol [8] after **Conversion to Metric System** and add footnote in lower margin:

[8] See supplement for a recommended metrication of the USLE in the International System of Units (SI), which may be substituted for this section.

TABLES 19 and 20, footnotes. Change E to $\underline{e}$ and I to $\underline{i}$ in the energy equations. 56

Below the footnotes for table 20, insert the note: The table values multiplied by 9.81 would equal kilojoules of energy in the SI system.

UNITED STATES DEPARTMENT OF AGRICULTURE

AGRICULTURE HANDBOOK NUMBER 537

PREPARED BY SCIENCE AND EDUCATION ADMINISTRATION

Washington, D.C.

PREDICTING RAINFALL EROSION LOSSES— A GUIDE TO CONSERVATION PLANNING

U.S.D.A. **Supplement to Agriculture Handbook No. 537**

METRICATION OF THE USLE IN THE INTERNATIONAL SYSTEM OF UNITS (SI)

The metric conversion originally presented in this handbook and in prior publications (*53, 60*) is not completely in the International System of Units (SI), which is expected to gain widespread usage. This supplement presents an alternative conversion in which all the Universal Soil Loss Equation (USLE) factors are expressed in standard SI units or approved multiples thereof, and the order of magnitude of each new unit is similar to the old.

Both conversion systems are authentic, and conservationists who have adopted the originally recommended metric units would not improve their USLE accuracy by changing to the new units. For future conversions, however, the revised procedure, which is fully outlined below, is recommended because its use will facilitate standardization of units.

The USLE terms **A, LS, C,** and **P** need no change from the recommendations in the preceding section. Strictly, the **SI** units for mass and area are kilograms and square meters. Because of common use, however, metric ton (a special name for megagram) and hectare (a special name for square hectometer) will be used. Soil loss (**A**) wil be expressed in metric tons per hectare, and factor **K** in metric tons per hectare per metric **EI** unit. Factors **LS, C,** and **P** are dimensionless. **L** is expressed relative to slope lengths measured in meters, but selecting 22 m as the basic slope length and retaining 9 percent as the basic slope gradient leaves the **LS** values essentially unchanged. **C** and **P** are not affected by the units selected for the other factors.

Factor **R** will be in different units than previously recommended. In the **SI** system, energy is measured in joules and rainfall in millimeters. The use of "centi" as a multiple is minimized. Metric **EI** values can be obtained in standard **SI** units by expressing rainfall energy in megajoules (**MJ**) per hectare and maximum 30-minute intensity (I_{30}) in mm/h, but use of cm/h to express I_{30} is more expedient for the following reasons: With I_{30} expressed in mm/h, the metric **EI** values would be 17 times the magnitude of **EI** in U.S. customary units. Annual erosion index values would be in four- or five-digit numbers, which are harder to visualize and compare mentally than the present smaller numbers. Of greater importance, the large metric **EI** values would result in extremely small metric **K** values, ranging downward from a maximum of about 0.09. Absolute differences between **K** values would be so small that many casual users of the USLE would tend to neglect important soil differences as insignificant.

Reducing the magnitude of I_{30} by a factor of 10 alleviates these disadvantages and does not preclude the use of mm as the unit for rainfall amounts and incremental intensities in energy computations. The energy equation or table will also be expressed in MJ/ha per mm of rain. Only I_{30} will be converted to cm as a matter of expedience. This is directly comparable to the U.S. customary procedure of computing energy in ft-tons/acre and dividing by 100 to obtain more convenient magnitudes. The metric **EI** will then equal storm energy in MJ/ha times I_{30} in cm/h.

Assuming use of the metric units specified above, a comparison of U.S. customary and **SI** dimensions for the terms in the USLE is as follows:

Term	*US customary dimensions*	***SI** dimensions*	*Symbol*
A	ton/acre	metric ton/hectare	t/ha
R	$\frac{\text{100 foot-ton inch}}{\text{acre hour}}$	$\frac{\text{megajoule centimeter}}{\text{hectare hour}}$	$\frac{\text{MJ cm}}{\text{ha h}}$
K	$\frac{\text{.01 ton acre hour}}{\text{acre foot-ton inch}}$	$\frac{\text{metric ton hectare hour}}{\text{hectare megajoule centimeter}}$	$\frac{\text{t ha h}}{\text{ha MJ cm}}$
L,S,C,P	dimensionless	dimensionless	

The USLE terms will usually be derived directly in the **SI** units by procedures outlined below. However, the following conversion factors will facilitate comparisons of the metric factor values with the U.S. customary values published in this handbook. Terms expressed in metric units are identified by the subscript $_m$.

To convert from:	*multiply by:*	*to obtain:*
A in tons/acre	2.242	A_m in t/ha
E in 100 ft-tons/acre	0.670	E_m in MJ/ha
I_{30} in in/h	2.540	I_{30m} in cm/h
EI in $\frac{\text{100 ft-ton in}}{\text{acre h}}$	1.702	$(EI)_m$ in $\frac{\text{MJ cm}}{\text{ha h}}$
K in $\frac{\text{.01 ton acre h}}{\text{acre ft-ton in}}$	1.313	K_m in $\frac{\text{t ha h}}{\text{MJ ha cm}}$

Page 56 revised

Factor R. The procedure for computing $(EI)_m$ for a given rain period is similar to that described in the preceding section for computing **EI**, but the input data will be in different units. If the raingage chart used for the example on page 51 had been calibrated in millimeters, the computation would have been as follows:

Chart readings		Storm increments			Energy	
Time	Depth (mm)	Duration (min)	Amount (mm)	Intensity (mm/h)	Per mm of rain (MJ/ha mm)	Increment total (MJ/ha)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
4:00	0					
:20	1	20	1	3	0.161	0.161
:27	3	7	2	17	.226	.452
:36	9	9	6	40	.259	1.554
:50	27	14	18	77	.283	5.094
:57	30	7	3	26	.242	.726
5:05	32	8	2	15	.222	.444
:15	32	10	0	0	0	0
:30	33	15	1	4	.172	.172
Totals		90	33			8.603

Kinetic energy of the storm: 8.60 MJ/ha

Values for column 6 are obtained by entering the revised table 20 with the intensities listed in column 5. The sum of the products of corresponding values from columns 4 and 6 (8.60) is the kinetic energy, E_m, of the 33 mm of rain expressed in megajoules per hectare. The maximum amount of rain in any 30-minute period was 27 mm, from 4:27 to 4:57. Therefore the maximum 30-minute intensity was 2×27, or 54, mm/h, and $I_{30m} = 54/10 = 5.4$ cm/h. $(EI)_m = 8.60 \times 5.4 = 46.4$ (MJ cm)/(ha h).

For the **EI** computations, the rain occurring between two successive periods of 6 hours or more with less than 1.3 mm (0.05 in) of precipitation is considered one storm. Rain showers of less than 12 mm are omitted as insignificant unless they include a 15-minute intensity of at least 25 mm/h. The erosion index at a given location, as mapped in figures 1 and 2, is the average annual total of storm **EI** values over 20 to 25 years. For predicting average annual soil losses from rainfall and its associated runoff, **R** equals the erosion index. Where runoff from thaw, snowmelt, or irrigation is significant, **R** equals the **EI** plus an R_s value as discussed on page 7.

The erosion index cannot be reliably estimated from annual-rainfall data alone. It is a function of the sizes and intensities of the individual rainstorms, and these have no common relationship to annual rainfall totals. However, later analyses of the U.S. annual erosion index values that had been derived by the above procedure indicated that they were roughly equal to the quantity $27.38\ P^{2.17}$, where P = the 2-year, 6-hour rainfall expressed in inches. By direct conversion, the average annual $(EI)_m$ would be roughly estimated by $0.0416\ P^{2.17}$, where **P** is expressed in mm. This estimating formula is appreciably less accurate than the standard erosion index calculation procedure and should not be substituted for it where intensity data are available.

Factor K. The soil-erodibility factor K is the average soil loss in metric tons per hectare per unit of metric **EI**, measured on unit plots of the given soil. A unit plot (see p. 8) is a 22-m length of uniform 9 percent slope that has been in clean fallow for more than 2 years and is tilled to prevent vegetative growth and surface crusting during the period of soil loss measurement. If a gradient other than 9 percent must be used, the data are adjusted by the appropriate **LS** factor. If the soil-erodibility nomograph (fig. 3) is used to evaluate K_m, the K value read from the nomograph must be multiplied by a conversion factor of 1.313.

The basic slope length used for K and **L** in this handbook is 72.6 ft, which equals 22.134 m. For experimental evaluation of factor **K** in metric units, rounding this to 22.0 m is more convenient and introduces no error when 22.0 m is also used as the basic length for **L**, as in figure 11. The slight reduction in basic length increases factor **L** by 0.3 of 1 percent and decreases factor **K** by the same percentage, so the product of **K** and **L** is unchanged. For conversion of the U.S. customary K values in this handbook to metric **K** values based on a 22.0 m length, the relatively insignificant potential error is avoided by including an **L**-value of 0.997 in the conversion factor. The **K**-conversion factor of 1.313 given above has been so adjusted.

Factor LS. The preceding paragraph applies here, also. For uniform slopes, **LS** may be obtained by entering figure 11 with the field slope length expressed in meters or it may be computed by the equation

$$LS = (\lambda/22)^m\ (65.41\ \sin^2\theta + 4.56\ \sin\theta + 0.065)$$

where λ = slope length in m; θ = angle of slope; and m = 0.5 if the percent slope is 5 or more, 0.4 on slopes of 3.5 to 4.5 percent, 0.3 on slopes of 1 to 3 percent, and 0.2 on uniform gradients of less than 1 percent. For concave, convex, or mixed-gradient slopes, the value so computed or read from figure 11 should be modified by the procedure outlined on page 16.

Factor C and P. Soil loss ratios (table 5) and **P** values (tables 13, 14, 15) are not affected by the units selected for the other factors and therefore need no conversion.

TABLE 20. (revised).—*Kinetic energy of rainfall at specified intensities, expressed in megajoules per hectare per millimeter of rain*[1]

Intensity (mm/h)	0	1	2	3	4	5	6	7	8	9
0 ..	0	0.119	0.145	0.161	0.172	0.180	0.187	0.193	0.198	0.202
10 ..	.206	.210	.213	.216	.219	.222	.224	.226	.229	.231
20 ..	.233	.234	.236	.238	.240	.241	.242	.244	.245	.247
30 ..	.248	.249	.250	.252	.253	.254	.255	.256	.257	.258
40 ..	.259	.260	.261	.262	.262	.263	.264	.265	.266	.267
50 ..	.267	.268	.269	.270	.270	.271	.272	.272	.273	.274
60 ..	.274	.275	.276	.276	.277	.277	.278	.278	.279	.280
70 ..	.280	.281	.281	.282	.282	.283	.283[2]			

[1] Computed by the equation $e = 0.119 - 0.0873 \log_{10} i$, where e = kinetic energy in megajoules/(hectare millimeter) and i = rainfall intensity in mm/h.

[2] The value of 0.283 also applies for all intensities greater than 76 mm/h.

Revision

ESTIMATING FACTOR C FOR AN UNUSUAL CONDITION OR CROP THAT IS NOT LISTED IN TABLES 5 through 5-D of Ag. Handbook No. 537.

W. H. Wischmeier, 11-13-79

Soil-loss ratios can sometimes be closely estimated by comparing characteristic conditions in each cropstage period with conditions associated with a crop and management that is listed in the table. The cropstage ratios may need to be selected from several lines rather than following one line across the table.

Another possible procedure is to multiply-together a number of subfactor values obtained from field observations, guided by the following information.

Benchmark values throughout table 5 were obtained from direct soil-loss measurements under conditions involving various combinations of the subfactors. However, study of the ratios obtained by this method suggested a number of underlying subfactor relationships that can help guide estimation of appropriate ratios for untested conditions or crops. Before using this procedure, please read carefully the background material on pages 18-21 of AH-537.

For each cropstage period, estimate the percentage of surface cover by canopy and the percentage of cover by mulch, using the definitions given on pages 18 & 19 and evaluating the two separately. Include expected volunteer vegetation in the estimates of cover if significant. Then, use the following guides to estimate a subfactor value for each of the listed sub-parameters:

1. Canopy without mulch. Enter Fig. 5 with percent canopy cover, move vertically to drop fall height, and read the subfactor value at the left.

2. Mulch without canopy. Enter Fig. 6 with the percent cover by mulch, move vertically to the line for zero percent canopy (upper curve), and read subfactor value at left.

3. Combination of canopy and mulch. Use the other curves of Fig. 6 or 7, interpolating between the lines.

4. Land-use residual. The greatest residual effect is from sod crops or longterm woodland. Obtain residual sod-effect subfactor from table 5-D. Virgin sod or woodland would be even more effective.

Some residual effect will be apparent on nearly any cropland. For continuous corn with residues removed annually before turnplowing, the residual factor seems to be about 0.82 to 0.86, depending on productivity level. (These are the values given for the SB period in lines 13-16 of table 5.) This is a good starting point from which to move with judgment. This subfactor is in addition to subfactors for residues incorporated or sod-effect when those are also applicable.

(continued, p.2)

5. Residues plowed-down annually by inversion plowing. Credit for this may be approximated by multiplying the number of tons of residue per acre plowed down annually by: 0.12 for periods F, SB and 1; by 0.09 for period 2; and by 0.06 for periods 3 and 4. The residue-incorporated subfactor is 1.0 minus this amount.

6. Residues incorporated in the upper few inches of soil by shallow non-inversion tillage. Estimate effect by multiplying tons of residue so incorporated annually by: 0.20 for periods SB and 1; 0.16 for period 2; 0.12 for period 3; and 0.06 for period 4. Subtract product from 1.0 to obtain subfactor.

7. Random surface roughness. The condition left by inversion plowing and several diskings (with residues removed) has a roughness factor of 1.0. Freshly plowed land would rate a roughness subfactor of from 0.8 to 0.5, depending on amount of residue, soil-moisture at time of plowing, and other conditions. Chiseled or disked land would fall between these extremes.

In all cases, the subfactor becomes larger for each successive cropstage period because of rainfall and tillage effects. It reaches a value of 1.0 no later than the end of cropstage 3 and in some cases appreciably sooner.

8. Detachability. Soil that receives no tillage or traffic gradually becomes less detachable by rainfall. No-till systems with crop residues on the surface seem to merit a detachability subfactor of about 0.7. This is in addition to the mulch factor and may vary with soil texture.

9. Orientation of residues. The mulch-effect curves of figures 6 and 7 are based on fairly uniform, random distribution of the mulch over the field. When residues are concentrated in strips by the harvester, the percent-cover is reduced. However, when the strips are across the slope, they are more effective than the reduced percent-cover would indicate. When the strips are across-slope, they can probably be evaluated as equivalent to the percent cover that they would have provided if they had been fairly uniformly distributed. See figure 10, page 50. However, this does not apply if the strips are up and down slope.

10. High population of close-growing stems (like wheat). More effective than canopy from spreading plants like corn or bushes.

When these guides have been used to estimate the listed subfactors for each cropstage period, the subfactors are multiplied together to compute the soil-loss ratios.

This procedure should not be used for conditions covered by table 5 and its supplements. The relationships given above are only approximate and will provide less accuracy than direct measurements such as used to develop the table.

Slope-length limits for effectiveness of moderate mulch rates and random roughness are of course also applicable with this procedure.

EXHIBIT 22

DEPARTMENT OF ENVIRONMENTAL QUALITY

OFFICE OF WASTE MANAGEMENT AND RADIOLOGICAL PROTECTION

SOLID WASTE MANAGEMENT

(By authority conferred on the director of the department of environmental quality by sections 11538, 11539, and 11540 of Part 115, Solid Waste Management, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, MCL 324.11538 to 324.11540)

PART 1. GENERAL PROVISIONS

R 299.4101 Definitions; A, B.

Rule 101. As used in these rules:

(a) "AASHTO" means American association of state highway and transportation officials.

(b) "Act" means 1994 PA 451, MCL 324.101 to 324.90106, and known as the natural resources and environmental protection act.

(c) "Act 299" means 1980 PA 299, MCL 339.101 to 339.2919, and known as the occupational code.

(d) "Act 399" means 1976 PA 399, MCL 325.1001 to 325.1023, and known as the safe drinking water act.

(e) "Active life" means the period of operation beginning with the initial receipt of solid waste and ending with the completion of closure activities in accordance with the act and these rules.

(f) "Active portion" means that part of a facility or unit that has received or is *receiving wastes and that has not been partially or finally closed in accordance with* these rules. The active portion does not include areas that have interim cover which complies with R 299.4429(7) or a constructed unit or portion of a unit that has not received waste.

(g) "Active work area" means the area which is or will be used for the storage, transport, or disposal of solid waste, methane gas, or leachate or in which heavy equipment is or will be used as part of the landfill operation. The active work area includes all of the following:

(i) The active portion.

(ii) Leachate collection and storage systems, exclusive of any of the following:

(A) Forcemains.

(B) Sewers.

(C) Enclosed manholes.

(D) Sewer hookups.

(iii) Gas collection and handling systems, exclusive of any of the following:

(A) Enclosed flares.

Editor's Note: An obvious error in R 299.4424 was corrected at the request of the promulgating agency, pursuant to Section 56 of 1969 PA 306, as amended by 2000 PA 262, MCL 24.256. The rule containing the error was published in *Annual Administrative Code Supplement,1999*. The memorandum requesting the correction was published in *Michigan Register,* 2012 MR 18.

R 299.4425 Type II landfill design standards; final cover.

Rule 425. (1) The owner or operator of a type II landfill unit shall install a final cover system which is designed to minimize infiltration and erosion and which is comprised of an erosion layer underlain by an infiltration layer, as specified in this rule.

(2) Except as provided for existing or preexisting units in subrules (3) and (4) of this rule, the owner or operator of a type II landfill shall install a final cover system that is comprised of all of the following components:

(a) An infiltration layer that is comprised of a composite liner. The lower soil component of such a composite liner shall consist of either of the following:

(i) A minimum of 18 inches of earthen material that has a permeability which is less than or equal to 1.0 x 10-5 cm/sec, as determined by test methods specified in R 299.4920.

(ii) A bentonite geocomposite liner which is in compliance with R 299.4914 and which is underlain by not less than 18 inches of earthen material to protect the liner from waste and minimize the effect of settlement.

(b) An erosion layer that consists of both of the following:

(i) A soil layer which is not less than 2 feet thick, which is immediately above the composite cover liner, and which is designed to do all of the following:

(A) Provide for the lateral drainage of precipitation off the cover of the landfill. The owner or operator may use permeable soil, geosynthetic drainage material, an alternative equivalent material approved by the director, or a combination to provide the lateral drainage.

(B) Minimize frost penetration into the infiltration layer.

(C) Protect the flexible membrane liner from root penetration, ultraviolet light, and other deleterious effects.

(ii) A minimum of 6 inches of earthen material capable of sustaining native plant growth.

(3) The owner or operator of an existing or preexisting type II landfill unit that does not contain a flexible membrane liner in all or portions of the bottom liner system may install a final cover system previously approved by the director over those portions if the final cover system contains both of the following:

(a) An infiltration layer that is comprised of a minimum of 2 feet of earthen material which has a hydraulic conductivity that is less than or equal to 1.0 x 10-7 cm/sec, as determined by test methods specified in R 299.4920. The earthen material shall meet standards for soil liners specified in R 299.4913.

(b) An erosion layer that consists of a minimum of 6 inches of earthen material which is capable of sustaining native plant growth.

(4) The owner or operator of an existing or preexisting type II landfill unit that does not contain a flexible membrane liner in the bottom liner system may enhance the final cover specified in subrule (3) of this rule by adding a flexible membrane liner if

the erosion layer specified in subrule (2)(b) of this rule is provided. The addition of the layer shall not constitute a vertical expansion.

(5) The director shall approve an alternative final cover design if the owner or operator of the landfill units demonstrates that the cover design includes both of the following components:

(a) An infiltration layer that achieves an equivalent reduction in infiltration as the infiltration layer specified in subrule (2) or (3) of this rule.

(b) An erosion layer that provides equivalent protection from wind and water erosion as the erosion layer specified in subrules (2) and (3) of this rule.

(6) The final cover of a type II landfill shall have either of the following to meet the gas control requirements of R 299.4433:

(a) A permeable soil layer which is not less than 1 foot thick and which is located directly below the infiltration layer that vents landfill gas to gas risers.

(b) Other means of assuring that gases cannot travel laterally from the site or accumulate in structures.

(7) To prevent the ponding of water on completed fill surfaces, the grading contours shall be sufficient to prevent the development of local depressions due to postconstruction settlement. Slopes of the final cover shall not be less than 4% at any location.

(8) Slopes of the final cover shall not exceed those necessary to prevent erosion and maintain slope stability. The final slope shall not be more than 1 vertical to 4 horizontal at any location, except where necessary to install berms for erosion control. If the final slope is more than 15%, then the slope shall include controls that the applicant demonstrates are sufficient to maintain slope stability, prevent erosion, and allow access. The controls shall be sufficient to limit erosion to not more than 2 tons per acre per year after vegetation is established based on the universal soil loss equation or other method approved by the director. The following ground cover estimates may be used in calculating erosion loss:

(a) Up to 95%, if the closure and postclosure plan provides for all of the following:

(i) Topsoil that has an organic matter content of more than 2.5%.

(ii) Fertilization consistent with the natural resources conservation service critical area planting guide.

(iii) Mowing twice annually until the required coverage is achieved.

(b) Up to 90%, if the closure and postclosure plan for the unit provides for both of the following:

(i) Topsoil that has an organic matter content of more than 1.25%.

(ii) Mowing annually until the required coverage is achieved.

(c) Up to 80%, if the organic content or mowing schedule is not specified.

(d) Other estimates approved by the director, if the estimates are supported by measures to establish vegetation specified in the closure and postclosure plan.

(9) All final covered areas shall be stabilized using appropriate shallow-rooted vegetation for the soil type, slope, and moisture conditions present. Seed and mulch rates shall, at a minimum, be consistent with recommendations contained in the United States department of agriculture document entitled "Natural Resources Conservation Service Critical Area Planting Guide." The natural resources conservation service critical area planting guide is adopted by reference in R 299.4141.

EXHIBIT 23

affected by releases from these units have been removed and groundwater monitoring concentrations do not exceed the groundwater protection standard established pursuant to §257.95(h) for constituents listed in Appendix IV for two consecutive sampling events using the statistical procedures in §257.93(g). Decontamination may include removal of all CCR materials above the geomembrane liner to facilitate inspection of the liner for evidence of damage that may indicate a potential release of CCR. If evidence of a release is identified during closure, materials impacted by the release will be removed or remediated, as appropriate. Existing embankments may be breached to limit collection of stormwater if consistent with future proposed land use.

3. Final Cover Requirements – §257.102(b)(1)(iii)

CCR will be removed from the Ash Surge Basin and the Bypass Basin in accordance with §257.102(c); therefore, no final cover system will be constructed for closure.

4. Maximum CCR Inventory - §257.102(b)(1)(iv)

Detailed records of the maximum inventory of CCR ever on site and stored in the Ash Surge and Bypass Basins are not available. For the purposes of this closure plan, the maximum CCR inventory for each basin was estimated to be the maximum quantity of CCR that could be reasonably stored in the basins. The table below presents the estimated maximum CCR inventory for the Ash Surge Basin and the Bypass Basin.

Basin	Estimated Maximum Quantity of CCR (cubic yards)
Ash Surge Basin	140,000
Bypass Basin	6,700

5. Maximum Area Requiring Final Cover – §257.102(b)(1)(v)

CCR will be removed from the Ash Surge Basin and the Bypass Basin in accordance with §257.102(c); therefore, no final cover system will be constructed for closure.

6. Closure Schedule – §257.102(b)(1)(vi)

Closure of the Ash Surge Basin and Bypass Basin is anticipated to begin in 2034 and be complete within five years of the commencement of closure in accordance with §257.102(f)(1)(ii). Prior to initiation of closure, a notice of intent to close will be prepared in